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The context of innovation journeys

1. Introduction

A lot is known about innovation – in so far as it is possible to ”know” a complex and uncertain phenomenon like innovation. Innovation and its management in organizations have been studied extensively. Less studied, but particularly interesting are the dynamics of innovation. Van de Ven et al. (1999) have emphasized vicissitudes of innovation by speaking of innovation journeys. Rip and Schot (2002) have extended this idea conceptually by including market introduction and embedding in society, and added an empirical claim, that there are certain patterns in the journeys, linked to institutional and broader contexts of innovation like the rise of industrial research (cf. also Rip 2010a).[1] The seminal work of Abernathy and Clark (1985) who mapped “the winds of creative destruction” by considering the extent to which existing technological capacities and market linkages have to be changed, is important to understand the dynamics of innovation. Again, an extension is in order, to include the changes involved in the embedding of technical innovations in society (Deuten et al. 1997).[2]

Innovation journeys do not occur in a vacuum. They are part of larger processes, and are entangled with organizations, other technologies, sector dynamics, and anticipations on, and responses from, society. One can analytically separate the innovation journey from its contexts when sufficient institutionalization of such contexts has occurred. This is already visible within an organization, when there is an R&D department responsible for working on innovation. In society, a division of labour has emerged between developers of technology and recipients, and there are framework conditions like the patent system, regulatory measures, insurance, and the role of consumer organizations. So it makes sense to speak of the context of innovation journeys, and inquire how this context influences the dynamics of innovation (as well as vice versa, ongoing innovation will lead to changes in contexts, through expectations and adaptations, cf. Nelson 1994).

This article makes a next step by recognizing that there are general patterns and structures in the context, relevant to innovation dynamics, over and above the specific constellation of actors and frame work conditions at play in the particular innovation journey that is considered. In claiming this, I can build on what has been called the multi-level model of niches, regimes and “landscapes” (Rip and Kemp 1998, Geels 2005). I will develop this

[1] This is not the same dynamics as path emergence and dependency (Garud and Karnøe 2001), but there are similarities: both trace emerging and stabilising patterns. Innovation journeys can also be followed by organisations (Visscher and De Weerd-Nederhof 2006).
[2] See also Nijhof, Fisscher and Looise (2002) on inclusive innovation.

in Section 3, but note here that niches (i.e. protected spaces), socio-technical regimes (i.e. a set of rules for further development of a technology), and "landscapes" providing a backdrop of opportunities and constraints, are always present, as it were as layers of the context. One or another layer may be more important than others at a particular stage of the innovation journey. For example, in an early stage when R&D is done in the protected space of the lab, the broader "landscape" is often backgrounded.

The concept of 'layer' is introduced to avoid relying on a terminology of levels, with their connotation of micro, meso and macro. The point is that the context influences the dynamics of innovation journeys in different ways, not that there are different levels in the context. This concept of 'layer' must be positioned theoretically, and I will do so in Section 2, drawing on co-evolutionary theory of technological change and Actor-Network Theory (ANT).[3] Empirically, one can ask whether there are further patterns in influencing dynamics of innovation, which have stabilized and thus become a layer, in addition to the three identified already. A candidate would be how in the new ecology of innovation, promises (and expectation more generally) play an important role, and how there are calls for anticipatory coordination, and concrete attempts to do so, for example in European Technology Platforms. In Section 4 I will explore the possibility that this adds up to a new layer.

While there are management implications of the analysis in this article, I will note them only occasionally. My main purpose is to draw attention to general patterns in the context of innovation journeys, which enable and constrain what happens.

2. A theoretical perspective drawing on Actor-Network Theory and (co-)evolutionary theory

To articulate the concept of 'layer', I will consider how such layers can emerge, and do so with the help of a simple example. The emergence of a new layer is central to Deuten's (2003) study of what he calls "cosmopolitanization" of technological knowledge after it starts out as local knowledge. This is now generally expected to occur, but even then, it requires work, for example on possible dominant designs (as he shows for the successive cases of videorecording). Earlier, as in the case of reinforced concrete, 1860 – 1920 (which he reconstructed), the companies kept their experience-based knowledge to themselves. Still, cosmopolitanization occurred but as a response to outside requirements. Authorities and users needed assurance that bridges and buildings made of reinforced concrete would not collapse, and this led to further experimentation to prove the robustness of technical designs as such. New activities and interactions occurred at

[3] Generally, I draw on theories like ANT and evolutionary sociology/economics, because they focus on dynamics. In these theories, agency, say of innovators and entrepreneurs, is an input into, but not the determinant of, eventual outcomes. This implies that my analysis is also a constructively critical contribution to the themes treated in the *Creativity and Innovation Management*, where agency is often foregrounded. My problematization of agency also challenges business ethics as traditionally discussed in terms of individual choices and their justification.

the cosmopolitan level, testifying to the existence of a somewhat independent layer with its own dynamics.

Thus, a two-layered constellation emerged, where local (cf. niche) and cosmopolitan (cf. regime) have their own dynamics, but are also mutually dependent. Actually, there is a third layer as well, that of 'landscape', the slowly changing backdrop against which interactions are played out. In the case of reinforced concrete, the emergence of the regulatory state by the end of the 19th century is one of the 'landscape' elements.[4]

What one sees happening is how ongoing actions, interactions and practices become entangled, and a reversal occurs: the somewhat stable result, for example the regime of reinforced concrete, starts to shape what happens locally. Thus, patterns are reproduced in the processes, and structures emerge (Rip 2010b). Such patterns and structures enable and constrain further actions and interactions, up to lock-ins and so-called path dependency. In contrast with structural theories in social science, the nature of such structures-by-entanglement is not given as such, it is an always precarious outcome of interactions and processes. But such structures can be reproduced over longer periods of time, and function as a backdrop which is encountered (and in that sense given) when one moves about in the world. That is why common notions of structure (including cultural patterns, industry structures, societal structures) are applicable to some extent.

Clearly, I am working with a non-structural theory here, while still recognizing the phenomenon of (precarious) social order. It is important to use such a theoretical perspective to capture dynamics of innovation in context, so as to do justice to open-ended character of innovation and the fluidity of the situation that goes with it.

Actor-network theory (ANT), an explicitly anti-structural theory (cf. Latour 2005), can address the fluidity. In Callon's version of actor-network theory, the distinction between unarticulated, fluid situations and articulated, stabilized situations is emphasized (Callon 2002). However, Callon, and ANT generally, prefer to study fluid, "hot" situations. In doing so, they recognize the existence of "cold" situations, but are not much interested in them. Thus, studies under the banner of ANT have neglected the processes of solidification and partial irreversibilisation turning the fluid into the stabilized.[5]

Transitions from "hot" to "cold" are exactly what is happening in cases of new and emerging science and technology. Not only do they have to survive and grow in existing, more or less stable regimes and landscapes, there is the experience – and thus expectation – that they will stabilize and become "cold" themselves. In fact, actors anticipate on possible future more stable assemblages. The literature on emergence of dominant designs is full of actors anticipating and struggling, "knowing" that such

[4] This notion of a three-layered constellation also applies to scientific development, with local search practices in the protected space of a lab, with emerging and stabilized paradigms, and the wider institutional landscape up to a social contract between science and society (Rip 2010c).

[5] These processes did come in for attention when tools to manage and influence developments were explored, as with techno-economic networks (Callon et al. 1992), future scripts (De Laat 2000), SocRobust (Larédo et al. 2002), and Constructive TA (Rip et al. 1995; Rip and Te Kulve 2008).

dominant designs will occur, eventually (Tushman and Anderson 1997, see also Deuten 2003).

ANT has the conceptual resources to address these challenges. In particular, the concept of entanglements – "associations that last longer than the interactions that formed them" (Callon and Latour 1981: 283) – is meant to emphasize that actors and activities can become mutually dependent: they cannot move independently anymore (Rip 2010b). There is some mutual accommodation, but not necessarily in the sense that conflict is reduced. (Cf. how parties on the battlefield recognize each other as enemy, and that is how the battle can proceed.) On the other hand, mutual dependence does lead to outcomes that are larger (or at least, "last longer") than the interactions that went into them. One can inquire into the alignments that have occurred, and how these alignments add up to configurations that work, to some extent.

Zooming in on the processes, one sees enrolment, obligatory passage points etc – the bread-and-butter of ANT analyses (Latour 1987, Callon 1986). ANT, in presenting its arsenal of mechanisms, emphasizes descriptions of what actors do and what the short-term outcomes are. Its advice is then often limited to the empty (because empirically almost circular) suggestion to have more allies, and longer (more extended) networks.

Zooming out again, one sees variety, and some novelties surviving, somehow. While translation and enrolment play a part, there are other actors, broader contexts, longer-term patterns which in a sense select what will survive and what not. Thus, evolutionary theories must be added to ANT analysis.

There is a range of evolutionary theories of technological change (e.g. Nelson and Winter 1977, Dosi 1982, Ziman 2000), often linked to evolutionary economics (Nelson and Winter 1982). There are good reasons to adopt evolutionary approaches because novelty is being introduced and its fate depends on factors and contexts outside the range of influence of the actors introducing the novelty (Rip 2006a). Evolutionary theory emphasizes that there are no prior determinants shaping developments. Instead, one should think and analyse in terms of variation and independent selection (and retention of what was selected). The outcomes, however, can then stabilize. One could speak of species (in a technological eco-system), also paradigms shaping technological trajectories (Dosi 1982), and patterns and regimes (Rip and Kemp 1998), which shape what will happen. All of them can be undermined by new variations and/or changes in selection environments.

In evolutionary theory, the unit of analysis is variation/novelty, not actors (cf. Fleck 2000). Actors are concerned about "their" novelties, however, and try to protect and nurture them. Or develop alternative novelties, for that matter. Thus, to understand novelties and their development, one should also study actor strategies and their interactions. In other words, evolutionary approaches should not just follow the biological model. A key difference with neo-Darwinian theories of evolution (including the economic theories which focus on variety in a population) is the occurrence of anticipation on future selection, and the institutionalization of such anticipations.

An instructive example of institutionalized anticipation is the use of tests and the emergence of test labs. In a sense, these internalize selection so that it can be experienced at a stage where corrections and alternative variation are still possible. As Van den Belt & Rip (1987) showed for the synthetic dye industry in the late 19th century, this can lead to

situations where market or other external selections become domesticated, i.e. depending on the supplier and his test labs. Another example of partial internalization of selection environments, particularly striking in recent decades, is the role of expectations and promises which mobilize resources from the selection environment, but have to adapt to the requirements that come with these resources (Van Lente and Rip 1998).

Both ANT and evolutionary theories take a strong position on agency: interactions, associations and their outcomes are more important to understand eventual order and change than intentions of actors and the actions that are assumed to follow from them.[6] In evolutionary theory, so-called agency can be positioned as variation rather than intentional action.[7] In so far there is agency, it is always embedded agency (cf. Garud et al. 2007).[8] Still, with hindsight, stories are told about heroic actors who accomplish great deeds; or just small stories about actors realizing something. The fact that such stories are told then colours our interpretation of ongoing events: we look for agents and causes, even while this is premature and potentially misleading.[9]

3. A multi-layered context

The general idea of entanglements leading to somewhat stable patterns in the selection environment for technological change and innovation has been specified in terms of niches, regimes, and landscape (Rip 1992, Rip and Kemp 1998, Kemp et al. 2001). As I noted in the introduction, this has been taken up in a multi-level model for technological

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[6] Tentative actions which might lead to novelty are often transformed back into the regular (cf. 'repair work' as studied in symbolic interactionism) or excluded or otherwise made invisible.

[7] An interesting example of such variation-in-context is how on 1 December 1955 Rosa Parks, a black lady from Montgomery (Alabama), sat down in the bus on a place reserved for whites. She was forced to get off the bus, and this sparked off the bus protest movement. Hundreds or thousands of black persons had had this experience without anything much happening. Now, the circumstances were right, and other actors in the situation, notably in the nascent civil rights movement in Alabama (and later more widely) who could use Rosa Parks as a case for their cause, co-produced the effect. The common storyline here is that of an individual act of courage that triggers collective display of defiance. Schuyt (1972) already emphasized the incidental character of the action itself, noting that Rosa Parks had no intention to protest, she was just too tired to remain standing. Whatever the intentions, a "lateral action" occurred, across rather than against the existing order. Lovell (2003) adds that Rosa Parks did have a history in human rights activities, and then shows that she, rather than other blacks who suffered this treatment, was selected as "standard bearer" because she was working class and respectable. Thus, as Beck et al. (2003: 26) phrase it: "The subject becomes part of a self-selected network which allows connection and communication, but also makes it the object of the choices and decisions of others."

[8] Garud and his colleagues tend to work with the theoretical perspective of symbolic interactionism, broadly speaking, but arrive at the same position as I come to in this section. Cf. these lines from the abstract of Garud et al. 2010): "Path creation entertains a notion of agency that is distributed and emergent through relational processes that constitute phenomena. Viewed from this perspective, 'initial conditions' are not given, 'contingencies' are emergent contexts for action, 'self-reinforcing mechanisms' are strategically manipulated, and 'lock-in' is but a temporary stabilization of paths in-the-making."

[9] This is also linked to a need to evaluate, up to allocation of praise and blame. Cf. also Garud 2008: the significance of an event cannot be readily understood in real time, but must be weighed against the overall flow of events over time.

change, which is now used extensively to analyse technological transitions (Geels 2002, 2005).

The model is visualized in Figure 1 (after Rip 2000). The arrows represent innovation journeys, and their location in the diagram reflects which of the layers influencing the journey is particularly prominent at that stage of the journey. This visualization actually combines two different topics, and can thus be misleading if used mechanically. One story that is told by the visualization, highlighted by the arrows, is about growth (increase of performance, increase of scope) over time, and perhaps decline. Such growth can lead to modification of a regime, or even a new regime (an example would be biotechnology), and eventually, changes in the landscape – this is what makes the model interesting for analysis of (socio-) technical transitions, and for suggestions how to work towards such transitions. The other story told by the visualization is about three layers influencing developments each in their own way, and evolving in their own right. What is influenced are ongoing 'local practices & novelty creation', depicted in Figure 1 under the bottom line. Each of the three layers functions as an affordance, enabling and constraining practices and novelty creation. The way they do so is different: niches are protected spaces, and thus shaped by requirements for protection, and some boundary maintenance; regimes are about rules (they provide a grammar for further development), while landscapes have effects through their gradients. Together, they constitute the general context of innovation journeys. This has to be filled in for particular cases, and then more complexity will become visible.

In the second story, there is no place to visualize the innovation journey in the two-dimensional diagram, one would need a third dimension. And the question would remain whether increase of performance and scope, important in the first story, would be a good way to characterize this third dimension. One might actually need more dimensions to characterize an innovation journey.

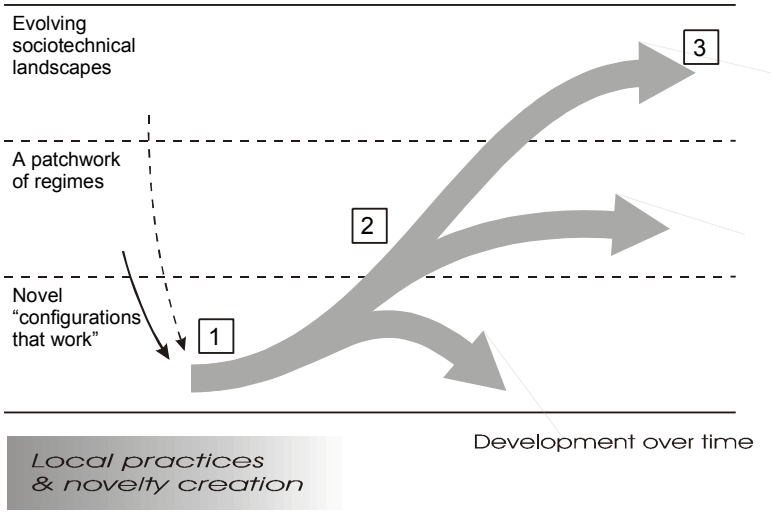

Figure 1: The three-layered model of sociotechnical change

Figure 1 combines the two stories in a visually powerful way, but one has to be careful about what it actually represents. Still, it is widely reproduced and referred to in the literature (and occasionally also criticized). For this article, the three layers, i.e. the second story, are important. The arrows are then a reminder that one might eventually also develop a proto-theory of innovation journeys, focusing on development of technology and its embedding in society.

In discussing the layers, let me start with how regimes emerge and become part of the overall constellation. Regime theorists like Nelson & Winter (1977), Dosi (1982) and Van den Belt and Rip (1987) have emphasized the importance of search routines, heuristics and other rules, and how these combine into a grammar that shapes action in and across communities of practice. Nelson & Winter's example is instructive: "… the advent of the DC3 aircraft in the 1930's defined a particular technological regime: metal skin, low wing, piston powered planes. Engineers had some strong notions regarding the potential of this regime. For more than two decades innovation in aircraft design essentially involved better exploitation of this potential; improving the engines, enlarging the planes, making them more efficient. (Nelson and Winter 1977, p.56, 57)

While rules (including possible standards) are proposed all the time, explicitly or *de facto* in ongoing activities, important is the shift from it being a tentative rule that has to be defended all the time, to an authoritative rule that shapes action, as a force in its own right. In other words, a "reversal" occurs, from being driven to being a driver. This

is characteristic for how the regime layer comes to shape activities in ongoing practices. After the reversal, there will be dynamics of its own, e.g. consideration and improvement of the rules (cf. Deuten 2003). An interesting example of a reversal, in the large, is the shift, in the 1960s, from a 'computing' regime (where the new computer substituted for earlier computing tasks) to a 'computer' regime where new types of application were developed, driven by the potential of the computer (Van den Ende and Kemp 1999). Enlightened technology strategies take the nature and ongoing dynamics of regimes into account (cf. Metcalfe and Boden 1992).

The regime or technological paradigm leads to recognizable 'trajectories' (in the sense of Dosi 1982) – the positive version of path dependency –, and its force also derives from the linkages, networks, and their alignment, in which it is embedded. Together, this shapes co-evolution of innovations and industry structures (Nelson 1994), and more broadly, of technology and society. There are definite patterns in such co-evolution (Rip and Kemp 1998). While there will always be contingencies (as emphasised in Darwinian evolutionary theory and in some approaches in technology studies), there is also linkage creation, increasing alignment, and *de facto* irreversibility leading to path dependencies (Rip, Robinson and Te Kulve 2007).

The layer of niches, i.e. protected spaces for vulnerable novelties, "hopeful monstrosities" (Mokyr 1999), has a different social location (cf. Schot and Geels 2007). Protected spaces are carved out in the selection environments, sometimes by benevolent selectors (sponsors, "uncles" of start-up firms). Technological development in a niche gives rise to mini-paths and a lock-in into the requirements of the protected space – and thus a risk of not being able to survive in the wider world. This observation led to the original idea of Strategic Niche Management (Van den Belt and Rip 1984, Rip 1992), using the evolutionary metaphor of survival of the fittest to define management strategies for gradual un-protection in order to become successful in addressing, and surviving in ever wider selection environments.

Protected spaces have different shapes and sizes. One example, mentioned already, is the test lab for new products, functioning as a domesticated selection environment (where the risks of selection occur in private). Instructive in how they extend the analysis of protected spaces is Law and Callon's (1992) study of the development of a fighter aircraft. The actual work on the project needed a physically and organizationally protected space, but to maintain such protection a macro-protected space was necessary consisting of an agreement between the relevant Ministers (including the French collaborators). The continuation of the macro-protection had to be fed with optimistic progress reports. When the macro-protected space collapsed (in this case, through a combination of political shifts and disappointing project results), the micro-protected space became exposed, and collapsed as well.

The third layer, of socio-technical landscapes, shapes activities and interactions by creating affordances and constraints through its gradients, as in a material landscape with its hills and valleys traversed by the traveler.[10] In Sahal's well-known picture (Figure 2), a path in such a landscape is depicted including a possible fork.

[10] Compare the notion of a "fitness landscape" (Lansing and Kremer 1993), and in biology, an "epigenetic landscape" (Waddington 1975).

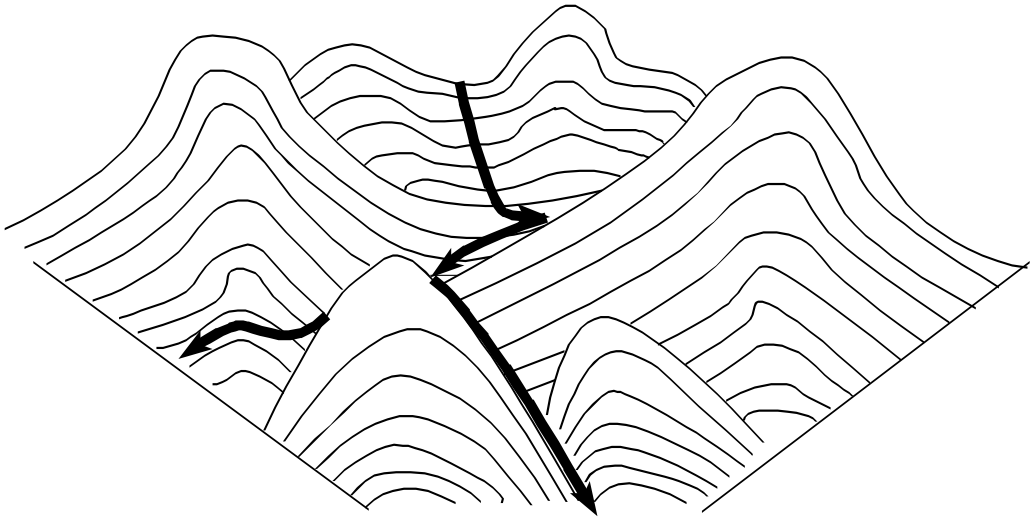

Figure 2. Gradients in a landscape affording certain paths (Sahal, 1985: 79)

An important component of sociotechnical landscapes is sociotechnical infrastructure. An example is the infrastructure of electricity generation and use, including the grids (nationally and internationally) and the billing systems. Electricity has become embedded in society, and its use has become so important that the infrastructure of electricity generation is an almost obligatory passage point for fuels and other energy carriers in order to reach end users. Alternatives to electricity stand little chance, at least in the short term.

A landscape with its gradients can be intentionally shaped, as in the example of Robert Moses, city architect of New York, who developed beaches and parks on Long Island, and made the overpasses over the roads leading to them so low that buses, on which blacks and poor whites had to rely, could not pass under them. Once in place, they continued to have their effect, independent of the original intentions (and their height can become irrelevant when everybody can go by private car).[11] It is a sociotechnical landscape because it has cultural components as well, for example the disciplining in the society of the 1920s which made the blacks and poor whites not think of tearing down the overpasses.

Sociotechnical imaginaries, for example about how and why to develop nuclear power (Jasanoff and Kim 2009), become embedded in institutions and sunk investments, and are then part of the sociotechnical landscape. They also shape actions and policies (by being followed, and occasionally by being contested) that constitute recognizable trajectories of development. In that sense, they are like rules, now at the macro-level of society.

5. The increasing importance of anticipatory coordination

[11] For further discussion of this example and how it has become iconic, so that the historical details do not matter very much, see Rip (2009).

The phenomenon of anticipatory coordination has become more important with increasing policy and strategic interest in new advanced technologies, biotechnology and recently nanotechnologies being prime examples (cf. Joly et al. 2010). Their promise becomes part of the context of concrete innovation journeys. And some of the coordination work is actually done by the promises, as they mobilize actors. Thus, there will be some shaping of technological development, and this will become stronger when there is institutionalization of anticipatory coordination as in the European Technology Platforms. This appears to be a different kind of shaping compared with niches, regimes and landscapes, and might thus be the beginning of a new layer.

As will be clear in the examples below, anticipatory coordination is an attempt to project a path into the future, which is to be co-produced by concerted action of the various actors. The projection is presented as having a certain inevitability to it, and may actually work as a self-fulfilling prophecy. There is also informal and *de facto* anticipatory coordination, for example through promises. The recurrent element is that projected futures are put forward in the present, and are taken up and thus influence shape and direction of innovation journeys.

The realization of the projected innovation will of course depend on the effort of various actors. There is also a choice, well known from the strategy literature, whether to go for "fit", keeping close to the present requirements and contexts, or "stretch", changing the context so that there will be space for, and receptivity to, the innovation. There is a link with the discussion of incremental and breakthrough or architectural innovation (Abernathy and Clark 1985), where the latter appears to require "stretch" strategies. One can also think of a sequence, starting with fit, say to existing markets, or existing technological competencies, and then becoming more ambitious.[12]

There will be self-fulfilling prophecy effects, for example when "stretch" strategies are justified through the reference to an impending and/or necessary transition, and then contribute to the actual realization of the "stretch".[13] In the complex interactions that are involved, the overall direction of development depends of course on much more than the specific "stretch" efforts. So there may not be a transition, or if there is, it might be of a different kind than intended. Still, actors can be mobilized by the notion of a transition. And there may be attempts at coordination of efforts, in the large and in the small.[14]

Thus, anticipatory coordination can be characterized in evolution-theoretical terms as a further move in the direction of domesticating a future selection environment

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[12] Hoogma (2000) has analyzed this retrospectively for experiments with electric vehicles (see also Hoogma et al. 2002). In Doorn (2006), an attempt is made to use the fit/stretch approach toanticipate on future developments in nano-electronics.

[13] There is a seeming contradiction: if something (here, the transition) is impending, there is no need to talk about its necessity. In practice, actors mix the two kinds of argument when they try to enrol others to the cause. "See how important a transition towards sustainability (or security, or ..), so you must join the effort." And: "You can't resist, because the transition is upon us."

[14] World Wars and other external pressure may lead to coordination of efforts and create direction to the outcome. The threat of war, and the need for external security can have similar effects, as in the Cold War development of military technologies. The metaphor of "war" is used to call for such coordination and thrust, as in the 'War on Cancer' (in the USA in the 1970s, cf. Rettig 1977) or the 'War on Poverty' (Edelman 1977).

which is unknown but is deemed to become more manageable thanks to forward-looking coordination.

Anticipation is a general phenomenon. Prudent actors anticipate, and will work to reduce threats and push opportunities. They encounter other (prudent as well as imprudent) actors, and these interactions lead to some *de facto* coordination, and some alignment. With such experience, anticipatory coordination can become sought after intentionally. The history of the International Technology Roadmap for Semiconductors (ITRS), responsible for a biannual roadmapping exercise, is illustrative, because of the gradual extension of the number of actors involved in the consortium, and for the dominant role it now plays in the sector.

The sector of semi-conductors shows rapid technological development, attempts to anticipate, and shifting industry structures which make anticipatory coordination both important and difficult. For a long time, reduction of uncertainty was realized by referring to Moore's Law, on the regular increase in speed, decrease in size, and decrease in production costs, as a guideline for what to expect and what efforts are necessary to achieve the expected performance (if only because one's competitors would otherwise create an advantage for themselves in the "semi-conductor race"). In this way, the validity of Moore's Law became a self-fulfilling prophecy since the late 1970s.

There is now discussion, not only of physical limits ("ceilings" or "red brick walls") to the continuation of Moore's Law, but also diverging searches and identification of options that are "More than Moore" or "Beyond Moore". The present opening up of micro-electronics to a variety of alternatives to the CMOS path as it was and is entrenched in practices and strategies of semi-conductor firms, can be seen in evolutionary terms as the punctuation of an equilibrium. New spaces emerge for production and recognition of variety, and alternative ways of anticipatory coordination emerge. This is visible in the European-based micro- and nano-electronics platform ENIAC, the European Nanoelectronics Initiative Advisory Council,[15] led by the big incumbents in the sector, and through its members also coordinating with their North-American and East-Asian counterparts.

These recent developments offer two insights into anticipatory coordination. First, the fact that ENIAC is recognized as a European Technology Platform, an instrument of the European Commission's technology and innovation policy, shows how these platforms may evolve to become informal consortia for coordination of strategies. This may take time. The Platform on NanoMedicine, led by directors of the relevant divisions of Philips and Siemens, draws on the strong interest in nanomedicine, but has not yet built a tradition of anticipatory coordination. It is still only a space in which new interactions occur, with little or no entanglement leading to dynamics of its own.

Second, the key to formal and informal anticipatory coordination are spaces for interaction where actors can mutually position their activities and strategies in relation to possible and emerging paths. Such spaces can emerge within ongoing entanglements, opening up, as it were, but also after a time closing down.[16] Important for the productivity

[15] Now evolved into the ENIAC Joint Undertaking, dispensing R&D funds. See http://www.eniac.eu/web/index.php

[16] This resembles de-alignment and re-alignment, but need not be linked to the introduction of a specific technological novelty; see for example Stirling (2008).

of spaces around new and emerging science and technology is the role of a public or semi-public actor offering room for interaction between private actors; this has been very visible in European Union Framework programs and projects (Edler 2000). A further important aspect is the role of linking-pin and other institutional entrepreneurs (Te Kulve 2010).

Anticipation builds on expectations, as technology development does anyhow. What is new is not just the importance of promises in resource mobilization, but their role in technology and innovation policy, and in strategies of various technology actors. A further phenomenon, important for my question about a possible new layer, is the role of globally formulated promises like "nanotechnology leads to a third industrial revolution"; "personalized medicine"; "the hydrogen economy"; and earlier, "the electronic superhighway".[17] Such global promises are part of policy and strategy discourses. They float above specific promises about better performance of a device and concrete resource mobilization (and the further articulation of requirements on the new option). The global promise often remains alive in policy independent of actual successes. Konrad (2006) has traced the dual dynamics of the surviving (and in that sense, successful) global promise of the electronic superhighway and the failure of a number of concrete projects (in her case studies, in the South of Germany). The pattern that is visible in her study can be recognized in other domains (see also Parandian et al. forthcoming). It is visualized in Figure 3, which builds on earlier analysis of promise-requirement cycles (Van Lente and Rip 1998).

[17] There is rhetoric force in such words and phrases. An earlier example is plastics – compare its use in the 1968 movie *The Graduate*, where Dustin Hoffman, playing the graduate, got this career advice: "I just want to say one word to you. Just one word. ... Plastics … There's a great future in plastics."

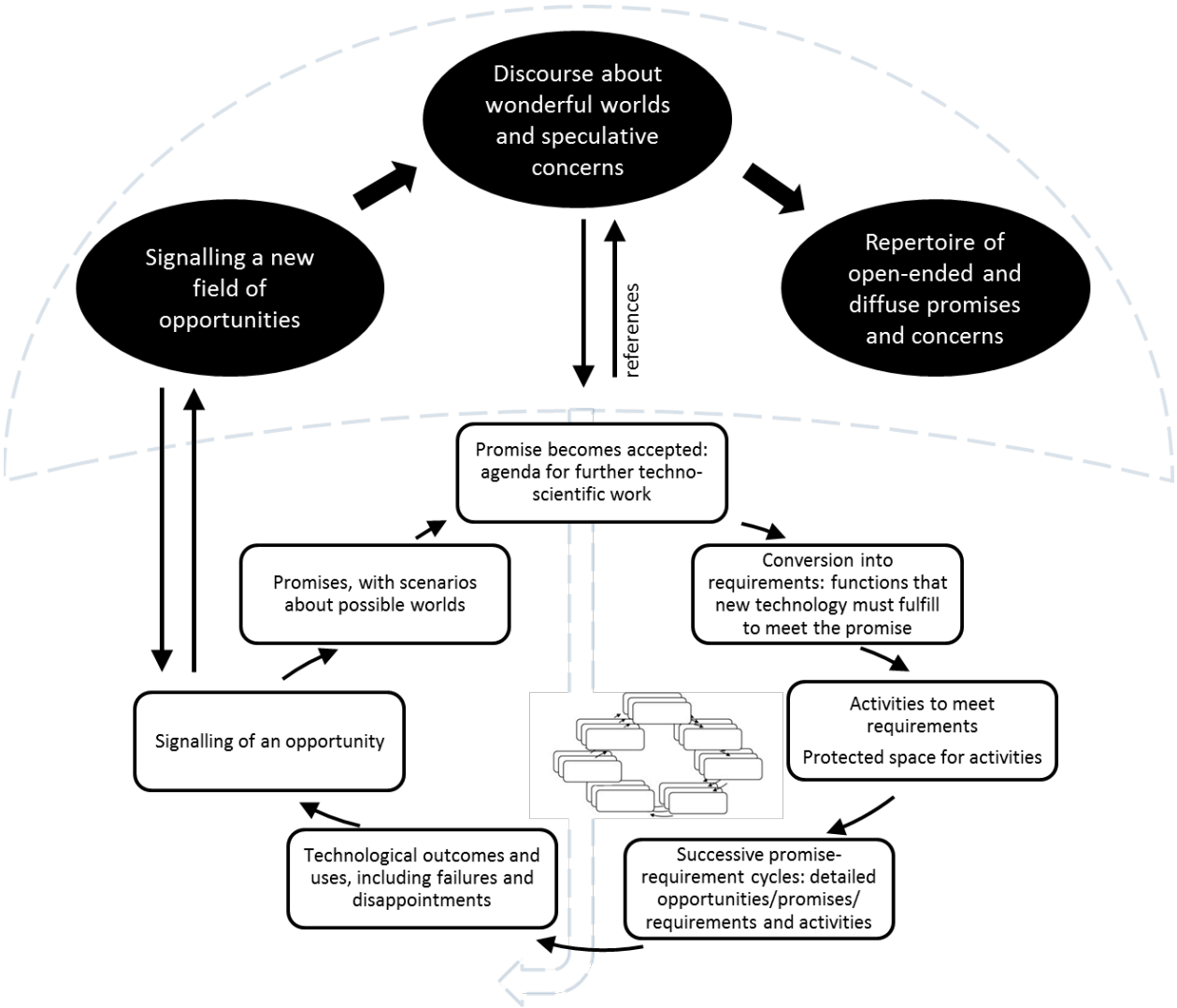

Figure 3. Dual promise dynamics (Figure courtesy of A. Parandian)

There is interaction between the global and the specific dynamics, starting (see left hand side of Figure 3) with the signaling of a specific opportunity linked to ideas about a new field of opportunities (say, a new diagnostic sensor and the field of point-of-care medicine). Brave new worlds are articulated in the global discourse, while specific performance promises are turned into requirements for further work, say lowering energy requirements and costs of the diagnostic sensor. Such requirements can be articulated as necessary to achieve part of the brave new world, and the success or failure of further development might lead to reconsideration of the global promise. In practice, success is often attributed to the "force" of the global promise, while failure is seen to derive from wrong choices and/or circumstances – so the global promise remains immune for criticism. The effect is that global promises survive and constitute a repertoire that can be drawn upon. As a relatively stable backdrop for specific discussions and concrete activities, the repertoire is part of the sociotechnical landscape: it is easy to quote from the repertoire, and if one wants to go against a global promise, that will take effort.

A counterpoint to these dual dynamics of promises is the possibility of inflated promises leading to disappointment. This possibility keeps spokespersons for nanotechnology worried: how much hype can we tolerate? What if an impasse occurs as has happened with "green" biotechnology? (see Rip 2006b). The possibility of a hype-disappointment cycle can be seen as a fact of life, a pattern that occurs repeatedly. It can then be exploited to anticipate, as the Gartner Group does with its hype-cycle. The hype-cycle of inflated expectations, ensuing disappointment and a shake-out, with only a few robust technologies remaining, was developed for information and communication technologies. Its use shows an interesting dialectics. There is reconstruction of the cycle, say for security technologies in various stages of development and attendant expectations (a master curve), and The Gartner Group then tells firm X where its technological option is located on the curve, and thus, what its future will be. But Gartner Group also advises about whether to follow the cycle or step out. Determinism is the basis for the analysis, but voluntarism shapes the advice. Things will go this way, but if you understand it (and hire Gartner Group as consultant) you can escape from it by acting (cf. Rip 2006b).

Actually, a general point about anticipation becomes visible here: there is an attempt to project a path into the future, with a certain inevitability to it. At the same time, the actors who are supposed to contribute to the realization of that path are invited to use the anticipation to develop better strategies, i.e. deviate from the path, perhaps undermine it.

There are many anticipatory activities and coordination initiatives, and this implies that the ecology of the innovation system is changing. In terms of evolutionary theory, concerted anticipation on future, and thus still unknown, performance and selection environments turns into vicarious pre-selection (vicarious because there is no way to test the promise other than through discussing it). This is a new type of enabling and constraining of innovation dynamics, and thus makes it a candidate for becoming a new layer in the context of innovation journeys. Whether it will actually become such a layer depends on how it will institutionalize. A key point is that there are now intermediary actors like consultants (Gartner Group is just one of many), working parties, and dedicated organizations (like the International Technology Roadmap for Semiconductors), all in the business of creating roadmaps and other foresight exercises. So it is not just a matter of actors anticipating and enrolling other actors. It might become a requirement on innovation to take existing roadmaps and other foresight results into account. Similarly, the repertoire of globally formulated and more specific promises is not something that innovators can just pick from. It creates soft requirements for directions to go, or at least how to justify the directions that are actually taken when they differ from the repertoire. Clearly, there are building blocks for a new layer in the context of innovation journeys.

6. In conclusion

While actual contexts of specific innovation journeys are varied, idiosyncratic and contingent, there are also overall patterns in the context, related to the way technological

innovation is organized and embedded in our societies. Given the institutionalized division of labour between promoting innovation and handling its embedding in society (Rip et al. 1995), there is somewhat independent variation and selection so that evolutionary theory can be applied in a straightforward way. However, prudent innovators anticipate on selection, and new intermediary institutions emerge to carry such anticipation.

Three overall patterns can be identified, and their relation with innovation journeys can be conceptualized as layers in the context of innovation journeys, which enable and constrain innovation practices. Niches, i.e. protected spaces, are explicitly conceptualized in evolutionary-theoretical terms (protection against selection), while the actual activities and interactions can be understood with the help of actor-network theory. Regimes and landscapes are sedimented outcomes of co-evolution of technology and society, guiding choices for further innovation as well as being relatively independent selection environments. However, novelties, and actors pursuing them, may well go against the existing regime and landscape and "stretch" them rather than attempt to survive by "fitting". In anticipatory coordination, depicted as a new layer in the context of innovation journeys, promises and roadmaps can become stabilized and shape developments – sedimentation-before-the-fact, as it were.

Niches, regimes and landscapes differ in scope and in their duration over time. Thus, they might be seen as a nested set of selection environments. But their relationship is not hierarchical. Rather, they embody different mechanisms and dynamics in how they shape innovation journeys. All three, as well as the emerging layer of anticipatory coordination, are present at the same time, even if some may be backgrounded. Innovation practices can refer to them, and play them out against each other, e.g. by pushing the innovative (breakthrough) character of what happens in the niche against the conservative thrust of the regime.

When patterns and their shaping of innovation practices are emphasized, there is the question how much scope there still is for agency. This question is important in its own right but also relevant for (enlightened) management of innovation. The heroic version of agency, as 'winning out against the odds', is of little help – even if such stories can be told --, if agency is embedded, and outcomes are shaped in interaction. The modest version is that innovators can recognize patterns and take them into account so as to become more successful in what is then seen as a choice between following rules or gradients or breaking them. In the case of anticipation, there is a dialectical relationship between projections of the future which must be sufficiently solid to base action on, and the possibility to choose for actions that go against these projections.

More concretely, management of innovation should be seen as management of novelties that are created and nurtured, and then exposed to the vicissitudes of the wider world, while anticipating on possible uptake and embedding in society and taking such anticipations into account at a relatively early stage in the innovation journey. There are general management issues involved, as well as specific dedicated (and creative) action. What I have added to this picture is the importance of taking general patterns in the context into account. By identifying them and showing how they work I have broadened the perspective, enabling enlightened management of innovation.

In doing so I have also created building blocks for a theory of dynamics of innovation journeys in context. In earlier work I focused on patterns in innovation journeys (and drew out implications for disaggregation of governmental technology and innovation policy). In this article I identified patterns in the context of such innovation journeys, and considered actions of innovators in relation to these patterns. Next steps would be, first, to do case studies informed by this theory-in-the-making so as to see how much of the dynamics of innovation can be understood in those terms, and perhaps modify and extend the theory. And second, to strengthen the theory by mobilizing general social science insights, in addition to co-evolutionary theory and Actor-Network Theory. To see the world as context for innovation dynamics is acceptable for an innovator, who starts with a concentric perspective (but should not remain imprisoned in it). A theorist should locate these contexts as part of how our late-industrial societies evolve.

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