



Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory



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ABSTRACT

The Multi-Level Perspective (MLP) is a prominent framework to understand socio-technical transitions, but its micro-foundations have remained under-developed. The paper's first aim is therefore to develop the MLP's theoretical micro-foundations, which are rooted in Social Construction of Technology, evolutionary economics and neoinstitutional theory. The second aim is to further identify crossovers between these theories. To achieve these goals, the paper analytically reviews the three theories, focusing on: (1) the relevance of each theory for transitions and the MLP, (2) the theory's conceptualisation of agency, (3) criticisms of each theory and subsequent conceptual elaborations (which prepare the ground for potential crossovers between them). Mobilizing insights from the analytical reviews, the paper articulates a multi-dimensional model of agency, which also provides a relational and processual conceptualization of ongoing trajectories in which actors are embedded. Specific conceptual linking points between the three theories are identified, leading to an understanding of socio-technical transitions as evolutionary, interpretive and conflictual processes.

1. Introduction

The Multi-Level Perspective (MLP) has become a popular framework to analyse socio-technical transitions, which are shifts to new kinds of (energy, mobility, housing, agro-food) systems that involve not just technological innovations, but also changes in consumer practices, policies, cultural meanings, infrastructures and business models (Elzen et al., 2004; Smith et al., 2010; Markard et al., 2012). The MLP has been used to analyze both historical transitions (Geels, 2002, 2005; Geels and Schot, 2007; Berkers and Geels, 2011) and contemporary and future sustainability transitions (Nykvist and Whitmarsh, 2008; Van Bree et al., 2010; Morrissey et al., 2014; Hynes, 2016; Osunmuyiwa et al., 2018; Moradi and Vagoni, 2018). It has become one of the core frameworks in the Sustainability Transitions Research Network (Köhler et al., 2019), which (in March 2019) had more than 1750 members from across the world.

The MLP is a useful framework to analyze transitions (Rip and Kemp, 1998; Geels, 2002), because its concepts accommodate both radical change (through the concept of *niches* as locus of radical novelty) and dynamic stability (through the concept of *socio-technical*

regimes, representing the institutional structuring of tangible socio-technical systems) and influences from broader contexts (through the *landscape* concept), which are unlikely to remain constant over decades-long processes. As a processual framework, the MLP suggests that socio-technical transitions come about through alignments of trajectories and ongoing processes within and between these three analytical levels. In a nutshell, these dynamics can be summarized as: (a) niche-innovations gradually build up internal momentum (e.g. through learning processes, price/performance improvements, expanding social networks), (b) changes at the landscape level create pressure on the regime, (c) destabilisation of the regime creates windows of opportunity for the diffusion of niche-innovations, which aligns with ongoing regime processes leading to substantial transformation and disruption (Fig. 1).¹

Poole and Van de Ven (1989) suggest that process theories of a phenomenon should have two complementing components: a global (or outside-in) model and a local (or inside-out) model: "The global (macro, long-run) model depicts the overall course of development of an innovation and its influences, while the local (micro, short-run) model depicts the immediate action processes that create short-run developmental patterns. (...) A global model takes as its unit of analysis the

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¹ Fig. 1 is reproduced here, because later arguments will refer back to parts of it.

Increasing structuration of activities in local practices

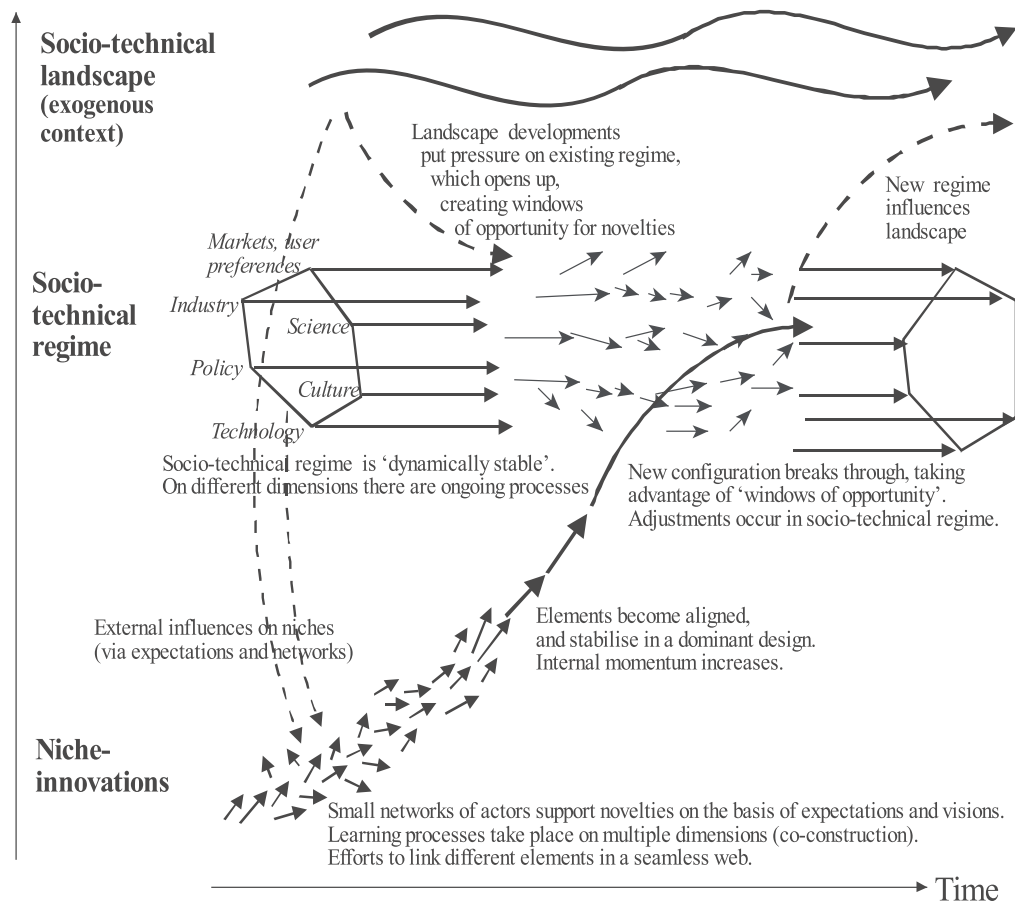


Fig. 1. Multi-level perspective on transitions (Geels and Schot, 2007: 401).

overall trajectories, paths, phases, or stages in the development of an innovation, whereas a local model focuses on the micro ideas, decisions, actions or events of particular developmental episodes" (p. 643).

Geels and Schot (2007) argue that the MLP was initially developed as a 'global' model to provide a big picture understanding of longitudinal socio-technical transition processes. As indicated by previous appreciative theorizing (Rip and Kemp, 1998; Geels, 2004; Geels and Schot, 2007; 2010), this global model combined core concepts from Social Construction of Technology (SCOT), evolutionary economics (EE), and neoinstitutional theory, e.g. regimes, niches, landscape, technological trajectories, institutional structures, radical innovation, social networks, interpretations, visions, learning processes, alignment, co-construction, seamless web, societal embedding (see also Fig. 1).

Although the MLP-processes and trajectories are always enacted,² Geels and Schot (2007) acknowledged that the MLP's local model had remained under-developed. They suggested that the MLP's underlying theories implied a "multi-dimensional model of agency", but only indicated the bare outlines: "We assume that actors are self-interested, act strategically, and try to calculate which actions will best achieve their

²"Because the linkages between processes at different levels are made by actors in their cognitions and activities, the dynamics are not mechanical, but socially constructed. (...) Transitions (...) are emergent outcomes of interactions between social groups with myopic views and differing interests, strategies and resources. (...) These social groups try to navigate a transition, find their way through searching and learning, interact in power struggles, controversies, and debates" (Geels, 2005: 453).

goals. But cognitive capabilities and time are limited (bounded rationality). Hence, actors use cognitive rules and schemas, some of which are shared with others. Formal rules, role relationships and normative ties also enter in decisions and actions, because actors are embedded in regulatory structures and social networks" (Geels and Schot, 2007: 403).

This article aims to make the next step by articulating the micro-foundations of the MLP's local model. To that end, the first goal is to elaborate the multi-dimensional model of agency, alluded to by Geels and Schot (2007). Weber (1978/1922) famously distinguished four types of social action: instrumental goal-oriented action, value-rational action (norm-orientation), traditional action (routines, habits, customs), and affective action (emotions). Emirbayer and Mische (1998) also proposed a multi-dimensional typology, which distinguishes iterational (repetition, habitual), projective (envisioning new possibilities, articulating goals, plans and objectives) and practical-evaluative (deliberation, judgment, choice, decision-making, execution) dimensions of agency, based on orientations towards the past, present, and future. To achieve the first goal, the paper's strategy is to provide a foundational discussion of the conceptualisation of agency in the MLP's underlying theories (and how these are relevant for the MLP and socio-technical transitions), and interpret the results with Emirbayer and Mische's general typology.

This development of a multi-dimensional model of agency not only articulates the MLP's local model, but also provides a response to the often-repeated criticism that the MLP insufficiently addresses agency. Smith et al. (2005: 1492), for instance, portray the MLP as "dominated

by rational action” and “too descriptive and structural, leaving room for greater analysis of agency”. [Genus and Coles \(2008: 1440\)](#) state that the MLP “undervalues the role of agency and politics” and ask for more “concern for actors and alternative representations that could otherwise remain silent” (p. 1441). [Fuenfschilling and Truffer \(2014: 773\)](#) simply state that the MLP has a “flawed conceptualization of agency” without further specification. Other papers repeat the lack-of-agency criticism, sometimes leading to ‘straw man’ framings that use broad-brush criticism to position their own research (e.g. [Avelino and Wittmayer, 2016](#)).

While the early lack-of-agency criticisms were understandable (since there were initially only a few case studies of transitions to support the generic MLP-framework), the later criticisms are a bit ‘surprising’, because conceptual and empirical MLP-studies have substantially progressed since the mid-2000s, both in the form of ontological discussions ([Geels, 2010](#); [Geels and Schot, 2010](#)) and identifications of many kinds of social actions in transitions, e.g. learning, network building, visioning ([Schot and Geels, 2008](#)), shielding, nurturing, empowering ([Smith and Raven, 2012](#)), selective translations between niche and regime ([Smith, 2007](#)), intermediation and boundary spanning between niche and regime ([Kivimaa, 2014](#); [Smink et al., 2015a](#)), political struggles between niche and regime actors ([Hess, 2016](#); [Roberts and Geels, 2019](#)), active resistance by regime incumbents ([Geels, 2014a](#); [Smink et al., 2015b](#)), discursive framing struggles ([Roberts and Geels, 2018](#)), strategic reorientations of incumbent firms towards niche-innovations ([Berggren et al., 2015](#); [Geels and Penna, 2015](#)).

Nevertheless, the development of the MLP’s micro-foundations and local model may help address the concerns about agency, which is defined as the capacity of an actor to act ([Giddens and Sutton, 2014](#)) which may instantiate itself in concrete actions in specific contexts. Agency is thus more foundational than action, because it refers to core characteristics or properties of actors (i.e. the ontological model of the actor). I briefly unpack three aspects of the above definition to contextualize the analyses in subsequent sections.

First, the capacity to act can be related to many different characteristics or properties (e.g. routines, capabilities, resources, positions, interpretations, goals, interests, templates), which have given rise to many social science theories that tend to focus on only a few characteristics. The result of this specialisation is that many theories only address a slice of social realities, which is unfortunate since “real human social behaviour is a complex mix of commitments, loyalties, emotions, solidarities, as well as purposes and goals” ([Little, 2016: 47](#)). The paper’s first goal of developing a multi-dimensional model of agency may go some way in addressing this problem, even if focused on the MLP and socio-technical transitions.

Second, methodological individualists suggest that only individual human beings should be considered as actors with the capacity to act (e.g. [Elster, 2007](#)). Such a conceptualisation is practically unworkable, however, for socio-technical transitions, which involve many thousands of individuals interacting over many years ([Geels, 2010](#)). Macro-sociologists interested in large-scale changes such as state formation, revolutions, wars or globalization therefore tend to focus on “socially coordinated and institutionalized actions of individual actors as well as actions of organized social groups (e.g. social movements and formal organizations)” ([Kaidesoja, 2013: 312](#)). Collective actors (like firms, social movements, consumer organizations, Ministries) are also prominent entities in socio-technical transition. Social theorists suggest that such collective actors can have capacity to act when their “basic characteristics persist over time”, when they have “an internal structural-functional organization” (aimed at achieving articulated goals), when there is “social cohesion among the individuals who constitute the entity”, and when there is “some sort of regulative social process that maintains the entity’s identity over time” ([Little, 2016: 74](#)). [Ritzer’s \(1992: 568\)](#) sociological handbook therefore concludes that: “While agency generally refers to the micro-level (individual human actors), it can also refer to (macro) collectivities that act (...) such as organized

groups, organizations and nations” ([Ritzer, 1992: 568](#)).

Third, agency is situated in and shaped by structural contexts ([Emirbayer and Mische, 1998](#)), such as cultural contexts (e.g. symbols, discourses, narratives, categories), social-structural contexts (e.g. social networks and relations), economic contexts (e.g. transactions, financial flows, competitors), and regulatory-institutional contexts (e.g. laws, regulations). This is an antidote to voluntarist micro-theories that associate agency with free will and heroic actors that shape the social world at will.³ The paper’s development of a multi-dimensional model of agency will therefore also address the role of structural contexts, which are conceptualized as recursively related to agency.

The paper’s second goal is to articulate complementarities between the MLP’s underlying theories, not with the aim of full integration, but with the aim of identifying possible crossovers and linking points (see [Geels, 2010](#), for a meta-theoretical discussion of integration, incommensurability, eclecticism, and crossovers). The potential of crossovers between these theories has long been recognized by scholars in science and technology studies (e.g. [Rip, 1992](#); [MacKenzie, D., 1992](#); [Garud and Rappa, 1994](#); [Rammert, 1997](#); [Bruun and Hukkinen, 2003](#)) without achieving integration, as noted by [Weber \(1997: 83\)](#): “A major convergence can be identified between evolutionary economics and the sociology of technology. Although they have very different roots, the basic understanding of the process of technological change is quite similar, and – even more important – sufficiently open to introduce elements of the other perspective. (...) What is still missing is the actual integration in a single framework which would allow to investigate different cases from a wider perspective, and to bridge explicitly between economics and sociology with regard to technology studies”.

Evolutionary economists have also begun to show an interest in this crossover agenda. [Nelson \(2013: 192\)](#), for instance, observes that: “Our present relationships with the historians and sociologists working on innovation has been perfectly amicable, but not particularly active. (...) In my view, how well our community fares in the coming years will be strongly affected by how our relationships with these potential partners evolve”. [Steinmueller \(2013\)](#) also calls for “a broader and more synthetic approach” (p. 164) and diagnoses that: “We have not done very well in including the fields of practice from afield such as the history or sociology of science and technology, policy sciences, or innovation management” (p. 158).

The mutual enrichment of sociological and evolutionary innovation theories is thus an important, but unfulfilled agenda. The paper’s second goal is therefore to contribute to this agenda by articulating complementarities and linking points between the MLP’s underlying theories.

The paper proceeds as follows. Sections 2, 3 and 4 analytically review SCOT, evolutionary economics and neoinstitutional theory, focusing on foundational assumptions and relevance for transitions. Drawing on analytical sociology ([Hedström and Swedberg, 1998](#); [Demeulenare, 2011](#)), this review is also interested in causal processes and social mechanisms and how these help explain outcomes. The analytical review is challenging, because each theory is broad and has internal variations. Because of space constraints, certain nuances and debates had to be left out. Nevertheless, the paper aims to acknowledge internal diversity by identifying on-going debates, criticisms and

³ [Smelser \(1999: 4\)](#) argues that that the ‘micro-scope revolution’ of the late 1960s and 1970s, which “involved the vitalization of social behaviourism, symbolic interactionism, ethnomethodology, hermeneutics and phenomenology” was an (over)reaction to the hegemony of structural functionalism (often associated with Parsons), which from the 1930s to the 1960s “was virtually unchallenged as the dominant sociological theory” ([Ritzer, 1992: 258](#)). With regard to the emphasis in these theories on creative and skilled micro-interactions, [Collins \(1992: 80\)](#) critically diagnosed that “This longing for agency is part of the romanticism of left intellectuals at the end of the 20th century” (p. 77) and that many “sociological theorists write as if the hippie anti-warrior is a universal hero”.

responses. The review of each theory is organised along three sub-headings: (1) relevance of theory for transitions and MLP, (2) understanding of agency, (3) criticisms and elaborations of the theory, which creates potential for crossovers with other theories. Section 5 articulates the implications of the analytical review for the two goals: developing a multi-dimensional model of agency in relation to the MLP and articulating crossovers between the theories. Section 6 draws conclusions.

2. Social construction of technology (SCOT)

2.1. Relevance of theory for transitions and MLP

The MLP accommodates several core notions of SCOT, and the field of Science and Technology Studies (STS) more broadly. First, the MLP conceptualises technologies as socially constructed, rather than developing according to an internal technical logic (Bijker, 1995). The bottom-left corner of Fig. 1 mentions core STS-notions such as and ‘co-construction’ and ‘seamless webs’ (Hughes, 1983), which indicate that innovation is a social process of aligning heterogeneous elements, which involves actors moving between spheres such as science, markets, regulation and production. Social constructivist ideas are also visible in the literature on niche-innovation, which emphasizes the role of social networks, cognition (expectations, visions, beliefs), learning processes and alignment (Kemp et al., 1998; Smith and Raven, 2012). The niche-innovation literature suggests that radical innovations are initially unstable and exist as multiple design variations (indicated by small, diverging arrows in the bottom-left corner of Fig. 1), which are developed by different social groups and networks. The initial variety, divergence and uncertainty gradually give way to convergence and the stabilization of problem agendas, heuristics, theories, test procedures, design methods and criteria (Bijker, 1995). The creation of closure and consensus is a community-wide process involving negotiation, debate, and social learning (Pinch and Bijker, 1984).

The emergence of a technological trajectory can thus be conceptualized as a socio-cognitive process, where rules are initially fuzzy and diverse. Circulation (of knowledge and actors between projects) and aggregation (abstracting generic trans-local rules) gradually lead to an identifiable trajectory (Fig. 2) as rules become more articulated and social networks expand and stabilize (Geels and Deuten, 2006). This stabilization process is accompanied by specialization, differentiation, and institutionalization of roles and responsibilities.

Second, the MLP shares the broader STS assessment that science and technology are omnipresent in modern societies, and have contributed to major transformations in agro-food, energy, transport, housing, entertainment, and communication in the last two centuries. STS-scholars therefore criticize mainstream sociology for talking abstractly about

agency and structure, while ignoring the pervasive influence of material and technological dimensions. Since the nineteenth century, technological change has acquired an incessant endogenous innovative dynamic as it became an important way for actors to advance the modernization process (Schot, 2003). This does not imply technological determinism, since technologies are potentials that can be used in different ways: “Social change and economic impact are not things that can be extrapolated out of a piece of hardware. New technologies are unrealised potentials: building blocks whose eventual impact will depend on what is designed and constructed with them” (Rosenberg, 1995: 181). STS-scholars therefore argue that technology is a fruitful *entrance point* to studying societal change (including sustainability transitions). Callon (1987), for instance, suggests that technology is a way of studying ‘society in the making’, while Latour (1991) sees technology as ‘society made durable’, arguing that material components provide ways of anchoring new routines and practices. This does not imply a supply-side focus, because following technologies over time will bring the analyst from invention to innovation to diffusion, societal embedding and actual use (Fischer, 1992; Lie and Sørensen, 1996). In fact, this analytical strategy is probably more likely to lead to co-evolutionary and multi-actor analysis than a disciplinary strategy that privileges certain social groups, asking ‘what is the role of policymakers/firms/users/NGOs in transitions’.

2.2. Agency

Agency is central in SCOT, because of its strategy to ‘open up the black box’ of technological change by ‘following the actors’ and their shifting coalitions and beliefs. Demonstrating the presence of alternatives and the contingent choices underlying socio-technical change enabled STS-scholars to maintain that ‘things could have been different’, which usually refers to the *shape* and the *design* of artefacts.

Inspired by micro-sociological theories (phenomenology and symbolic interactionism), social constructivists often focus on a particular kind of agency, which highlights the *active* and *creative* engagement of actors in *meaning-making*. Technological change is conceptualized as an interpretive process of collective sense-making (Bijker, 1995). When new technologies emerge, there is much uncertainty about their form and function. Different social groups have different problem definitions and interpretations. New technologies are thus characterized by ‘interpretative flexibility’. Over time, actors interact with each other and with the technology, negotiate, learn and gradually build up shared meanings. The variety of meanings is thus gradually reduced through ‘closure’, an interactive process of negotiations and coalition building. One interpretation becomes dominant and others cease to exist. The selection of a dominant design thus coincides with the build-up of a

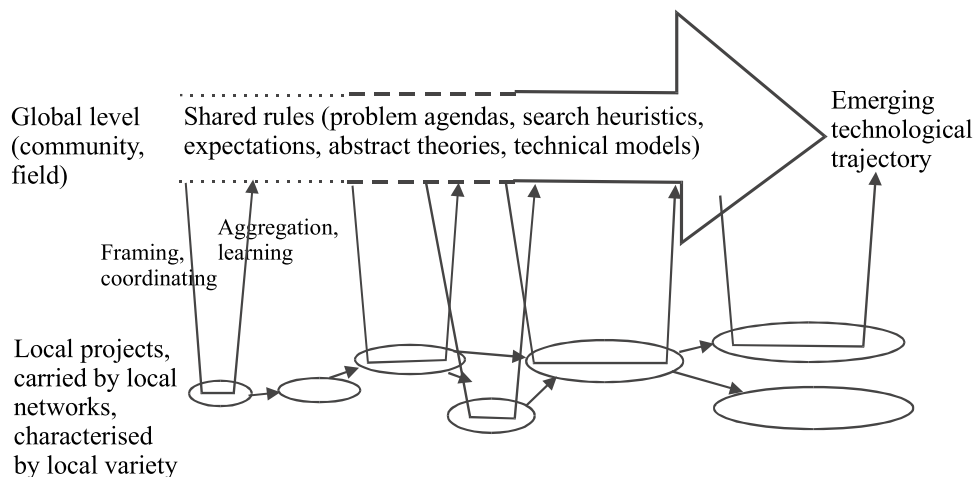


Fig. 2.. Emerging niche trajectory carried by local projects (Geels and Raven, 2006: 379).

shared technological frame (Bijker, 1995).

Although SCOT emphasizes socio-cognitive dimensions, it has evolutionary mechanisms: the initial variety of meanings is reduced through inter-group selection processes and build-up of a shared cognitive frame. "In SCOT the developmental process of a technological artifact is described as an alteration of variation and selection" (Pinch and Bijker, 1984: 411). The evolutionary dynamics in socio-cognitive processes are played out at the community level: at conferences, in journals, and struggles for research grants. "Researchers with different beliefs attempt to sway each other with respect to the routines utilized to judge the technology. It is in this sense that technological systems are negotiated. Therefore, competition between different paths occurs not only in the market, but also in the institutional environment" (Garud and Rappa, 1994: 347).

STS-scholars more broadly tend to focus on particular kinds of actors, often inspired by normative (emancipatory, humanistic) motivations.

- Social movements and activists have been studied with regard to protest activities (towards nuclear power, bio-technology, cloning) or their role in nurturing grassroots innovations (Hess, 2005; Hargreaves et al., 2013).
- Wider publics have been studied in relation to social acceptance, public debates and controversies over new technologies. STS-scholars offer both *analytical* insights on this topic (Nelkin, 1992) and *normative* appeals for more public participation and deliberation (Stirling, 2008).
- Users have been studied, not only as passive adopters of new technologies, but also as creative contributors and co-constructors (Fischer, 1992; Oudshoorn and Pinch, 2003). Adoption of radically new technologies involves 'domestication' activities such as *symbolic* work to develop the cultural categories that give meaning to new technologies, *practical* work through which actors integrate artefacts in user practices, and *cognitive* work that includes learning about the artefact and developing new user routines (Lie and Sørensen 1996).
- STS-scholars also study the effects of (new) technologies on marginal groups, underdogs, lay people, or the poor (Broerse and Bunders, 2000). From a critical theory stance, they often criticize the power structures or procedures that exclude these actors from decision-making. In this respect, STS-scholars are often critical of experts, highlighting the risk of technocracy for democratic control and open debate (Turner, 2001).

2.3. Criticisms and elaborations

Because of its assumptions and orientations, SCOT emphasizes some dimensions, but backgrounds others, which creates potential for conceptual elaborations. First, the strong focus on agency, local contingency, variability and contextual specificity has been criticized for voluntarist tendencies, heroic storylines, and a neglect of wider social structures. "As in most actor-centered accounts, these studies do less well at illuminating institutions, culture or society. The latter project calls for an altogether more expansive imagination and a more layered sensitivity" (Jasanoff, 2012: 439). Misa (1994: 119) also suggests that STS scholars have over-emphasized micro-studies in their attempt to debunk rationality and the linear model: "macro studies tend to abstract from individual case studies, to impute rationality on actor's behalf or posit functionality for their actions, and to be order driven. (...) Micro studies tend to focus solely on case studies, to refute rationality (...) and functionality, and be disorder-respecting". To overcome this dichotomy, Misa (1994: 140–141) suggests that "a focus on meso-level institutions and organisations that mediate between the individual and the cosmos (...) offers a framework for integrating the social shaping of technology and the technological shaping of society."

The MLP goes some way towards developing Jasanoff's "more layered sensitivity" and navigating Misa's dilemma by combining

constructivist micro-insights with macro-patterns. Bijker's (1995) notion of technological frames (which structure interactions between relevant social groups) and Klein and Kleinman's (2002: 46) efforts to "bring structures back in" (by proposing notions such as design forum, access rules, cognitive structures, relations of power and dependency, resources) also aim to address SCOT's voluntarist tendencies and create the potential for crossovers between SCOT and neoinstitutional theory.

Second, the STS strategy of 'opening up the black box' of technology has led to an 'upstream' focus on early technological development. Consequently, STS has paid relatively less attention to diffusion, overthrow of existing technologies, and technological 'impacts' on society. So, while STS scholars rightly emphasize complexity, fluidity and contingency, they often fail to analyse what happens *after* stabilization has occurred. Because of this bias, "questions about the effects and autonomy of technology are neglected. Important underexplored areas of inquiry include the study of the political effects of technology, the inertia of technological systems, the existence of trends and (...) the historical transformations associated with key technological innovations" (Dafoe, 2015: 1049). The topic of socio-technical transitions (and the MLP) is a way of reintroducing such longer-term, large-scale questions.

Third, SCOT privileges socio-cognitive (or 'ideational') kinds of agency (e.g. creative sense-making, social interactions), but downplays other kinds of agency such as competition, resource allocation, capabilities, and strategic calculation. Martin et al. (2012: 1194) suggests that "the focus on the capacity of human beings to construct their world-views, to act and to generate meaning, restricted researchers to relatively narrow analyses, making many STS practitioners critical of general theoretical frameworks". Crossovers with evolutionary economics, which emphasizes economic ('material') dimensions, therefore offer potential for developing more comprehensive, less lopsided explanations.

Fourth, STS runs the risk of ideological privileging of certain actors, thus conflating normative and analytical concerns.⁴ The normative literature about public debates has been criticized, for instance, for "an overly optimistic Enlightenment vision of what can be achieved by means of 'free' debate" (Radder, 2000: 541). Collins and Evans (2002: 263) similarly expressed unease about excessive emphases on public participation, feeling "a little uncomfortable when every treatment has the same political recipe, because it makes it all too easy to imagine that the prime motivation is political rather than analytical".

Fifth, in terms of theoretical repertoire, Guggenheim and Nowotny (2003: 232) diagnose that STS "has lost some of its previous links to the other social sciences", including general sociology, organizational sociology, history and the economics of research and innovation. They also suggest that a penchant for critical theory may have weakened analytical ambitions: "Theory in STS is often understood in the sense of critique, as a way of questioning the arrangements that one has found rather than coming up with propositions which would allow us to find to some regularities to explain different kinds and realms of order and disorder. (...) This is not to be taken as a plea for any particular theory, but a general call for integrating social theory into STS" (p. 255).

3. Evolutionary economics

3.1. Relevance of theory for transitions and MLP

Evolutionary economics has two complementary components, which are relevant for transitions and the MLP. *Macro-evolution* addresses long-term techno-economic patterns such as transformation of core characteristics of a population of firms, speciation (emergence of radical novelty), competition, replacement (of one population by

⁴ Purist STS-scholars may, of course, argue that norms and facts cannot be separated.

another), extinction, punctuated equilibrium. Schumpeter (1939: 102) initially developed these ideas, suggesting that economic “evolution is lopsided, discontinuous, disharmonious by nature (...) studied with violent outbursts and catastrophes (...) more like a series of explosions than a gentle, though incessant, transformation.” Later work on technological discontinuities and disruptive innovation further developed these ideas. *Micro-evolution* concerns mechanisms of variation, selection and retention that underlie genealogical lineages and trajectories. These ideas were initially developed by Nelson and Winter (1982), and further elaborated in literatures on routines, capabilities, and learning.

The MLP includes several core concepts from evolutionary economics.

- It accommodates the macro-evolutionary idea of transitions as involving technological overthrow and disruption, although later work (Geels and Schot, 2007) also distinguished more gradualist transition paths. The MLP understands transitions as struggles between radical niche-innovations and existing systems, which are reproduced by incumbent actors acting in the context of regimes. Transitions do not occur easily, because niche-innovations face uphill struggles to enter mainstream selection environments (which are usually aligned with dominant populations). Diffusion of niche-innovations and replacement of existing regimes therefore depends on multi-level alignments and regime tensions, which creates ‘windows of opportunity’ (see Fig. 1).
- The MLP’s notions of socio-technical regime, technological trajectories, and path dependence trace their origin to evolutionary economics. Rip and Kemp (1998) broadened the understanding of *technological* regimes from Nelson and Winter’s (1982) emphasis on routines and capabilities to the sociological category of ‘rules’. Geels (2004) further broadened the concept to *socio-technical* regimes to include not only engineers/firms, but also other social groups (policymakers, consumers, NGOs, publics).
- The MLP-notion of *niches* comes from evolutionary biology, particularly allopatric speciation theory (Mayr, 1963), which suggests that new species emerge in geographically isolated niches or in niches at the periphery of dominant ecosystems. In technological evolution, niches are also important because they can act as ‘protective spaces’ where selection criteria are more favourable to new technologies than in mainstream markets related to dominant regimes (Levinthal; 1998; Schot and Geels, 2007). Such protection is needed, because radical novelties initially have low price/performance characteristics and cannot survive mainstream market selection. Niches thus act as ‘incubation rooms’, where radical innovations can be nurtured and gradually improved.
- The MLP accepts that radical innovations initially emerge in a variety of forms and designs. The initial variety and divergence gradually gives way to convergence, stabilization and the selection of a *dominant design*. Whereas SCOT emphasizes socio-cognitive selection processes, evolutionary economics emphasizes market selection processes and the role of competition, struggle for resources, and economic performance.
- The MLP also accommodates the notion of punctuated equilibrium, which suggests that long periods of incremental change (represented by straight regime arrows in Fig. 1) are alternated by relatively brief periods of ferment and disruption (represented with diverging arrows). While evolutionary economics attributes this disruption mostly to the breakthrough of radical innovations (Tushman and Rosenkopf, 1992), the MLP also accommodates the possibility of external landscape pressures.

3.2. Agency

Focusing on firms-in-industries, the micro-assumptions of evolutionary economics build on two sources. First, the behavioural theory of the firm (Cyert and March 1963) conceptualizes actors as boundedly

rational, which means that decisions are guided by routines and standard-operating procedures as long as performance leads to satisfactory outcomes (Nelson and Winter, 1982). Second, the resource-based theory of the firm suggests that technological capabilities, which include both operational knowledge and search heuristics, are core dimensions of strategic and organizational action (Dosi, 1982). When performance falls below certain thresholds, organizations can activate search heuristics to explore the knowledge space and develop new innovations that allow adaptation to changing selection environments. These combined assumptions inform a micro-evolutionary perspective on organizational action and variation, selection and retention mechanisms.

In stable situations with satisfactory performance, organizational actions are shaped by routines, standard-operating procedures and capabilities, which are metaphorically seen as ‘genes’ that create stability over time and act as *retention* (inheritance) mechanism of previously successful variations (Nelson and Winter, 1982). On the one hand, firms-in-an-industry differ in their *specific* routines and capabilities, which leads to some variation in their actions and products. On the other hand, firms-in-an-industry share *general* routines and capabilities, called technological regimes (Nelson and Winter, 1982), which make them recognizable as belonging to the same population. Because of these shared routines, engineers in different firms search and innovate in similar directions, giving rise to technological trajectories (Dosi, 1982).

Variation in technological products can be understood in two ways. Firstly, engineers may make lucky discoveries or accidental mistakes or imitation errors when they reproduce existing routines and search heuristics, which lead to ‘blind’ or random mutations that in some cases generate new innovations. Secondly, innovations may result from ‘directed variation’, in which firm-specific routines and capabilities lead managers and engineers to make deliberate decisions about R&D projects, resource allocation, and search processes that generate products variations (Dosi, 1982). In established regimes, these directed variations do not deviate much from existing trajectories since engineers engage in localized search, which stays close to what they already know: “the probability distribution of what is found is concentrated on techniques close to the current one” (Nelson and Winter, 1982: 211). Sequences of minor variations add up to technological trajectories that develop in particular directions within shared technological regimes.

Markets (which are shaped by policies) are the primary *selection* environment, in which firms and their product variations compete for scarce resources. Consumers buy some product variations, thus offering performance feedback to firms (e.g. via financial resources), allowing successful firms to learn and replicate their routines and invest in new rounds of innovation. Successful variations can spread more widely in an industry through differential growth of successful firms or through imitation by other firms (Nelson and Winter, 1982).

Fig. 3 schematically summarizes the main causal mechanisms that underlie technological trajectories in evolutionary economics.

3.3. Criticisms and elaborations

The above conceptualization has been criticized for downplaying important dimensions, leading to (scope for) elaborations and cross-overs with regard to each evolutionary mechanism.

Sociologists have long criticized the idea of blind *variation* for downplaying agency. But also the idea of directed (routine-based) variation has been criticized for paying limited attention to cognition and deliberate strategy (Fagerberg, 2003). “Much theorizing within the tradition of the behavioural theory of the firm (...) is relatively silent on the issue of how alternatives are to be evaluated or issues of cognition more generally. (...) The image of organizational action as largely driven by routines seems to negate the role of strategic choice” (Gavetti and Levinthal, 2004: 1314). One elaboration is the dynamic capability literature, which introduced more purposive roles for

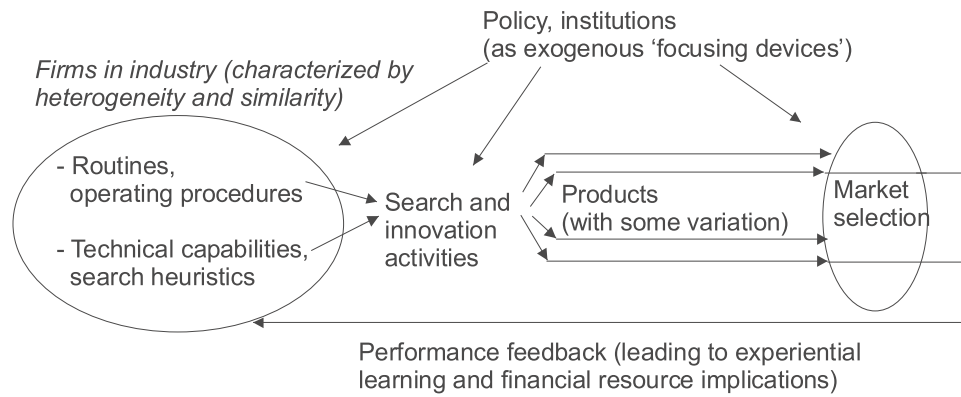


Fig. 3. Schematic summary of causal logic in evolutionary economics'.

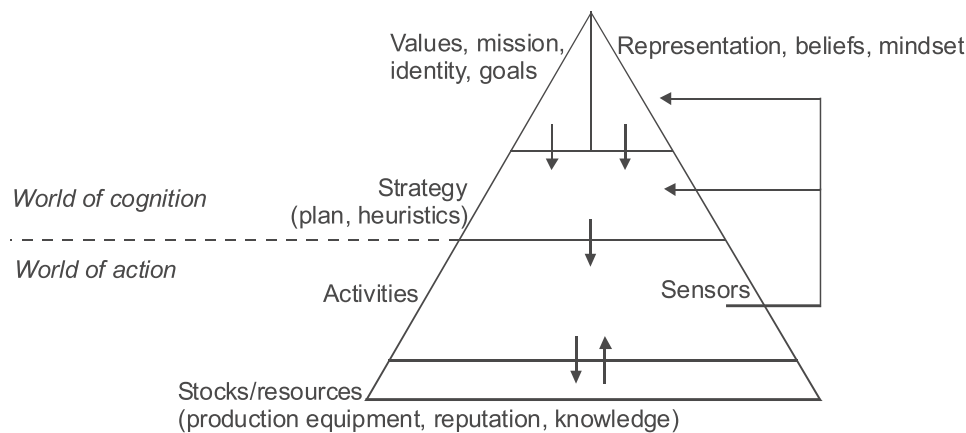


Fig. 4. Organizational hierarchy of mental and physical elements (adapted from Gavetti and Rivkin, 2007: 432).

strategic management in stimulating variations (Teece et al., 1997). Another way of addressing the criticism is to broaden the theory of the firm, by including cognitive maps (Nelson, 2008), beliefs, values and strategies (Fig. 4). Whereas evolutionary economics traditionally focuses on the ‘world of action’ (routines, capabilities, resources), this broader view also acknowledges a ‘world of cognition’, which allows beliefs and strategies to shape search processes. This elaboration also offer potential linkages to institutional theory (discussed below), because field-level categories and understandings can shape firm-level beliefs and values.

With regard to *selection*, evolutionary economics focuses mainly on markets and policies. It hardly accommodates influences from civil society, public opinion, cultural discourse, or social movements. Evolutionary economics also has a limited understanding of institutions. It acknowledges the role of public policies as ‘focusing devices’ (Dosi, 1982), which shape markets (via taxes, subsidies, regulations) and innovation activities (via technology programs, R&D policies, intellectual property rights). But it does not accommodate broader, informal institutions (templates, categorizations, institutional logics) and does not have a clear understanding of institutional change, meaning that institutions typically remain exogenous. Some scholars have tried to address the role of institutions in evolutionary economics, with Nelson (2002) conceptualizing institutions as ‘social technologies’ and ‘modes of governance’ that lower transaction costs and Pelikan (2003) conceptualizing institutions as constraints that reducing the choice-set of agents. Both attempts, however, only limitedly draw on neoinstitutional theory (discussed below). More systematic crossovers could lead to deeper understanding of selection as multi-dimensional process in which firms compete not only in markets, but also in institutional environments.

Another debate is about *what* is being selected. While evolutionary

economics mostly focuses on firms and their products in markets, Mokyr (2000) suggests two additional entities: a) engineering communities that select bodies of knowledge, b) firms that select (internally) on alternative projects and technologies. Both options refer to what Dosi (1982) calls ‘ex-ante selection’ (selection of the *direction* of mutation) in contrast to Darwinian ‘ex-post selection’ (of products in markets). Both ex-ante selection options enable crossovers with SCOT which understands socio-cognitive processes in evolutionary terms (Pinch and Bijker, 1984; Garud and Rappa, 1994).

While evolutionary economists highlight *indirect* mechanisms for the incorporation of selected mutations into the *retention* structure (via differential growth and imitation), sociologists focus more on *direct* mechanisms of institutionalization process. Intermediary organizations (branch organizations, professional societies) may formulate and codify new rules and routines (Geels and Deuten, 2006; Kivimaa, 2014). Institutional entrepreneurs may use political tactics to shape standards and regulations (Garud et al., 2007).

This discussion shows that the concrete conceptualization of the evolutionary principles of variation-selection-retention is flexible. Evolutionary economists tend to focus on tangible, economic dimensions (R&D investments, price/performance competition, market selection, differential growth, imitation). But the evolutionary mechanisms can also be operationalized in broader sociological terms (interpretation, legitimacy, negotiation, institutionalization, codification).

4. Neo-institutional theory

4.1. Relevance of theory for transitions and MLP

Institutional theory is important, because “rules, norms, and belief

Table 1
Three pillars of institutions (adapted from Scott, 1995: 52).

	Regulative	Normative	Cultural-cognitive
Basis of compliance	Expedience	Social obligation	Taken-for-grantedness, shared understanding
Mechanisms	Coercive, sanctions, incentives	Normative pressure (social sanctions such as 'shaming')	Mimetic, learning, imitation
Basis of legitimacy	Legally sanctioned	Morally governed	Culturally supported, conceptually correct
Examples	Laws, regulations, standards, procedures, incentive structures, governance systems	Roles, values, responsibilities, codes of conduct, behavioural practice.	Belief systems, models of reality, categories, guiding principles

systems undergird all stable social systems, including economic systems" (Scott, 2008: 437). Most transitions will therefore involve changes in institutions, although the depth of change may vary. Evolutionary economics recognizes the importance of institutions, but focuses mainly on formal policies and treats them mostly as exogenous. Neo-institutional theorist in organizational sociology developed broader and more dynamic understandings. Scott (1995), for instance, distinguishes three different kinds of institutions (regulative, normative and cultural-cognitive) with different logics and mechanisms (Table 1).

The MLP used institutional theory in its conceptualization of regimes as semi-coherent set of rules and institutions (Geels, 2004). Fuenschilding and Truffer (2014) further conceptualised different degrees of regime institutionalization, using Tolbert and Zucker's (1999) notion of successive stages: (a) habituation (when new behaviours or practices are created by a small number of actors without explicit coordination), (b) objectification (when a degree of social consensus is formed through framing, persuasion, theorization, alliance building, resource mobilization), (c) sedimentation (when a new practice has diffused, become taken-for-granted, and supported by vested interests).⁵ To further understand the content of regimes, they introduce the concept of 'institutional logics', which is defined as "the socially constructed, historical patterns of cultural symbols and material practices, including assumptions, values and beliefs, by which individuals and organizations provide meaning to their daily activity" (Thornton et al., 2012: 2).

Institutional theory emphasizes that organizations operate not only in economic environments, but also in institutional environments. "In institutional environments, organizations compete for social fitness rather than economic efficiency" (Powell, 1991: 184). The selection criterion for social fitness is appropriateness or legitimacy, which Suchman (1995: 574) defines as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs and definitions". Legitimacy is not peripheral, but may influence reputations, license-to-operate, access to capital and governmental support (Lounsbury and Glynn, 2001).

Early, organization-centric institutional theory emphasized one-directional causality, with institutions exerting selection pressures and organizations conforming to them, leading to relative homogeneity and isomorphism. In the last 10–15 years analytical attention has shifted from organizations towards organizational fields, leading to more relational and interactive views of institutions. "The concept of field identifies an arena (a system of actors, actions, and relations) whose participants take one another into account as they carry out interrelated activities" (McAdam and Scott, 2005: 10). Field actors typically include firms, consumers, government actors, regulatory bodies, lobbying groups, unions, professional and trade organizations, organized public opinion and social pressure groups (Beckert, 2010), which conceptually resonates with the MLP's interest in socio-technical systems and regimes. Field boundaries are not fixed, and "the players that populate

the field and the nature of their play can change over time" (Davis and Marquis, 2005: 337). An organizational field is relationally differentiated, with different positions providing actors different institutional opportunities: central actors can use their power to shape institutions to their advantage (Greenwood et al., 2002); actors in the middle mostly conform to institutional pressures; peripheral actors may find it easier to deviate (Leblebici et al., 1991). Institutional causality thus came to be seen as bi-directional and recursive: institutions differentially influence field actors (their identities, perceptions, preferences); but actors also try to shape institutions to suit their interests.

Organizational fields became increasingly conceptualised as sites of struggle, e.g. between incumbents and challengers (Hoffman, 1999; Fligstein and McAdam, 2012), which conceptually fits well with the MLP. Challengers can be peripheral groups or social movements, which criticize existing institutions. "It is frequently social movements and challengers that (...) serve as both carriers of new logics and forms, and platforms for theorization and new policy discourse" (Schneiberg and Clemens, 2006: 218). Major institutional change is difficult, however, because incumbents engage in "defensive institutional work" (Maguire and Hardy, 2009). Challengers and social movements may also "lack access to the institutional maintenance mechanisms that reinforce extant ideas and practices in the field" (Van Wijk et al., 2013: 360), e.g. trade and professional associations, policy advisory bodies.

Because of these difficulties, some institutional scholars emphasize the role of environmental jolts and external shocks in major institutional change (a notion that resonates well with landscape concept in the MLP). Examples are terrorist attacks (Corbo et al., 2016), oil crises (Sine et al., 2003), external social movement protests (Van Wijk et al., 2013), or imposition of values from outside the field (Maguire and Hardy, 2009).

4.2. Agency

While early neoinstitutional theory had a relatively passive view of actors (over-emphasizing conformity and isomorphism), the turn towards organizational fields entailed a more dynamic view. One reason is that actors in fields are fundamentally oriented towards each other, leading to a relational view of agency. Actors have different positions in fields (e.g. central, peripheral, middle), and different interests, resources and interpretations. This heterogeneity means that fields are characterized by interactions, exchange, debate, struggle, and jockeying for position (Hoffman, 1999), leading to a degree of variation and innovation. "There is constant jockeying going on in fields as a result of their contentious nature. Actors make moves and other actors have to interpret them, consider their options, and act in response. (...) Even in settled fields, constant low-level contention and incremental change are the norm rather than the image of routine reproduction" (Fligstein and McAdam, 2012: 12).

A second reason is that the understanding of institutions changed from monolithic, inert structures (exerting one-directional force) towards more malleable patterns that are reproduced (and gradually changed) over time. Field actors may face tensions between institutions (Seo and Creed, 2002) or conflicting institutional logics (Purdy and Gray, 2009), which lead to varying interpretations and diverging

⁵ These stages could quite easily be linked to the phases in the emergence of niche-innovations (Fig. 2).

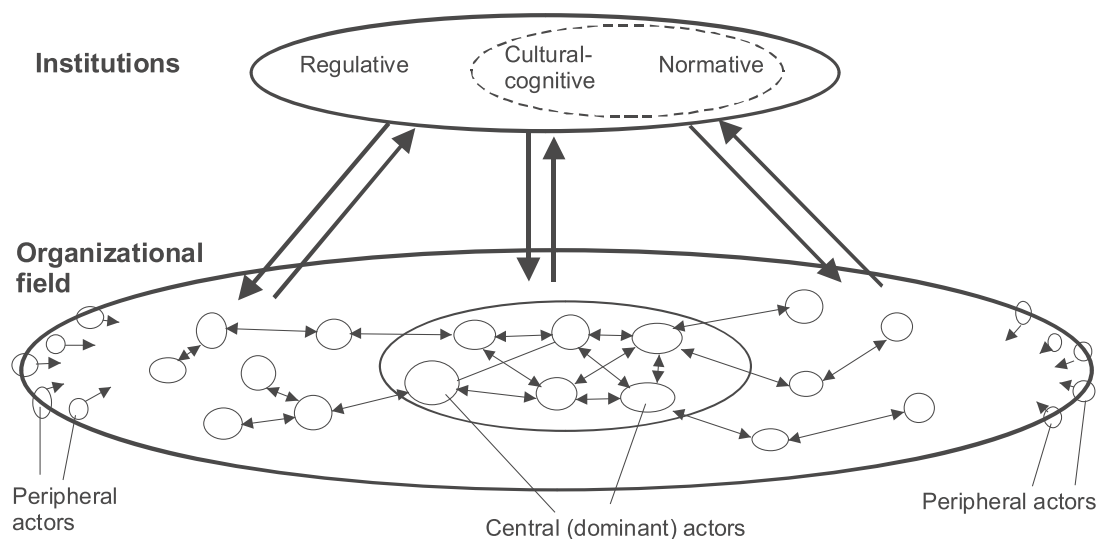


Fig. 5. Bi-directional influences between institutions and actors in organizational fields.

Fig. 5 also suggests that the concept of 'institutional logics' (e.g. Thornton et al., 2012) merges cultural-cognitive and normative institutions, with certain advantages and disadvantages.

actions. In this more dynamic view, actors not only *adapt* to institutional pressures, but also *act strategically* to shape them, using various forms of 'institutional entrepreneurship' (Oliver, 1991; Garud et al., 2007). Fig. 5 schematically summarizes the notion that the field approach "permits seeing agents as entangled in a grid of different social forces that position them in the social space, provides resources for realizing their goals as well as limitations on their opportunities" (Beckert, 2010: 619).

Field-approaches have moved from understanding institutions as *things* towards institutions as *processes*, enacted by actors via causal mechanisms (Davis and Marquis, 2005). Because they accommodate both diversity/variety in local practices and field-level selection pressures, one can understand them "as a complex evolutionary phenomenon that depends on specific mechanisms of variation, selection, and retention (Jessop, 2001: 1221).

I propose that an expanded and reformulated version of Archer's (1982; 1995) morphogenetic cycle offers a processual sociological model of institutional change that has close analogies to the evolutionary mechanisms (variation, selection, retention). This dynamic conceptualization offers an understanding of trajectories that can operate in tandem to the one provided by evolutionary economics (Fig. 3).⁶ Archer's model is based on analytical *dualism* (instead of Giddens's *duality*), which examines structure *in relation to* action and action *in relation to* structure (Jessop, 2001). The four sub-processes of the morphogenetic cycle accommodate different kinds of agency.

- (1) *Structural conditioning* refers to the 'downward' influence from structures on actors. Institutional structures act as the "carriers of history" (David, 1994) and logically exist *prior* to action which they otherwise cannot influence. Downward influence is not deterministic, because institutional pressures require interpretation, which varies depending on the field-position of actors and thus gives rise to (some) *variation*. However, despite interpretive flexibility, institutional pressures are not completely malleable. Existing institutions "may privilege some actors, some identities, some strategies, some spatial and temporal horizons, some actions over others" (Jessop, 2001: 1223).
- (2) *Social interaction* refers to the moves and countermoves by field

actors who are oriented towards each other.⁷ These actions can be routine-driven (staying close to scripts or logics) or more strategic and deliberate (Fligstein and McAdam, 2012). Strategic games are constrained by formal rules, while the beliefs, norms and interests of actors are partly constituted by cognitive and normative institutions (Scott, 1995). Creative actors can *deviate* (to some degree) from institutions to gain advantage (Oliver, 1991). But *variation* may also occur unplanned, in response to local conditions or via improvisations in performances (Lounsbury and Crumley, 2007). In stable fields, game playing takes form of jockeying for position (Fligstein and McAdam, 2012), leading to incremental changes. More heated and foundational struggles may occur when new institutional logics or practices challenge incumbent ones.

- (3) *Structural elaboration* refers to 'upward' actions that reproduce existing institutions ("morphostasis") or transform them ("morphogenesis"). Dedicated macro-actors (Mouzelis, 1995) or intermediary actors (Geels and Deuten, 2006) directly influence field-level institutions, e.g. professional societies, industry associations, standardization organizations. These actors compare experiences in local practices and extract general lessons for the field as whole (Geels and Deuten, 2006). Local innovations and initiatives are unlikely to have broader effects if they are not *selected* and advanced at the field-level. "While idiosyncratic deviations from scripts occur, perhaps even with some frequency, such random deviations are apt to have only passing impact on social arrangements" (Barley and Tolbert, 1997: 102).

To advance local initiatives and change field-level institutions, actors need to engage in institutional entrepreneurship, e.g. framing, persuasion, theorization, alliance building, and resource mobilization (Garud et al., 2007; Battilana et al., 2009).⁸ But field-level selection and anchoring of initiatives may be resisted by the "defensive institutional work" (Maguire and Hardy, 2009) of

⁷ This kind of strategic action may apply less to consumers/households than to firms, policymakers and civil society actors.

⁸ There is also a broad literature on corporate political strategies, which analyzes how firms shape political rules and institutions. Social movement theory also offers relevant insights, suggesting that movement organizations may shape institutions via framing and resource mobilization, but that these activities are constrained by the degree of openness/closedness of opportunity structures.

⁶ While Archer's model contains three sub-processes, I follow Barley and Tolbert (1997) in adding a fourth.

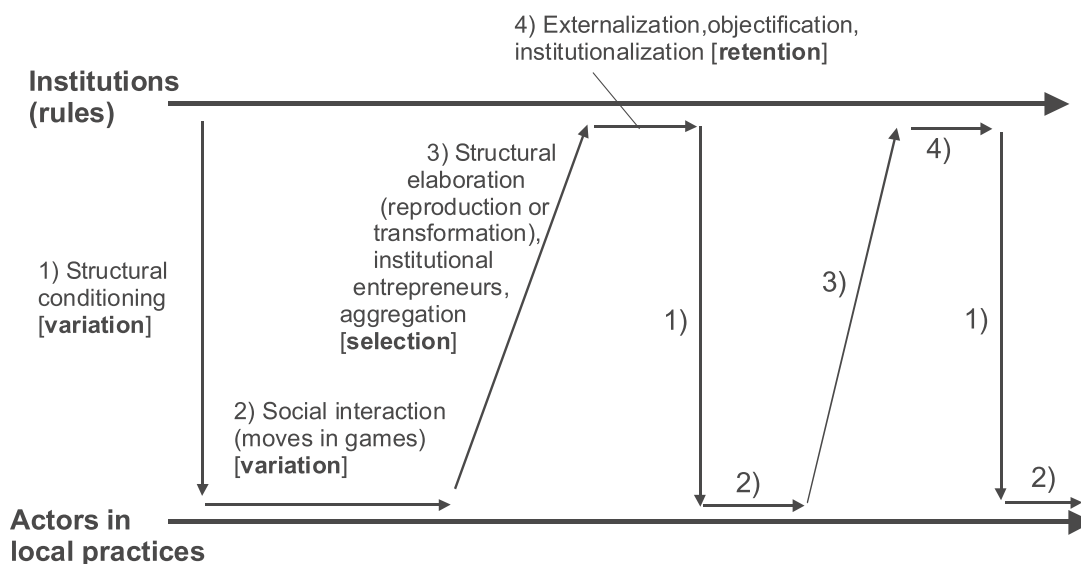


Fig. 6. Conceptualizing field-level trajectories as successive morphogenetic cycles (substantially expanded from Barley and Tolbert, 1997: 101).

incumbents.

- (4) *Externalization and institutionalization* refer to the field-wide acceptance and **retention** of institutional changes. Permanent changes require not only community-wide selection, but also institutionalization (in handbooks, training manuals, standards, laws) and endorsement from authoritative actors (Tolbert and Zucker, 1999).

Fig. 6 schematically summarizes the four sub-processes in a morphogenetic cycle (Archer, 1982; 1995), with the bold text between brackets relating them to evolutionary variation, selection, and retention mechanisms. A single morphogenetic cycle can be analysed as one ‘round of moves’ that reproduces or changes field-level institutions. Trajectories can then be analysed as sequences of morphogenetic cycles, which lead to field-level event chains.

4.3. Criticisms and elaborations

One criticism of neoinstitutional theory is a general neglect of the role of technology in changing organizational fields (Pinch, 2008; Jones et al., 2013). Although the definition of institutional logics includes reference to ‘material practices’ (Thornton et al., 2012), technological innovation is often superficially conceptualized (or seen as exogenous force). This lacuna creates opportunities for crossovers of neoinstitutional theory with evolutionary economics and SCOT. Orlikowski’s (2007) work on socio-materiality is promising in that respect, because it understands human action and technology as intrinsically entangled. Drawing explicitly on STS and neoinstitutional theory, she also suggests that technology is both enacted in practice and has structuring properties that act as institutional templates: “Because technology-in-practice is a kind of structure, the same recursive constitution applies here too. When people use a technology, they draw on the properties comprising the technological artifact—those provided by its constituent materiality, those inscribed by the designers, and those added on by users through previous interactions. (...) Ongoing enactment of a technology-in-practice reinforces it, so that it becomes regularized and routinized” (Orlikowski, 2000: 410). Seeing technology as entangled with both practice and institutional structures fits very well with the perspective described in section 4.2 and Fig. 6.⁹

⁹ Geels and Deuten (2006) and Geels and Raven (2006) also distinguish local and global dimensions of technology, the former as ‘artefact-activity’ and the

A second criticism is the limited attention for economic processes (markets, competition, resources). This relative neglect is understandable, because organizational sociology initially highlighted the role of institutions and legitimacy *besides* economic processes. But as the analytical attention has moved towards organizational fields, it is important to investigate both institutional *and* economic processes (Oliver, 1997; Geels, 2014b).

Third, formal institutions are under-addressed in neoinstitutional theory, despite their initial acknowledgement (DiMaggio and Powell, 1983; Scott, 1995). This is probably due to the ideational/cognitive focus and the conviction that “cultural-cognitive frameworks provide the deeper foundations of institutional forms. (...) Although regulative features are more visible, they can also be more superficial, “thinner,” and less consequential than normative and cultural elements” (Scott, 2008: 429). The relative neglect of regulatory institutions has exacerbated with the recent focus on institutional logics. The study of formal institutions, interest-based politics and agenda control thus seems increasingly relegated to historical institutionalism, political science, and institutional economics. This is unfortunate, because it hinders a comprehensive study of organizational fields (and transitions), which should include multiple kinds institutions (Table 1; Hoffman, 1999; Beckert, 2010). It also hinders neoinstitutional theory to engage with broader forms of power and politics (Munir, 2015). Pleas to combine ‘old’ and ‘new’ institutional theories thus remain pertinent (Hirsch and Lounsbury, 1997; Lockwood et al., 2017).

5. Discussion

5.1. A multi-dimensional model of agency in the MLP

The three previous sections discussed how insights from three theories are relevant for transitions and the MLP. They also discussed conceptualisations of agency, thus articulating the theoretical micro-foundations of the MLP, which particularly for neoinstitutional theory involved new appreciative theorizing. The sections also discussed criticisms of each theory, due to foundational assumptions or biases, and identified elaborations in response to criticisms. Table 2 summarizes the main strengths and weaknesses of each theory with regard to

(footnote continued)

latter as cognitive rules (e.g. search heuristics, abstract theories, technical models).

Table 2
Strengths and weaknesses in SCOT, evolutionary economics and neoinstitutional theory.

	Strengths	Less elaborated topics and dimensions
SCOT	<p>Transitions:</p> <ul style="list-style-type: none"> - Interest in shape/design of artefacts and patterns of use - Sophisticated understanding of <i>emergence</i> of radical innovation (social networks, learning processes, expectations, circulation, aggregation). <p>Agency:</p> <ul style="list-style-type: none"> - Focus on socio-cognitive processes (<i>content</i> of beliefs/meanings, disagreement between social groups; controversies; debates, consensus). 	<p>Transitions:</p> <ul style="list-style-type: none"> - Less interest in dynamics after stabilization (diffusion, societal ‘impact’, overthrow of existing system) - Limited understanding of broader patterns (due to focus on contingency, complexity, local specificity). - Limited link to broader social sciences (due to dominance of micro-interactionism). <p>Agency:</p> <ul style="list-style-type: none"> - Voluntarist tendencies (limited attention for wider structures). - Idealist bias (limited attention for competition, markets, financial resources)
Evolutionary economics	<p>Transitions:</p> <ul style="list-style-type: none"> - Macro-patterns relevant for transitions (trajectories, speciation, radical novelty, replacement, punctuation, extinction). - Micro-dynamics span local practices (variation) and population level (selection, retention). <p>Agency:</p> <ul style="list-style-type: none"> - Deep understanding of ‘material’ processes (market competition, resources, performance, investment) and knowledge/capabilities (search, learning). 	<p>Transitions:</p> <ul style="list-style-type: none"> - Limited interest in technical details (due to primary interest in economic implications of technology for firms/sectors). - Narrow view of selection environment (mainly markets). Limited understanding of institutions (as exogenous regulations). <p>Agency:</p> <ul style="list-style-type: none"> - Limited attention for strategy and cognition/interpretation. - Supply side focus (firms, universities, policymakers); less attention for consumers, wider publics, NGOs.
Neo-institutional theory	<p>Transitions:</p> <ul style="list-style-type: none"> - Relational, processual understandings of institutions. - Recursive interactions between local practices and organizational fields. <p>Agency:</p> <ul style="list-style-type: none"> - Agency in recursive relations to multi-dimensional structures (cognitive, normative, regulatory). - Accommodates struggle, conflict, variation, strategy. 	<p>Transitions:</p> <ul style="list-style-type: none"> - Limited focus on technology and ‘material’ dimensions. - Limited focus on economic processes. - Limited focus on formal, regulatory institutions (due to ideational focus) <p>Agency:</p> <ul style="list-style-type: none"> - Limited focus on technical innovation processes and economic actions. - Some (political) dimensions of power are under-developed.

transitions and agency.

Table 2 demonstrates that the three theories highlight different dimension of agency and transitions. These differences relate to ontological assumptions with regard two sociological problems: the problem of order and the nature of reality (Ritzer, 1980; Alexander, 1982; Geels, 2010). With regard to the first problem, some ontological positions assume that order is externally created by *collective* phenomena (e.g. cultures, deep structures, structural relations), while others assume that order aggregates from multiple *individual* micro-actions (e.g. choices, sense-making). With regard to the second problem, some ontological positions assume that reality is *objective*, that actors having fixed preferences, and that action is instrumental and motivated by material interests. Other positions assume that reality is *subjective*, that actors have fluid preferences and identities, and that action is motivated by ideas, meanings and norms.

Geels (2009) combined these problems into a 2×2 -matrix which articulates the theoretical logic of four ontological positions: structuralism, interpretivism, rational choice and conflict theory. Fig. 7 schematically positions the three specific theories into this ontological 2×2 -matrix, thus capturing some of the findings from the analytical review. Evolutionary economics tends to focus on material/objective dimensions, whereas SCOT and neoinstitutional theory privilege ideational/subjective dimensions. In terms of the collectivism/individualism dichotomy, SCOT privileges actors, creativity, and freedom, whereas evolutionary economics acknowledges both collective structures (technological regimes, selection environments) and individual action (variation). Neo-institutional theory initially privileged collective structures (isomorphic pressures), but later also acknowledged deviation and creativity. The arrows in Fig. 7 also aim to indicate that theories are not fixed, monolithic structures, but are instead characterized by (some degree of) debates and disagreement which may lead to elaborations (to accommodate criticisms or

weaknesses), as the previous analytical reviews showed.¹⁰

Following Rueschemeyer (2009), I distinguish between *theories* (which are general orientations or ‘ways of looking’ at the world) and *analytical frameworks* (which are more focused and aimed at understand substantive topics). So, while the three theories discussed above offer specific *lenses* (which are internally coherent but emphasize only certain dimensions), the MLP is an analytical framework that pragmatically combines theoretical insights into a more comprehensive perspective. Porter (1991: 98) suggests that frameworks are particularly useful for big, multi-dimensional topics, because “A framework (...) encompasses many variables and seeks to capture much of the complexity (...). All the interactions among the variables in the frameworks cannot be rigorously drawn. The frameworks, however, seek to help the analyst to better think through the problem”.

The Geels and Schot (2007: 403) quote in the introduction alluded to a multi-dimensional model of agency that mobilizes insights from all three theories to acknowledge that human beings have *multiple* faculties. So, instead of reducing agency to one capacity, actors are conceptualised as having multiple interacting properties (Table 2). Drawing on evolutionary economics, actors are characterized by material properties like interests, goals, financial resources, technical capabilities, skills, which they use in various activities (e.g. investment, innovation, competition, behavioural learning). Drawing on SCOT, actors also have interpretive and socio-cognitive properties (cognition, ideas, sense-making skills, relations), which shape some of the material properties (goals and interests need to be defined; investment and innovation strategies are guided by beliefs and visions; performance feedback needs to be interpreted and translated into lessons). But sense-

¹⁰ Abbott (2001: 138) metaphorically characterizes disciplines and associated theories as “amoebas putting our pseudopods as they move in a multi-dimensional intellectual space”.

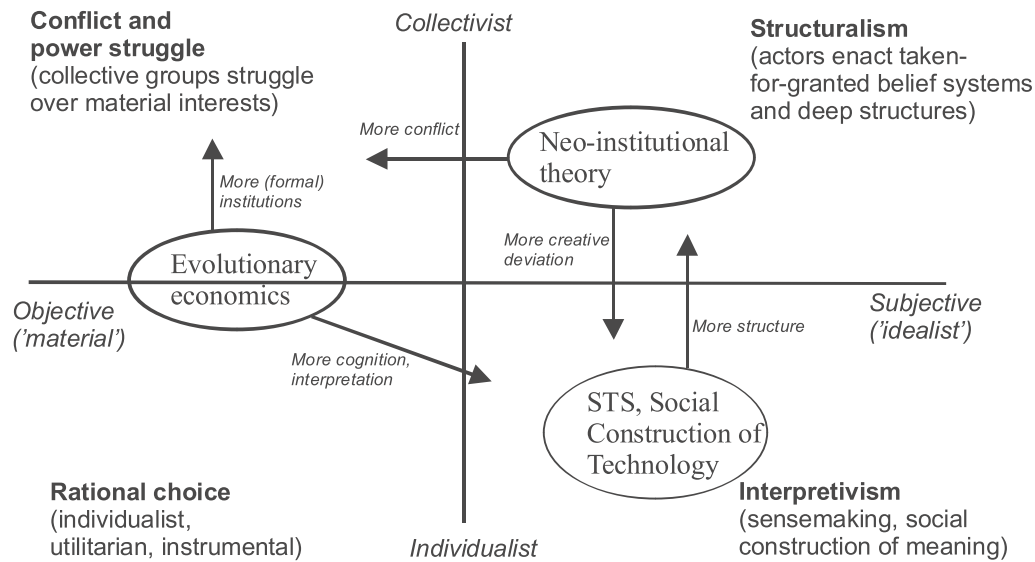


Fig. 7. Positioning theories (in circles) with regard to ontological assumptions and characterizing recent conceptual elaborations (as arrows) (substantially adapted from Geels, 2009: 827).

making is also influenced by deeper templates, cultural categories and taken-for-granted belief systems, as neoinstitutional theory suggests. These interactions reinforce the point, quoted in the introduction, that “real human social behavior is a complex mix” of multiple capacities and activities (Little, 2016: 47).

Table 3 further systematizes the MLP’s model of agency by linking the different properties and activities from the three theories to Emirbayer and Mische’s (1998) three dimensions, discussed in Section 1.

The three dimensions of agency are not continuously prevalent, because the “agentic orientation of actors (along with their capacity for inventive or deliberate response) may vary in dialog with different situational contexts” (Emirbayer and Mische, 1998: 1004). Iterational, routine-based actions are prevalent in settled times and stable regimes. But “during periods of upheaval, other forms of agentic activity may come into play” (p. 1006), such as projective and practical-evaluative dimensions.

These considerations are clearly relevant for transitions. While routines and institutional logics may dominate iterational action in ‘eras of incremental change’, transitions are ‘eras of ferment’, where other kinds of agency are more prevalent: search, visioning, making plans, strategic maneuvering, debates, deliberations, new capability development, learning. Socio-political disruption tends to be greater for large, complex socio-technical systems (Fig. 8), which is why a multi-dimensional framework (like the MLP) is needed to address both techno-economic and socio-institutional processes in transitions.

More generally, this means that relations between institutional and (evolutionary) economic theories vary over time. In settled times, institutions form taken-for-granted background structures that undergird the economy so that calculations and routine-based action are possible. But during transitions, when institutions lose their stability, economic calculations become more difficult and disagreement becomes more

intense: “In ‘hot’ situations, everything becomes controversial. (...) In ‘cold’ situations, on the other hand, (...) the possible world states are already known or easy to identify: calculated decisions can be taken” (Callon, 1998: 261).

5.2. Crossovers between SCOT, evolutionary economics and neoinstitutional theory

These theoretical differences, summarized in Tables 2 and 3, suggest there may be complementaries and potential linking points. The MLP was developed in this crossover spirit (Geels, 2010), i.e. not as a ‘theory of everything’, but as a middle-range framework. Based on the previous analytical reviews, I identify several crossovers and linking points between the different theories:

- Institutions (particularly formal policies such as regulations, taxes, subsidies) influence market selection processes in evolutionary economics. (Institutional theorists would go further, however, arguing that markets do not simply exist as ‘things’, but are constituted and undergirded by formal and informal institutions).
- Institutions also shape variation processes in evolutionary economics in two ways. Formal policies (R&D subsidies, tax incentives, collaborative grants) influence the generation of techno-scientific novelties. But a broader, interpretive view of the firm (Gavetti and Levinthal, 2004; Nelson, 2008; Fig. 4) also allows institutional logics to influence perceptions, which, in turn, shape the direction of search activities.
- There are also conceptual linking points from evolutionary economics to neoinstitutional theory. First, successful organizations with strong financial resources and economic positions (which evolutionary economics helps explain) have greater possibilities to shape institutions.

Table 3
Dimensions of agency in various theories.

	Iterational	Projective	Practical-evaluative
SCOT	Action guided by technological frames	Sense-making, visions, expectations, imaginaries.	Interpretations, debates, deliberations.
Evolutionary economics	Action guided by routines, standard-operating procedures, heuristics.	Objectives, performance targets, guided search, innovate.	Decisions, resource allocations, learning, capabilities.
Neo-institutional theory	Action guided by taken-for-granted categories, schemas, templates, logics.	Deviation, strategies, plans, maneuvering.	Reflexivity, theorization, justification, aggregation.

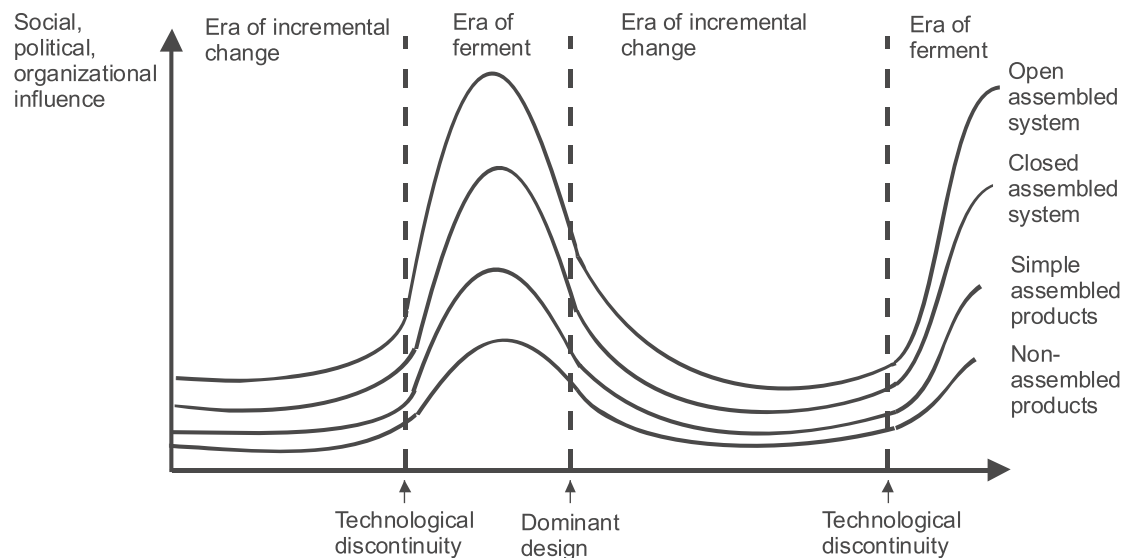


Fig. 8. Degrees of social influences for different technologies and development stages (adapted from Tushman and Rosenkopf, 1992: 342).

Tushman and Rosenkopf (1992) distinguish four kinds of technology with increasing complexity and geographical span: (1) non-assembled products (cement, glass, steel), (2) simple assembled products made up of a few subsystems (stoves, skis, guns), (3) closed assembled systems made up of many interacting subsystems (watches, automobiles), (4) open systems involving combinations of artefacts and extending across geographical areas (television, electric power, telephone).

Second, firms generate technologies, which shape institutions endogenously (Nelson, 1994) rather than as exogenous forces.

- SCOT and neoinstitutional theory both focus on ideational/subjective dimensions, which facilitates crossovers between them. Cultural-cognitive institutions can be seen as providing structural contexts for interpretive activities in SCOT, whereas the stabilization of shared cognitions in SCOT merges into cultural-cognitive institutions. While neoinstitutional theory often ignores technology or sees it as exogenous force, SCOT shows that technology can be endogenised and studied as a socio-cognitive process. Technology and technological knowledge can be seen institutions (Pinch, 2008). Stages in institutional theory (habitualisation, objectification/theorization, sedimentation) are very similar to the stages in SCOT (local tinkering, gradual closure, cognitive consensus).
- There are also possible crossovers between SCOT and evolutionary economics: search activities can be seen as guided by visions and expectations; technological development involves not just firms, but also broader social networks; technological selection occurs not just in markets, but also through policies, cultural discourses, social acceptance.

These crossovers are possible, because every theory foregrounds certain concepts and backgrounds others. A taken-for-granted concept in one theory (e.g. market, institution, technology) can be 'opened up' and endogenised by another theory. This creates the possibility for linking points between theories, as specified above for the three theories that inform the MLP. This does not mean that the MLP provides a fully integrated theory of socio-technical transitions. But it does mean that a comprehensive understanding can be developed by acknowledging two points. First, socio-technical transitions are multi-dimensional, entailing many causal processes which can be fruitfully studied with different theories. Second, there are crossovers and linking points between theories, which enable more comprehensive understandings of co-evolution, spillovers and lateral effects, which are pervasive in transition processes.

5.3. Relational conceptualization of agency as embedded in unfolding trajectories

While the MLP always emphasized alignments between ongoing

processes and trajectories, the conceptualization of trajectories has remained under-developed. The appreciative theorizing in sections 3 and (especially) 4 made advances in that respect, arguing that agency is always relational (oriented towards other actors) and processual (through recursive interactions with structures). Trajectories have thus been conceptualized as successive 'rounds' in ongoing games, where each round involves the interplay of several causal processes: variation-selection-retention in evolutionary economics (Fig. 3) and structural conditioning, social interaction, structural elaboration, and externalization in neoinstitutional theory (Fig. 6).

In terms of Burns and Flam's (1987) analytical framework, both conceptualizations of 'rounds' can be understood as operating in tandem but via different loops and through different agentic mechanisms (Fig. 9). Evolutionary economics explains trajectories via the lower-loop ('actor structuring'), which emphasizes material mechanisms (market feedback influencing resource positions and behavioural learning) and indirect effects on technological regimes (differential growth, imitation). Institutional theory explains trajectories more via the upper-loop ('social learning'), which emphasizes cognitive and institutional processes that directly shape rules and regimes.

Furthermore, as demonstrated in section 4.2, the institutional sub-processes in the morphogenetic cycle (Fig. 6) can be understood in terms of variation, selection, and retention, although the specific causal mechanisms are conceptualised in social-institutional terms. This suggests that evolutionary theory may potentially act as conceptual meta-framework, as proposed by Hodgson and Knudsen (2004: 15): "Darwinism provides an over-arching framework of explanation, but without claiming to explain every aspect or detail. (...) Selection is the general principle, but it operates in different ways. (...) The sources of variation are very different in different contexts. (...) the transfer of Darwinian principles from biological to social evolution does not imply that the detailed mechanisms of selection, variation and inheritance are similar. (...) there are bound to be many detailed mechanisms in the social world that are not found in biology".

This may dismay STS-scholars, who often dislike evolutionary theories, which they (incorrectly) associated with a lack of agency and teleology. Space constraints prevent addressing these concerns, but it is worth noting that Pinch and Bijker (1984) characterized the SCOT-approach as an alteration of variation and selection. Rammert (1997: 171) also suggests that STS can be rethought so that "a constructivist

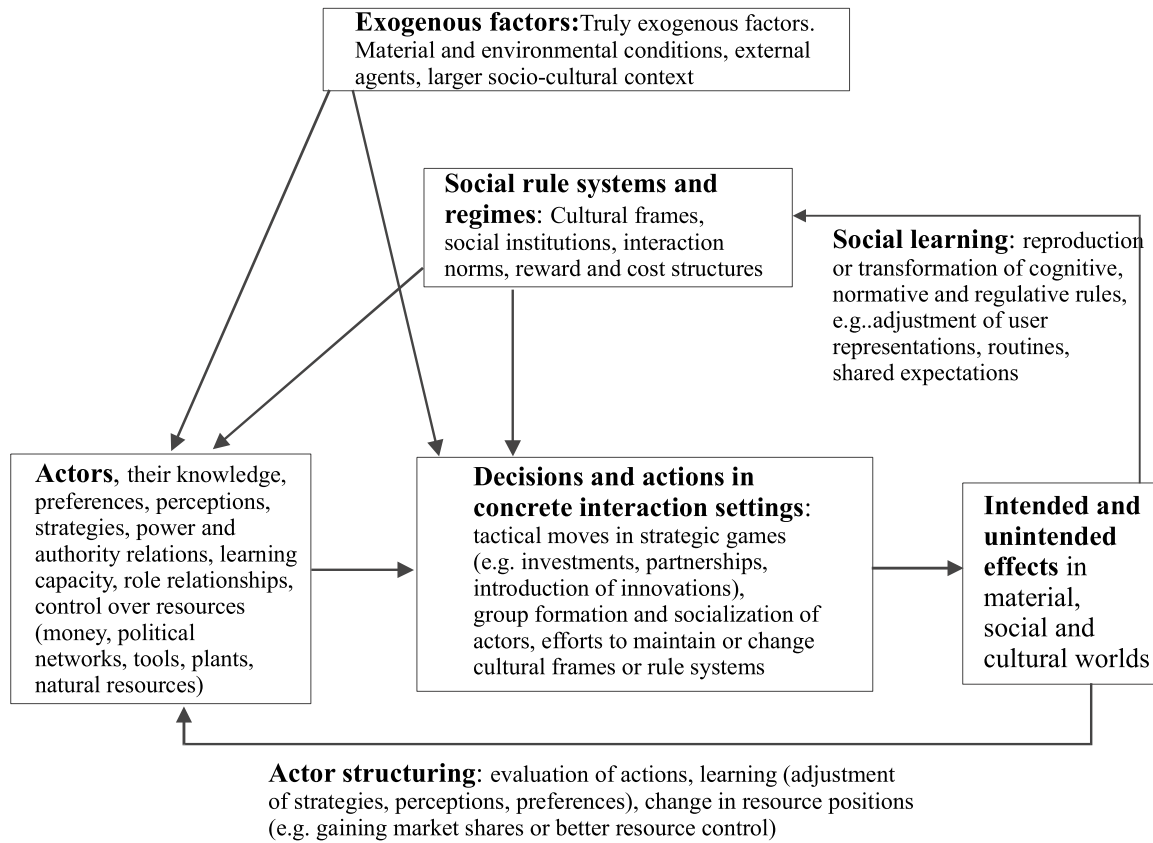


Fig. 9. Actor-rule system dynamics (Geels, 2004: 908; adapted from Burns and Flam, 1987: 4).

explanation of technology's generation on the local level is combined with a social evolutionary approach of structural selection on the global [i.e. field] level".

6. Conclusions

The paper has articulated the micro-foundations of the MLP by further elaborating its theoretical roots in SCOT, evolutionary economics and neoinstitutional theory. With regard to the paper's first goal, the analytical review and appreciative theorizing produced a relational and multi-dimensional understanding of agency, which spans iterational, projective and practical-evaluative dimensions as well as material and ideational ones. This local (inside-out) model of the MLP also provides a processual conceptualisation of trajectories as the outcome of recursive interactions between agency and structure: actors are conceptualised as oriented *towards* other actors and socio-technical systems and as engaged in ongoing games which are structured by multi-dimensional institutions. Evolutionary-economic and morphogenetic cycles offer two complementary ways of understanding agency as embedded in on-going processes and trajectories.

The broader implication of this conceptualisation is that analyses of transitions should not focus on agency as such, but always in relation to social networks, institutional contexts and on-going processes (see also King, 2004; Tilly, 2008; Abbott, 2016). "Agency is always agency *towards* something, by means of which actors enter into relationships with surrounding persons, places, meanings, and events. Viewed externally, agency entails actual interactions with its contexts, in something like an ongoing conversation" (Emirbayer and Mische, 1998: 973; emphasis in original). Elsewhere, Emirbayer (1997: 292) suggests that this "resembles moves in a game, or perhaps even attempts to change the *rules* of the game", and argues that "a 'sociology of occasions' is called for that takes as its unit of analysis a gamelike, unfolding, dynamic process" (p. 295). This paper has developed the outlines of such a

framework, building on insights from SCOT, evolutionary economics and neoinstitutional theory.

With regard to the second goal, the paper has articulated crossovers and linking points between these three theories, which produced an analytical framework that goes some way in spanning several dichotomies: (a) long-term patterns (at the field/population level) and local variability, (b) material and ideational dimensions, (c) (dynamic) stability and change, (d) agency and structure (via recursive interactions), (e) social networks (via relational interactions and game-playing) and institutional structures (that shape the game and constitute actors). The wider implication of this cross-over analytical framework is that transitions have the following processual and agentic characteristics.

- Socio-technical transitions are *evolutionary* processes, i.e. open-ended, non-linear, and fundamentally uncertain. For radical niche-innovations, it is difficult to predict which design variation will become dominant in 10–20 years' time, what its price/performance characteristics are, and how it will be used. If *multiple* niche-innovations exist (as is presently the case in electricity, mobility, heat, and agro-food domains), it is difficult to predict relative diffusion rates, meaning that multiple transitions pathways are possible. Both considerations imply that experimentation, search, trial-and-error, and learning are crucial agentic processes of socio-technical transitions. Search processes, experiments and diffusion require financial resources, meaning that resource allocation and investment are also important agentic processes. More generally, evolution is not only about variety creation and 'opening up', but also about competition, struggles for resources, selection and 'closing down', which implies that transitions involve 'losers' as well as 'winners'.
- Socio-technical transitions are *interpretive* and *socio-cultural* processes. Meanings, interpretations, and beliefs shape the motivations and preferences of actors and their definition of interests. They also

influence the social acceptance of particular innovations and the legitimacy of policy efforts. “Whatever can be done through the State will depend upon generating widespread political support from citizens within the context of democratic rights and freedoms” (Giddens, 2009: 91). This does not imply that transitions will be consensual, since different groups have different beliefs and interpretations. In fact, transitions are likely to involve discursive struggles about the framing of problems and solutions (Roberts and Geels, 2018). Framing struggles are consequential because it matters if a problem like climate change is framed as a ‘market failure’ (which would lead to market-based instruments such as a carbon tax) or as a ‘planetary boundary’ (which may lead to stronger regulatory or innovation policies with greater urgency). It also matters how specific innovations are framed: are wind turbines seen as renewable energy technologies or as ugly artefacts that spoil the landscape and kill birds? Are nuclear plants framed as low-carbon technologies or as existential threats? The implication is that transitions should *not* only be seen as techno-economic management challenges, but also as socio-cultural processes which involve wider publics and cultural meanings.

- Socio-technical transitions are *contested, conflictual* processes. Interactions between niche-innovations and existing regimes may involve struggles on multiple dimensions: (1) *business struggles* between new entrants and incumbents, (2) *technological competition* between new and old technologies, (3) *discursive struggles* about the framing of problems and solutions, (4) *institutional struggles* between dominant logics and new templates (pioneered by challengers or peripheral actors), and (5) *political struggles* about agendas, goals, and policies.¹¹ Consequently, “transitions are not teleological and deterministic, but continuously enacted by and contested between a variety of actors. (...) So, transitions are likely to be non-linear; two steps forward may be followed by one step back (or steps in a different direction if actors change their beliefs and goals or if there is growing contestation of particular pathways)” (Geels et al., 2016: 900).

In sum, the MLP has become a cumulative, synthetic research program for understanding socio-technical system change and sustainability transitions. It also offers a way of making crossovers between evolutionary economics and STS, which many scholars see as important for overcoming the institutional fragmentation of the broader STI-field.

The MLP is not without problems or under-developed topics. More could be done, for instance, to further develop the role of *politics and power* in the MLP (and transitions more generally). Some scholars have started to work on this (Geels, 2014a; Smink et al., 2015b; Hess, 2016; Markard et al., 2016) and this paper made some efforts by discussing relevant insights from neoinstitutional theory. But since neoinstitutional theory limitedly engages with formal policies and overt political conflict, it seems fruitful to explore how ideas from political science and historical institutionalism can be accommodated in the MLP (see Kern, 2011, Lockwood et al., 2017, and Roberts and Geels, 2019 for initial attempts). Future research could also fruitfully focus on the role of cultural discourses and narratives in transitions and the MLP, and some scholars have started to work on this (Hermwille, 2016; Rosenbloom et al., 2016; Roberts, 2017; Roberts and Geels, 2018). These theoretical problems and under-developed topics will hopefully further stimulate community-wide efforts in transitions research, since “problems are more important structurally than solutions, in that they can better muster the energy and interest of a community of intellectuals” (Collins, 1986: 1346).

¹¹ Transitions may also involve interactions between dominant and new user practices, but these often involve less explicit contestation.

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References

- Abbott, A., 2001. *Chaos of Disciplines*. University of Chicago Press, Chicago.
- Abbott, A., 2016. *Processual Sociology*. University of Chicago Press, Chicago.
- Alexander, J.C., 1982. *Theoretical Logic in Sociology: Positivism, Presuppositions, and Current Controversies*. University of California Press, Berkeley.
- Archer, M., 1982. Morphogenesis versus structuration: on combining structure and action. *Brit. J. Sociol.* 33 (4), 455–483.
- Archer, M., 1995. *Realist Social Theory: The Morphogenetic Approach*. Cambridge University Press, Cambridge.
- Avelino, F., Wittmayer, J.M., 2016. Shifting power relations in sustainability transitions: a multi-actor perspective. *J. Environ. Pol. Plan.* 18 (5), 628–649.
- Barley, S.R., Tolbert, P.S., 1997. Institutionalization and structuration: studying the links between action and institution. *Org. Stud.* 18 (1), 93–117.
- Battilana, J., Leca, B., Boxenbaum, E., 2009. How actors change institutions: towards a theory of institutional entrepreneurship. *Acad. Manag. Ann.* 3 (1), 65–107.
- Beckert, J., 2010. How do fields change? the interrelations of institutions, networks, and cognition in the dynamics of markets. *Org. Stud.* 31 (5), 605–627.
- Berggren, C., Magnusson, T., Sushandoyo, D., 2015. Transition pathways revisited: established firms as multi-level actors in the heavy vehicle industry. *Res. Policy* 44 (5), 1017–1028.
- Berkers, E., Geels, F.W., 2011. System innovation through stepwise reconfiguration: the case of technological transitions in dutch greenhouse horticulture (1930–1980). *Technol. Anal. Strateg.* 23 (3), 227–247.
- Bijker, W.E., 1995. *Of bicycles, Bakelites and Bulbs: Towards a theory of Sociotechnical Change*. MIT Press, Cambridge, MA.
- Broerse, J.E.W., Bunders, J.F.G., 2000. Requirements for biotechnology development: the necessity of a participatory innovation process. *Int. J. Biotechnol.* 2 (4), 275–296.
- Bruun, H., Hukkinen, J., 2003. Crossing boundaries: an integrative framework for studying technological change. *Soc. Stud. Sci.* 33 (1), 95–116.
- Burns, T.R., Flam, H., 1987. *The Shaping of Social Organization: Social Rule System Theory With Applications*. Sage Publications, London.
- Callon, M., 1987. Society in the making: the study of technology as a tool for sociological analysis. 1987 In: Bijker, W.E., Hughes, T.P., Pinch, T. (Eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. MIT Press, Cambridge, Massachusetts, pp. 83–103.
- Callon, M. (Ed.), 1998. *The Laws of the Market*. Blackwell, Oxford.
- Collins, R., 1986. Is 1980s sociology in the doldrums? *Am. J. Sociol.* 91, 1336–1355.
- Collins, R., 1992. The romanticism of agency/structure versus the analysis of micro/macro. *Current Sociol* 40 (1), 77–97.
- Collins, H.M., Evans, R., 2002. The third wave of science studies: studies of expertise and experience. *Soc. Stud. Sci.* 32 (2), 235–296.
- Corbo, L., Corrado, R., Ferriani, S., 2016. A new order of things: network mechanisms of field evolution in the aftermath of an exogenous shock. *Org. Stud.* 37 (3), 323–348.
- Cyert, R.M., March, J.G., 1963. *A Behavioral Theory of the Firm*. Prentice Hall, Englewood Cliffs, NJ.
- Dafoe, A., 2015. On technological determinism: a typology, scope conditions, and a mechanism. *Sci. Technol. Hum. Val.* 40 (6), 1047–1076.
- David, P.A., 1994. Why are institutions the ‘carriers of history’? path dependence and the evolution of conventions, organizations and institutions. *Struct. Chang. Econ. Dyn.* 5 (2), 205–220.
- Davis, G.F., Marquis, D., 2005. Prospects for organization theory in the early twenty-first century: institutional fields and mechanisms. *Org. Sci.* 16 (4), 332–343.
- Demuelenare, P. (ed.), 2011. *Analytical Sociology and Social Mechanisms*. Cambridge University Press, Cambridge.
- DiMaggio, P.J., Powell, W.W., 1983. The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. *Am. Sociol. Rev.* 48 (2), 147–160.
- Dosi, G., 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. *Res. Policy* 6 (3), 147–162.
- Elster, J., 2007. *Explaining Social Behavior: More Nuts and Bolts for the Social Sciences*. Cambridge University Press, Cambridge.
- Elzen, B., Geels, F.W., Green, K. (eds.), 2004. *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*. Edward Elgar, Cheltenham.
- Emirbayer, M., 1997. Manifesto for a relational sociology. *Am. J. Sociol.* 103 (2), 281–317.
- Emirbayer, M., Mische, A., 1998. What is agency? *Am. J. Sociol.* 103 (4), 962–1023.
- Fagerberg, J., 2003. Schumpeter and the revival of evolutionary economics: an appraisal of the literature. *J. Evol. Econ.* 13 (2), 125–159.
- Fischer, C.S., 1992. *America Calling. A Social History of the Telephone to 1940*. University of California Press, Berkeley, California.
- Fligstein, N., McAdam, D., 2012. *A Theory of Fields*. Oxford University Press, Oxford.
- Fuenshilling, L., Truffer, B., 2014. The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Res. Policy* 43 (4), 772–791.
- Garud, R., Rappa, M.A., 1994. A socio-cognitive model of technology evolution: the case

- of cochlear implants. *Org. Sci.* 5 (3), 344–362.
- Garud, R., Hardy, C., Maguire, S., 2007. Institutional entrepreneurship as embedded agency: an introduction to the special issue. *Org. Stud.* 28 (7), 957–969.
- Gavetti, G., Levinthal, D., 2004. Strategy field from the perspective of management science: divergent strands and possible integration. *Man Sci.* 50 (10), 1309–1318.
- Gavetti, G., Rivkin, J.W., 2007. On the origin of strategy: action and cognition over time. *Org. Sci.* 18 (3), 420–439.
- Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Res. Policy* 31 (8–9), 1257–1274.
- Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. *Res. Policy* 33 (6–7), 897–920.
- Geels, F.W., 2005. The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technol. Anal. Strateg.* 17 (4), 445–476.
- Geels, F.W., Deuten, J.J., 2006. Local and global dynamics in technological development: a socio-cognitive perspective on knowledge flows and lessons from reinforced concrete. *Sci. Pub. Pol.* 33 (4), 265–275.
- Geels, F.W., Raven, R.P.J.M., 2006. Non-linearity and expectations in niche-development trajectories: ups and downs in DUTCH biogas development (1973–2003). *Technol. Anal. Strateg.* 18 (3/4), 375–392.
- Geels, F.W., Schot, J.W., 2007. Typology of sociotechnical transition pathways. *Res. Policy* 36 (3), 399–417.
- Geels, F.W., 2009. Foundational ontologies and multi-paradigm analysis, applied to the socio-technical transition from mixed farming to intensive pig husbandry (1930–1980). *Technol. Anal. Strateg.* 21 (7), 805–832.
- Geels, F.W., Schot, J.W., 2010. The dynamics of transitions: a socio-technical perspective. In: Grin, J., Rotmans, J., Schot, J., Geels, F.W., Loorbach, D. (Eds.), *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. Routledge, pp. 9–87.
- Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Res. Policy* 39 (4), 495–510.
- Geels, F.W., 2014a. Regime resistance against low-carbon energy transitions: introducing politics and power in the multi-level perspective. *Theor. Cult. Soc.* 31 (5), 21–40.
- Geels, F.W., 2014b. Reconceptualising the co-evolution of firms-in-industries and their environments: developing an inter-disciplinary triple embeddedness framework. *Res. Policy* 43 (2), 261–277.
- Geels, F.W., Penna, C.C.R., 2015. Societal problems and industry reorientation: elaborating the dialectic issue lifecycle (DILC) model and a case study of car safety in the USA (1900–1995). *Res. Policy* 44 (1), 67–82.
- Geels, F.W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., Wassermann, S., 2016. The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). *Res. Policy* 45 (4), 896–913.
- Genus, A., Coles, A.-M., 2008. Rethinking the multi-level perspective of technological transitions. *Res. Policy* 37 (9), 1436–1445.
- Giddens, A., 2009. *The Politics of Climate Change*. Polity Press, Cambridge, UK.
- Giddens, A., Sutton, P.W., 2014. *Essential Concepts in Sociology*. Polity Press, Cambridge, UK.
- Greenwood, R., Suddaby, R., Hinings, C.R., 2002. Theorizing change: the role of professional associations in the transformations of institutional fields. *Acad. Manag. Rev.* 45, 58–80.
- Guggenheim, M., Nowotny, H., 2003. Joy in repetition makes the future disappear: a critical assessment of the present state in sts. In: Joerges, B., Nowotny, H. (Eds.), *Social Studies of Science & Technology: Looking Back, Ahead*. Kluwer, Dordrecht, pp. 229–260.
- Hargreaves, T., Hielscher, S., Seyfang, G., Smith, A., 2013. Grassroots innovations in community energy: the role of intermediaries in niche development. *Global Environ. Change* 23 (5), 868–880.
- Hedström, P., Swedberg, R., 1998. *Social Mechanisms: An Analytical Approach to Social Theory*. Cambridge University Press, Cambridge.
- Hermwille, L., 2016. The role of narratives in socio-technical transitions—Fukushima and the energy regimes of Japan, Germany, and the united kingdom. *Energ. Res. Soc. Sci.* 11, 237–246.
- Hess, D.J., 2005. Technology and product-oriented movements: approximating social movement studies and science and technology studies. *Sci. Technol. Hum. Val.* 30 (4), 515–535.
- Hess, D.J., 2016. The politics of niche-regime conflicts: distributed solar energy in the united states. *Environ. Innov. Soc. Trans.* 19, 42–50.
- Hirsch, P.M., Lounsbury, M., 1997. Ending the family quarrel: toward a reconciliation of “old” and “new” institutionalisms. *Am. Behav. Sci.* 40 (4), 406–418.
- Hodgson, G.M., Knudsen, T., 2004. Why we need a generalized darwinism: and why a generalized darwinism is not enough. *J. Econ. Behav. Org.* 61 (1), 1–19.
- Hoffman, A.J., 1999. Institutional evolution and change: environmentalism and the US chemical industry. *Acad. Manag. J.* 42 (4), 351–371.
- Hughes, T.P., 1983. *Networks of Power: Electrification in Western Society, 1880–1930*. Johns Hopkins University Press, Baltimore.
- Hynes, M., 2016. Developing (tele)work? a multi-level sociotechnical perspective of telework in Ireland. *res. transp. Econ.* 57, 21–31.
- Jasanoff, S., 2012. Genealogies of STS. *Soc. Stud. Sci.* 42 (3), 435–441.
- Jessop, B., 2001. Institutional re(turns) and the strategic-relational approach. *Environ. Plann. A* 33 (7), 1213–1235.
- Kemp, R., Schot, J., Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technol. Anal. Strateg.* 10, 175–196.
- Jones, C., Boxenbaum, E., Anthony, C., 2013. The immateriality of the material in institutional logics. *Res. Sociol. Org.* 39, 51–75 Part A.
- Kaidesoja, T., 2013. Overcoming the biases of microfoundationalism: social mechanisms and collective agents. *Phil. Soc. Sci.* 43 (3), 301–322.
- Kern, F., 2011. Ideas, institutions and interests: explaining policy divergence in fostering ‘system innovations’ towards sustainability’. *Environ. Plann. C* 29 (6), 1116–1134.
- King, A., 2004. *The Structure of Social Theory*. Routledge, London.
- Kivimaa, P., 2014. Government-affiliated intermediary organisations as actors in system-level transitions. *Res. Policy* 43 (8), 1370–1380.
- Klein, H.K., Kleinman, D.L., 2002. The social construction of technology: structural considerations. *Sci. Technol. Hum. Val.* 27 (1), 28–52.
- Köhler, J., Geels, F.W., Markard, J., Wieczorek, A., Alkemaade, F., Avelino, F., Bergek, A., Boons, F., Fuenfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M.S., Nykvist, B., Onsongo, E., Pel, B., Raven, R., Rohracher, H., Sandén, B., Schot, J., Sovacool, B., Turnheim, B., Welch, D., Wells, P., 2019. An agenda for sustainability transitions research: state of the art and future directions. *Environ. Innov. Soc. Trans.* 31, 1–32.
- Latour, B., 1991. *Technology is society made durable*. In: Law, J. (Ed.), *A Sociology of Monsters: Essays on Power, Technology and Domination*. Routledge, London, pp. 103–131.
- Leblebici, H., Salancik, G.R., Copay, A., King, T., 1991. Institutional change and the transformation of interorganizational fields: an organizational history of the U.S. radio broadcasting industry. *Admin. Sci. Quart.* 36 (3), 333–363.
- Levinthal, D.A., 1998. The slow pace of rapid technological change: gradualism and punctuation in technological change. *Ind. Corp. Change* 7 (2), 217–247.
- Lie, M., Sørensen, K.H. (eds.), 1996. *Making Technology our Own: Domesticating Technology into Everyday Life*. Scandinavian University Press, Oslo.
- Little, D., 2016. *New Directions in the Philosophy of Social Science*. Rowman & Littlefield International, London.
- Lockwood, M., Kuzemko, C., Mitchell, C., Hoggett, R., 2017. Historical institutionalism and the politics of sustainable energy transitions: a research agenda. *Environ. Plann. C* 35 (2), 312–333.
- Lounsbury, M., Glynn, M.A., 2001. Cultural entrepreneurship: stories, legitimacy, and the acquisition of resources. *Strat. Manag. J.* 22 (6–7), 545–564.
- Lounsbury, M., Crumley, E.T., 2007. New practice creation: an institutional perspective on innovation. *Org. Stud.* 28 (7), 993–1012.
- MacKenzie, D., 1992. Economic and sociological explanations of technical change. In: Coombs, R., Saviotti, P., Walsh, V. (Eds.), *Technological Change and Company Strategies: Economic and Sociological Perspectives*. Academic Press, London, pp. 25–48.
- Maguire, S., Hardy, C., 2009. Discourse and deinstitutionalization: the decline of DDT. *Acad. Manag. J.* 52 (1), 148–178.
- Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. *Res. Policy* 41 (6), 955–967.
- Markard, J., Suter, M., Ingold, K., 2016. Socio-technical transitions and policy change: advocacy coalitions in Swiss energy policy. *Environ. Innov. Soc. Trans.* 18, 215–237.
- Martin, B.R., Nightingale, P., Yegros-Yegros, A., 2012. Science and technology studies: exploring the knowledge base. *Res. Policy* 41 (7), 1182–1204.
- Mayr, E., 1963. *Animal Species and Evolution*. Harvard University Press, Cambridge MA.
- McAdam, D., Scott, W.R., 2005. Organizations and movements. In: Davis, G.F., McAdam, D., Scott, W.R., Zald, M.N. (Eds.), *Social Movements and Organization Theory*. Cambridge University Press, Cambridge, pp. 4–40.
- Misa, T.J., 1994. Retrieving sociotechnical change from technological determinism. In: Smith, M.R., Marx, L. (Eds.), *Does Technology Drive History? The Dilemma of Technological Determinism*. MIT Press, Cambridge, Massachusetts, pp. 115–141.
- Mokyr, J., 2000. Evolutionary phenomena in technological change. In: Ziman, J. (Ed.), *Technological Innovation as an Evolutionary Process*. Cambridge University Press, Cambridge, pp. 52–65.
- Moradi, A., Vagoni, E., 2018. A multi-level perspective analysis of urban mobility system dynamics: what are the future transition pathways? *Technol. Forecast. Soc.* 126, 231–243.
- Morrissey, J., Miroso, M., Abbott, M., 2014. Identifying transition capacity for agri-food regimes: application of the multi-level perspective for strategic mapping. *J. Environ. Pol. Plann.* 16 (2), 281–301.
- Mouzelis, N., 1995. *Sociological Theory: What Went Wrong? Diagnoses and Remedies*. Routledge, London.
- Munir, K.A., 2015. A loss of power in institutional theory. *J. Manag. Inq.* 24 (1), 90–92.
- Nelson, R.R., Winter, S.G., 1982. *An Evolutionary Theory of Economic Change*. Belknap Press, Cambridge MA.
- Nelson, R.R., 1994. The co-evolution of technology, industrial structure, and supporting institutions. *Ind. Corp. Change* 3 (1), 47–63.
- Nelson, R.R., 2002. Bringing institutions into evolutionary growth theory. *J. Evol. Econ.* 12 (1–2), 17–28.
- Nelson, R.R., 2008. Bounded rationality, cognitive maps, and trial and error learning. *J. Econ. Behav. Org.* 67 (1), 78–89.
- Nelson, R.R., 2013. Reflections on the study of innovation and those who study it. In: Fagerberg, J., Martin, B.R., Andersen, E.S. (Eds.), *Innovation Studies: Evolution and Future Challenges*. Oxford University Press, Oxford, pp. 187–193.
- Nelkin, D. (ed.), 1992. *Controversy: Politics of Technical Decisions*. Sage, Newbury Park, CA.
- Nykvist, B., Whitmarsh, L., 2008. A multi-level analysis of sustainable mobility transitions: niche developments in the UK and Sweden. *Technol. Forecast. Soc.* 75 (9), 1373–1387.
- Oliver, C., 1991. Strategic responses to institutional processes. *Acad. Manag. Rev.* 16 (1), 145–179.
- Oliver, C., 1997. The influence of institutional and task environment relationships on organizational performance: the Canadian construction industry. *J. Manag. Stud.* 34

- (1), 99–124.
- Orlikowski, W.J., 2000. Using technology and constituting structures: a practice lens for studying technology in organizations. *Org. Sci* 11 (4), 404–428.
- Orlikowski, W.J., 2007. Sociomaterial practices: exploring technology at work. *Org. Stud* 28 (9), 1435–1448.
- Osunmuyiwa, O., Biermann, F., Kalfagianni, A., 2018. Applying the multi-level perspective on socio-technical transitions to rentier states: the case of renewable energy transitions in Nigeria. *J. Environ. Pol. Plann.* 20 (2), 143–156.
- Oudshoorn, N., Pinch, T. (eds.), 2003. *How Users Matter: The Co-Construction of Users and Technology*. MIT Press, Cambridge, Massachusetts.
- Pelikan, P., 2003. Bringing institutions into evolutionary economics: another view with links to changes on physical and social technologies. *J. Evol. Econ.* 13 (3), 237–258.
- Pinch, T.J., Bijker, W.E., 1984. The social construction of facts and artifacts: or how the sociology of science and the sociology of technology might benefit each other. *Soc. Stud. Sci.* 14 (3), 399–441.
- Pinch, T., 2008. Technology and institutions: living in a material world. *Theo. Soc.* 37 (5), 461–483.
- Poole, M.S., Van de Ven, A.H., 1989. Towards a general theory of innovation processes. 1989 In: Van de Ven, A.H., Angle, H.L., Poole, M.S. (Eds.), *Research On the Management of Innovation: The Minnesota Studies*. Harper & Row Publishers, New York, pp. 637–662.
- Porter, M., 1991. Towards a dynamic theory of strategy. *Strat. Manag. J.* 12, 95–117 (Winter Special Issue).
- Powell, W.W., 1991. Expanding the scope of institutional analysis. In: Powell, W.W., DiMaggio, P.J. (Eds.), *The New Institutionalism in Organizational Analysis*. The University of Chicago Press, Chicago, pp. 183–203.
- Purdy, J.M., Gray, B., 2009. Conflicting logics, mechanisms of diffusion, and multilevel dynamics in emerging institutional fields. *Acad. Manag. J.* 52 (2), 355–380.
- Radder, H., 2000. Review essay on 'The governance of science' by Steve Fuller. *Sci. Technol. Hum. Val* 25 (4), 538–545.
- Rammert, W., 1997. New rules of sociological method: rethinking technology studies. *Brit J. Sociol.* 48 (2), 171–191.
- Rip, A., 1992. A quasi-evolutionary model of technological development and a cognitive approach to technology policy. *Riv. Stud. Epistem. Soc. Sulla Sci. Tecnol.* 2, 69–103.
- Rip, A., Kemp, R., 1998. Technological change. In: Rayner, S., Malone, E.L. (Eds.), *Human Choice and Climate Change*. Battelle Press, Columbus, Ohio, pp. 327–399.
- Ritzer, G., 1980. *Sociology: A Multiple Paradigm Science*. Allyn and Bacon, Boston.
- Ritzer, G., 1992. *Sociological Theory*. McGraw-Hill, New York.
- Roberts, C., 2017. Discursive destabilisation of socio-technical regimes: negative story-lines and the decline of the American railroads. *Energy Res. Soc. Sci.* 31, 86–99.
- Roberts, C., Geels, F.W., 2018. Public storylines in the british transition from rail to road transport (1896–2000): discursive struggles in the multi-level perspective. *Sci. Cult.* 27 (4), 513–542.
- Roberts, C., Geels, F.W., 2019. Conditions for politically accelerated transitions: historical institutionalism, the multi-level perspective, and two historical case studies in transport and agriculture. *Technol. Forecast. Soc.* 140, 221–240.
- Rosenberg, N., 1995. Innovation's uncertain terrain. *McKinsey Quart* 3, 170–185.
- Rosenbloom, D., Berton, H., Meadowcroft, J., 2016. Framing the sun: a discursive approach to understanding multi-dimensional interactions within socio-technical transitions through the case of solar electricity in Ontario, Canada. *Res Policy* 45 (6), 1275–1290.
- Rueschemeyer, D., 2009. *Usable Theory: Analytic Tools For Social and Political Research*. Princeton University Press, Princeton.
- Schot, J.W., 2003. The contested rise of a modernist technology politics. In: Misa, T.J., Brey, P., Feenberg, A. (Eds.), *Modernity and Technology*. MIT Press, Cambridge, Massachusetts, pp. 257–278.
- Schot, J.W., Geels, F.W., 2007. Niches in evolutionary theories of technical change: a critical survey of the literature. *J. Evol. Econ.* 17 (5), 605–622.
- Schneiber, M., Clemens, E.S., 2006. The typical tools for the job: research strategies in institutional analysis. *Sociol Theor* 24 (3), 195–227.
- Schumpeter, J.A., 1939. *Business cycles: a theoretical. Historical and Statistical Analysis of the Capitalist Process*. McGraw-Hill, New York.
- Scott, W.R., 1995. *Institutions and Organizations*. Sage Publications, Thousand Oaks, CA.
- Scott, W.R., 2008. Approaching adulthood: the maturing of institutional theory. *Theor. Soc.* 37, 427–442.
- Seo, M.-G., Creed, W.E.D., 2002. Institutional contradictions, praxis and institutional change: a dialectical perspective. *Acad. Manag. Rev.* 27 (3), 222–247.
- Sine, W.D., David, R.J., 2003. Environmental jolts, institutional change, and the creation of entrepreneurial opportunity in the US electric power industry. *Res Policy* 32 (2), 185–207.
- Smelser, N.J., 1999. Looking back at 25 years of sociology and the annual review of sociology. *Ann. Rev. Sociol.* 25, 1–18.
- Smink, M., Negro, S.O., Niesten, E., Hekkert, M.P., 2015a. How mismatching institutional logics hinder niche–regime interaction and how boundary spanners intervene. *Technol. Forecast. Soc.* 100, 225–237.
- Smink, M.M., Hekkert, M.P., Negro, S.O., 2015b. Keeping sustainable innovation on a leash? exploring incumbents' institutional strategies. *Bus. Strat. Environ* 24 (2), 86–101.
- Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. *Res Policy* 34 (10), 1491–1510.
- Smith, A., 2007. Translating sustainabilities between green niches and socio-technical regimes. *Technol. Anal. Strateg.* 19 (4), 427–450.
- Smith, A., Jan-Peter Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of a multi-level perspective and its challenges. *Res. Policy* 39 (4), 435–448.
- Smith, A., Raven, R., 2012. What is protective space? reconsidering niches in transitions to sustainability. *Res. Policy* 41 (6), 1025–1036.
- Steinmueller, W.E., 2013. Innovation studies at maturity. In: Fagerberg, J., Martin, B.R., Andersen, E.S. (Eds.), *Innovation Studies: Evolution and Future Challenges*. Oxford University Press, Oxford, pp. 147–167.
- Stirling, A.C., 2008. 'Opening up' and 'closing down': power, participation, and pluralism in the social appraisal of technology. *Sci. Technol. Hum. Val* 33 (2), 262–294.
- Suchman, M.C., 1995. Managing legitimacy: strategic and institutional approaches. *Acad. Manag. Rev.* 20 (3), 571–611.
- Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. *Strat. Manag. J.* 18 (7), 509–533.
- Thornton, P., Ocasio, W., Lounsbury, M., 2012. *The Institutional Logics Perspective: A New Approach to Culture, Structure and Process*. Oxford University Press, Oxford.
- Tilly, C., 2008. *Explaining Social Processes*. Paradigm Publishers, Boulder.
- Tolbert, P.S., Zucker, L.G., 1999. The institutionalization of institutional theory. In: Clegg, S., Hardy, C. (Eds.), *Studying Organization: Theory and Method*. Sage, London, pp. 169–184.
- Turner, S., 2001. What is the problem with experts? *Soc. Stud. Sci.* 31 (1), 123–149.
- Tushman, M.L., Rosenkopf, L., 1992. Organizational determinants of technological change: Towards a sociology of technical evolution. In: Cummings, L.L., Staw, B.M. (Eds.), *Research in Organizational Behavior*. 14. JAI Press Inc, Greenwich, Connecticut, pp. 311–347.
- Van Bree, B., Verbong, G.P.J., Kramer, G.J., 2010. A multi-level perspective on the introduction of hydrogen and battery-electric vehicles. *Technol. Forecast. Soc.* 77 (4), 529–540.
- Van Wijk, J., Stam, W., Elfring, T., Zietsma, C., Den Hond, F., 2013. Activists and incumbents structuring change: the interplay of agency, culture, and networks in field evolution. *Acad. Manag. J.* 56 (2), 358–386.
- Weber, M., 1978/1922. *Economy and Society: An Outline of Interpretative Sociology*. University of California Press, Berkeley.
- Weber, K.M., 1997. *Innovation Diffusion and Political Control of Energy Technologies: A Comparison of Combined Heat and Power Generation in the UK and Germany*. Ph.D thesis, Institut für Sozialforschung der Universität Stuttgart. .

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