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A Micro-theoretical Perspective of Multi-Level Systems of Innovation

Julian Kahl (Ruhr University Bochum, julian.kahl@rub.de)

Abstract

Comparative institutional analysis focuses on the impact of cross-national variation of institutional structures on economic growth and innovation. A fundamental concern of this literature is that national institutional arrangements are the foundation from which comparative advantage and innovative performance is derived. However, these analyses have tended to disregard the ample scope for heterogeneity at the regional, sectoral and micro-level within economic systems. In view of this lack of theoretical and empirical treatment of micro-diversity which is increasingly recognized as one of the key growth drivers and sources of evolutionary change of economic systems across a broad range of disciplines, comparative institutional analysis fails to provide a convincing explanation for the processes by which these institutional structures emerge and evolve. Taking issue with the institutional determinism as well as the static conception of economic systems underlying the varieties of capitalism framework, this paper argues that a micro-theoretical perspective on multi-level systems of innovation may provide a more nuanced view on the processes underpinning innovative activity. In this framework economic systems are conceptualized as inherently multi-level and co-evolutionary entities. That is, their structure emerges from continuous interactions of heterogeneous micro-agents embedded in innovation networks generating varied sets of resources on the one hand. On the other hand, institutional structure provides micro-agents with variegated resources that in turn may be exploited, recombined or modified at the micro-level. The main research interest in the proposed micro-theoretical framework lies in unpacking the co-evolution of micro-diversity embodied in organizational capabilities as well as institutional structure at multiple levels of innovation systems.

1 Introduction

Comparative institutional analysis and the literature on the varieties of capitalism (VoC) (Hall/Soskice 2001, Hollingsworth 2000) investigate the impact of cross-national variation of institutional structures on economic growth and innovation. The fundamental point of departure in this body of literature is that innovative performance is the result of the interplay of different national institutional arrangements. Even though micro-agents take a central position in the VoC framework, it has tended to disregard the ample scope for heterogeneity at the micro-level. In particular, patterns of economic behaviour at the micro-level are frequently conceptualized as a result of institutional logics at the macro-level. It is argued here that this takes a rather narrow view of agency and variation at the micro-level denying any strategic leeway micro-agents have to circumvent institutionally impoverished environments by drawing on different combinations of institutions (Lange 2009) available at the regional, sectoral, national or international level. The VoC's conception of economic systems also neglects the endogenous potential of micro-agents to alter macro-structures. This is unsatisfactory as micro-diversity and its transformation into novelty is recognized as the key growth driver as well as the fundamental source of the evolution of economic systems across a wide range of theoretical frameworks including complex adaptive systems approaches (Cooke 2012), evolutionary economic geography (Boschma/Martin 2010) and complex systems theory (Kauffmann 2008). Therefore, it is argued here that one of the most important issues an evolutionary theory of innovation needs to elucidate relates to the co-evolution of micro-diversity on the one hand and institutional structure on the other (Ahrweiler 2010; Cooke 2012; Saviotti 2009).

While theoretical frameworks from evolutionary economics (Lundvall 1992; Nelson 1993) initially focused on national systems of innovation (Freeman 1987; Lundvall 1992; Nelson 1993), economic systems have been shown to display considerable heterogeneity at the regional (Cooke 1992; Braczyk/Cooke/Heidenreich 1998), sectoral (Breschi/Malerba 1997; Malerba 2004) as well as the micro-level (Butzin/Rehfeld/Widmaier 2012; Cooke 2012). Moreover, innovation networks represent the central form of organization by which increasingly complex innovation processes unfold (Ahrweiler 2010; Pyka/Scharnhorst 2009; Powell 1990). These networks, shaped by geographical (Glückler 2007) as well as sectoral specificities (Kogut 2000), link heterogeneous micro-agents including firms, universities, research institutes and government agencies with varied organizational capabilities in the generation of innovation. Moreover, micro-agents' organizational capabilities are institutionally embedded (DiMaggio 2001; Granovetter 1985), that is, these agents do not innovate in isolation and depend on specific institutions – defined as "sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups and organizations" (Edquist/Johnson 1997: 46). Innovation thus emerges from multiple levels of innovation systems including micro-processes that are endogenous to innovation networks as well as institutional structure (Whitley 2007) that is exogenous to these networks. A current frontier in the field of innovation studies relates to the integrated analysis of these levels as well as their impact on the evolution of innovation networks (Kudic/Pyka/Günther 2012; Parkhe/Wasserman/Ralston 2006). This paper seeks to make a contribution to this body of literature by proposing a micro-theoretical perspective on multi-level systems of innovation (MMLS) that provides a framework for the inte-

grated analysis of micro-level change processes on the one hand and institutional selection environments at multiple levels on the other (DiMaggio 2001; Padgett/Powell 2012; Kudic/Pyka/Günther 2012).

By unpacking the fine-granulation of innovation processes (e.g. Butzin/Rehfeld/Widmaier 2012; Cooke 2012), the proposed MMLS seeks to shed light on the co-evolution of actors, networks and institutions. In contradistinction to the VoC approach that places its main emphasis on the institutional structure of innovation systems to explain innovative activity and in reference to (Ahrweiler 2010; Cooke 2012; Pyka/Scharnhorst 2009) it is argued here that innovation emerges from ongoing interactions at the micro-level. Therefore, this MMLS framework takes as a starting point that in order to understand outcomes at the macro-level, a more nuanced perspective of the micro-mechanisms and their interrelations with institutional structure that jointly produce micro-diversity is needed. Such a framework may provide important insights into the extent of the institutional structuring of firms' strategies as well as the factors that impact the evolution of micro-agents' organizational capabilities which in turn forms the basis for understanding the drivers of evolutionary change of economic systems. While acknowledging the impact of institutional forces on micro-agents, the MMLS accommodates the notion of heterogeneous actors and agent autonomy relaxing the structuralist determinism of the varieties of capitalism approach. Departing from this monolithic conception, innovative activity is conceptualized as a process embedded in multi-level systems relating to the micro-level (e.g. organizations), meso-level (regional and sectoral systems of innovation) and macro-level (national institutional settings).

This paper proceeds as follows. First, by reviewing the varieties of capitalism literature, the rationale for a multi-level analysis of innovation systems is provided. Second, an overview of the multi-level characteristics of innovation is given by addressing various theoretical frameworks that deal with innovation from different perspectives. Third, to elucidate the interrelations between the different levels of innovation systems, the co-evolution of micro-diversity and institutional structure is addressed. Ultimately, central pillars of the proposed MMLS framework are explored.

2 Varieties of capitalism

The varieties of capitalism (Hall/Soskice 2001) framework remains highly influential in comparative institutional analysis, economic sociology and institutional economics (Hancké et al. 2009). One major theoretical assumption underlying the VoC-framework is that national economies differ with regard to their institutional foundations, which has a considerable impact on behavioral patterns of micro-agents, sectoral specialization and economic output of economic systems. The interplay of different institutions provides national economies with specific comparative advantages and gives rise to distinct 'system logics' that generate particular behavioural patterns of micro-agents in terms of innovation strategies and routine problem solving approaches. The ways in which firms deal with coordination problems in specific institutional arrangements is at the heart of the VoC-approach. Hall and Soskice (2001) conceptualize firms as developing dynamic capabilities which provide them with competitive advantage. In order to develop these dynamic capabilities, firms need to coordinate relationships both internally, e.g. with their employees, as well as with their external environment, e.g. suppliers, stakeholders and trade unions. From a transaction cost theory perspective these relationships are problematic; therefore, the ways in which firms solve these coordination

problems depends on their relational capabilities. A core assumption of the VoC-framework is that firms solve these coordination problems in system-specific ways relating to different spheres of the national institutional setting, i.e. industrial relations, vocational training and education systems, financial systems, corporate governance and inter-firm relations. The VoC-approach provides a supply-side theory of institutional arrangements with a view to explaining how these institutional configurations affect the supply of inputs (e.g. capital, trained personnel) available for micro-agents (Deeg/Jackson 2007). Moreover, a central starting point of the framework is the path-dependent development of economic systems. National economies are not converging on a superior model in the wake of intensified globalization. By contrast, it is assumed that these systems adhere to specific institutional trajectories which to some extent exhibit persistent characteristics.

The varieties approach identifies two different types of economic systems – coordinated (CME) and liberal market economies (LME) which, among other things, display system-specific corporate strategies, innovation patterns and inter-firm interactions. Liberal market economies such as the USA and UK are characterized by market-based institutions. In these economies, the interactions between micro-agents are based on formal contracting and competition. By contrast, in coordinated market economies such as Germany and Austria, the coordination of economic activity rests on strategic interactions, i.e. non-market-relations between economic actors. Due to their specific institutional set-up Hall and Soskice (2001) find that LMEs excel at radical innovation, while CMEs are found to specialize in incremental innovation.

2.1 National institutional domains

The following section turns to the national institutional domains and the stylized patterns of innovation of the two archetypical systems. Among the institutional domains briefly reviewed here are financial systems and corporate governance, labour markets as well as educational and training systems.

Corporate governance and financial systems represent important institutional domains in the VoC-framework. Acknowledging that there is considerable cross-country variation in the structure of these domains, different modes of coordination among micro-agents arise in light of the central coordination problem underpinning these institutional sectors, i.e. firms attempting to access finance on the one hand and investors looking to safeguard their returns on the other (Hall/Soskice 2001). Moreover, newer findings indicate that the breadth and depth of financial systems has a major impact on the output of the economy in terms of entrepreneurial activity (King/Levine 1993), technological progress (Dosi 1990), sectoral specialization (Tylecote/Conesa 1999) and macro-economic growth (Hirsch-Kreinsen 2011).

A fundamental distinction between financial systems in LMEs and CMEs refers to the type of finance provided. CMEs are characterized by bank-based and decentralized financial systems where credits are the dominant form of finance, whereas LMEs are marked by highly developed capital and equity markets. The 'insider' and 'outsider' models highlight further differences with regards to ownership, access to information and patterns of innovation. While the insider model pervasive in CMEs is particularly well-suited for sectors based on incremental innovation and patient capital, the outsider model dominant in LMEs is more conducive to the generation of radical innovation based on risky investments

and in particular relating to the provision of venture capital for start-ups. The emergence of high technology sectors in liberal market economies is attributed to recent innovations in the financing of innovation (Mayer 2002) as well as institutional complementarities with other institutional domains. By contrast, financial systems in CMEs provide firms with access to credit-based patient capital that is less dependent on publicly available financial data or current profitability and more inclined to longer investment horizons. Investment decisions are frequently based on insider knowledge of firm competencies and profitability. This insider knowledge is harnessed in dense networks inside firms and with its stakeholders (suppliers, clients) providing opportunities for reputational monitoring (Hall/Soskice 2001). Moreover, the strategic mode of interaction in CMEs is also reflected in the two-tier board system, corporate constitution and employee representation within these firms wherein works councils have a strong position in strategic decisions (e.g. hiring of new employees, negotiation of severance payments), while managers have little scope for unilateral action (Vitols 2001). These institutional structures provide a fertile ground for long-term, yet low-risk investments in traditional sectors, whereas venture capital for risky ventures is scarce in these institutional environments.

National institutional frameworks also strongly influence the dynamics of labour markets which in turn impact the pattern of technological specialization and competitive advantage. A parsimonious distinction is made between internal and external labour markets. CMEs are characterized by internal labour markets which are based on long-term employment contracts and the internal creation of human capital. External labour markets refer to the practice of recruiting qualified personnel on markets. In industries where competitive advantage is achieved in high-product quality segments based on continuous product and process development, internal markets provide firms with a comparative institutional advantage. Whereas external markets are favourable in rapidly innovating science-based sectors based on short product life cycles and the reconstitution of teams of highly skilled personnel. Moreover, the highly developed equity markets also provide incentives for firms to acquire trained personnel or technologies on (external) markets. Highly qualified personnel is acquired and retained by high powered incentive systems. Due to the weak labour regulations recruiting personnel on highly fluid labour markets is pervasive which enables firms to react to developments on (equity) markets swiftly (Hall/Soskice 2001). By contrast, impoverished external markets in CMEs may substantially mitigate the capacity of firms to compete on these markets (Coriat/Weinstein 2004)

Finally, among educational and training systems there exists considerable cross-country variation. In broad terms, the inclination of these systems towards basic or vocational training has an impact on the type of skills readily available for firms in national economies (Hall/Soskice 2001). Moreover, national systems of innovation also differ markedly with regards to the commercialization of knowledge and technological transfer between basic science and business (Feldman et al. 2006).

2.2 Pitfalls of the varieties of capitalism framework

While the VoC-approach provides a simple, yet powerful way of comparing economic systems, it cannot explain the variation at the regional level, sectoral and micro-level. Furthermore, the approach cannot explain why and how economic systems change. Indeed, the varieties of capitalism approach has recently been subjected to intensive critique (Akkermanns et al. 2009; Allen 2004; Lange 2009; Peck/Theodore

2007; Taylor 2004). By way of conceptualizing economic systems as homogeneous entities, the varieties approach adopts a highly-stylized perspective of economic development falling short on some of the most fundamental aspects of economic activity. One central criticism levelled at the VoC-approach in this regard concerns the lack of heterogeneity afforded in this framework. Allen (2004) challenges the premise of a homogeneous mode of coordination within economic systems underlying the VoC-framework. From this perspective, although there may exist dominant sets of institutions, these institutions may not radiate across entire economic systems as readily as assumed in the VoC-framework. On the contrary, some sets of institutions may follow their own logic remaining largely unaffected by national institutional arrangements. Moreover, in contrast to the varieties literature Hollingsworth et al. (1994) find that within countries there is ample variation among sectors with regards to governance structures (e.g. level of state intervention or type of inter-organizational networks) which has a considerable impact on the performance of these sectors. While acknowledging the specificities of sectoral governance within economies, it is argued that these governance structures are also highly varied across countries as national institutions and sectoral governance regimes interact giving rise to varied economic performance and innovative output. By contrast, in a dynamic perspective, the second-order coordination argument holds that the increasing internationalization of some of the components of economic systems results in a structural alignment which gradually erodes national institutional arrangements (Ahrweiler/Gilbert/Pyka 2006). Collaborative activities within internationalized networks are identified as central drivers facilitating a harmonization of structures that increasingly displaces national institutional frameworks. For instance, the recent success of high technology sectors such as the biotechnology or the internet software industry in Germany or Sweden are indications of the erosion of structural differences between the CMEs and LMEs. In contradistinction to these findings, a wide range of studies emphasizes the persistence of cross-national differences in terms of strategy (Haeussler 2011), sectoral specialization (Casper 2006) and venture capital (Ahlstrom /Bruton 2006).

3 Rationales for a micro-theoretical perspective of multi-level systems

A key premise of the VoC-framework relates to the institutional structuring of agency. Institutional frameworks provide certain types of resources for micro-agents thereby supporting different innovation strategies, which is why firms in favourable environments outperform their counterparts in more institutionally impoverished environments. However, in doing so, the varieties framework theorizes economic actors as having uniform preferences endogenous to certain types of institutional environments (Allen 2004). By way of conceptualizing economic systems and micro-agents as homogeneous entities, the 'varieties' approach thus adopts a highly-stylized perspective of economic development 'reading-off' micro-level properties from macro-institutions. This view represents a structuralist determinism reducing the scope of individual manoeuvre drastically (Deeg/Jackson 2007). The lack of empirical treatment of the firm may be attributed to the aggregate perspective underlying the VoC approach. This perspective may explain why firms' strategies as well inter-firm networks have not been central aspects in this framework. Also, due to the preoccupation with aggregates, the interrelations between the micro-level and the macro-level have been underrepresented. In order

to understand outcomes at the macro-level, however, it is argued that processes at the micro-level need to be taken into consideration as individual economic agents do not intentionally produce some sort of institutional or spatial structure.

The proposed MMLS may provide a more nuanced perspective on the institutional structuring and evolution of organizational capabilities by affording attention to the interplay of two superordinate dimensions, notably structure and agency (Giddens 1984). In line with the notion of the duality of structure underlying structuration theory, the MMLS is attentive to the structural properties of systems which "are both medium and outcome of the practices they recursively organise" (Giddens 1984: 25). A starting point is that the hierarchical structure of multi-level systems has a bearing on micro-agents in terms of providing latent institutional resources on the one hand and constraints on the other impacting micro-agents, for instance, in terms of innovative performance (DiMaggio 2001). Organizational capabilities and the processes by which firms exploit, recombine and modify latent institutional resources as well as their capacity to circumvent impoverished institutional environments are contended to vary considerably at the micro-level. The aggregate of these processes generate and incrementally change macro-structures. In contrast to the varieties of capitalism literature, the structuralist determinism is thus relaxed providing considerable scope for agency and variation. 'Structure' may be decomposed into three interrelated analytical components, notably the macro-level (national institutional settings), meso-level (regional and sectoral systems of innovation) as well as the micro-level ('agency') relating to the behavioural patterns of micro-agents at the firm and network level. Understanding the complex interplay between structure and agency may provide meaningful insights into the drivers of innovative performance and the evolution of these systems.

In the following sections the theoretical frameworks dealing with innovation on the different levels of innovation systems will be reviewed. Following this review, the outlines of a MMLS will be elucidated. A starting point relates to the question why firms should be conceptualized as heterogeneous entities.

4 Micro-theoretical foundations of MLS

4.1 Theory of the firm

An answer to the question posed above (Nelson 1991) is provided by the resource-based view of the firm (RBV) (Penrose 1959). Rather than industry structure and the static equilibrium framework of industrial organization (Porter/Caves 1977), the RBV argues that understanding differential firm behaviour and performance rests on the persistent heterogeneity of resource endowments and the creation of idiosyncratic firm-internal resources. While many resources can be bought and sold on factor markets, some assets remain non-appropriable as factor markets remain incomplete. Moreover, in many cases implementing certain firm strategies requires highly firm-specific assets, which are developed internally. In a standard static equilibrium perspective, these differential resource endowments would simply erode due to the perfect mobility of resources (Dierickx/Cool 1989). Therefore, resources are defined as those (tangible and intangible) assets which are tied semi-permanently to the firm (Wernerfelt 1984). Firm's competitive positions are therefore shaped by internal resources and capabilities which are also the main source of their profit[1].

[1] More particularly, resources relate to the firm's capital consisting of physical, financial and immaterial capital. Physical capital

With a view to explaining the size and scope of firms, Penrose (1959) points to the type of resources firms utilize: it is the abundance or the scarcity of resources that impacts the choice of markets and profits. Constraining factors for firm growth include (1) limited supply of labour or physical inputs, (2) financial restrictions, (3) investment opportunities and (4) inadequate managerial competence – all of which may vary considerably across the multiple levels of innovation systems. It follows from this view that if all firms were endowed with the same stocks of resources, there would be no above-normal rents and first-mover advantages. Therefore, an industry must necessarily be made up of heterogeneous components for there to exist competitive advantage (Barney 1991). Drawing on Schumpeter (1942), Penrose (1959) conceptualizes the competitive process in which micro-agents vie for resources for survival as being shaped by uncertainty and disequilibrium. Moreover, in this process micro-agents may accumulate knowledge through learning and R&D investments thus fostering absorption capacities (Cohen/Levinthal 1990) which implies that this is an evolutionary and path-dependent process (Mahoney/Pandian 1992; Nelson/Winter 1982; Teece et al. 1997; Teece 1991).

4.2 Dyadic relations and networks

A main focus in strategy research has been on explaining differential firm performance viewing firms as autonomous entities. More recent studies expand on this view of firms in a world that is increasingly organized in networks of inter-organizational relations. Ibarra et al. (2005) note that the network literature has evolved along two distinct trajectories. One trajectory is concerned with the micro-level of networks (e.g. Dyer/Singh 1998; Gulatti et al. 2000; Hite/Hesterly 2001; Larson 1992), whereas the other deals with networks from a macro perspective (e.g. Barabási/Albert 1999; Watts/Strogatz 1998).

A starting point of micro-theoretical perspectives of networks is that that understanding differential firm strategies and performance necessitates the investigation of network ties encapsulating firms in multiple relationships (Gulatti et al. 2000). Acknowledging that any network may be disassembled into a given number of dyads, the basic unit of analysis is the dyad in these studies (e.g. Mowery 1998; Mytelka 1991; Teece 1997). One of the approaches dealing with this basic unit of network relations is the 'relational view' (Dyer/Singh 1998). A central assumption underpinning this approach is that a firm's competitive resources may be embedded in inter-organizational networks producing relational rents, i.e. rents created from pooling resources generating products or services that could not have been created by either firm in isolation (Dyer/Singh 1998). In this view, relational rents are strongly connected to firm-internal competencies. Therefore, the relational-view may be seen as a logical extension of the resource-based view.

Rather than focusing on dyads, social network theory (SNT) examines entire networks. Networks are conceptualized as "a set of actors connected by a set of ties" (Borgatti/Foster 2003). Actors are often referred to as nodes which are connected by shared endpoints that directly or indirectly link nodes producing a particular network structure with different topological characteristics (e.g. "centrality", "betweenness", "density", "homophily"). A fundamental concern of SNT relates to the topological characteristics of net-

includes access to natural resources, raw materials, machinery, inventories etc. Financial capital comprises liquid capital, shares, bonds, securities and so on. Immaterial capital refers to both embodied and disembodied capital such as know-how, business ideas, licenses, designs and copyrights (Grant 1991).

work structure and nodes' positions within them in relation to outcomes at the node and network level of analysis (Borgatti 2011). While a rich body of literature has emerged in SNT (see Bergenholtz/Waldström 2011 for a literature review), three major perspectives will be considered briefly, that is, the structuralist and the institutional as well as an approach that will be referred to as technologist.

One of the earliest approaches of network analysis is the structuralist perspective (Burt 1992), in which a fundamental claim is that nodes that occupy similar network positions exhibit commonalities in terms of a defined outcome (e.g. innovative output). In the structuralist view individual nodes are by and large homogeneous entities – the only distinction being structural positions that provide opportunities (e.g. ability to innovate) and constraints. Structurally equivalent nodes are expected to display common attributes (e.g. behaviour) (Borgatti et al. 2009; Borgatti/Foster 2003). Moreover, Barabási and Albert (1999) make a seminal contribution to the structuralist perspective by showing that networks across a broad range of systems including genetic networks as well as socio-economic systems undergo constant expansion by adding new nodes. More precisely, new nodes are added by preferential attachment, that is, the new nodes enter into already well connected network regions.

However, the structuralist perspective of networks affords little attention to node properties and agency (Ahrweiler 2010). Thus from a MMLS perspective, this view of networks may be criticized in terms of its inherent structuralist determinism and the lack of agency treating central features of network nodes and ties as well as the processes by which networks evolve as black-boxes. That is, the growth dynamics of Barabási-type complex networks do not provide insights into the micro-mechanisms by which networks and individual nodes co-evolve. We argue here that due to various endogenous as well as exogenous factors, network evolution should rather be understood as a nonlinear process. Therefore, even though relational rents may arise from the position of firms within a network, network nodes' heterogeneous organizational capabilities should receive equal attention. To illustrate the point why it is important to conceptualize networks as consisting of heterogeneous agents, consider the following: The capability of building and occupying a certain position within a network vis-à-vis competitors or strategic partners depends on mobilizing internal resources. This implies that attaining a network position necessarily presupposes efforts by heterogeneous actors for any sort of order to emerge. Once these positions are captured, they may yield certain rents. However, it is argued here that understanding how network structures have developed and in which direction they are going to evolve requires a more nuanced perspective.

In this context Powell et al. (2005) argue that structuralist approaches focusing on topological characteristics of networks have neglected institutional underpinnings as well as the heterogeneous demography of nodes - all of which substantially impact the flow of information and evolution of networks. A starting point of this literature is that that formal structures of organizations are shaped by institutional environments (Meyer/Rowan 1977). Recognizing that organizations are embedded in relational and institutional contexts in organizational fields, networks are conceptualized as transmission channels of organizing principles. In organizational fields, particular patterns of information flows emerge from the status order of individual organizations, which engenders a core and periphery. In broad terms, agents in the periphery emulate the structure and behaviour of the most central ones by mimetic processes. In the process of structural convergence, institutional

logics such as rules and conventions representing specific organizing principles play a major role (Powell et al. 2005). By contrast, rather than focusing on institutional principles of network structure a related strand of literature highlights the technological underpinnings of networks. The technologist view argues that technological generative rules give rise to network structure, which in turn influences firm' behaviour (Kogut 2000). In these approaches, network structure reflects different sets of operating principles ensconced in technologically specific knowledge bases underlying industries.

Taking technologies or institutions as a starting point, however, may considerably underestimate the scope for variation at the national and micro-level. Moreover, the question remains how technological and institutional organizing principles interact and impact the structure and dynamics of networks. Informing the construction of our MMLS framework, we draw from these analyses the differential impact of technological knowledge bases as well as institutional environments on network structure and the evolution of organizational capabilities. In addition, fundamental questions relating to the analysis of MMLS include: Why is there ample scope of variation among network structures in the same technological field? Does the structure and evolution of networks vary in different national and regional contexts? Are there indications of structural alignment or convergence among industries embedded in different national institutional settings? In what ways do networks and institutional environments co-evolve? The meso-level of innovation systems may shed light on a number of these issues.

5 Meso-level

The varieties of capitalism framework conceptualizes economic systems as flat and closed entities. Evolutionary economic geography, however, shows that economic and innovative activity are highly concentrated (e.g. Jaffe/Henderson/Trajtenberg 1993) within a variegated and evolving landscape of interconnected regional economies (Boschma/Martin 2010; Cooke 2001; Doloreux/Parto 2005; Martin/Sunley 2006), wherein various sectoral systems of innovation (Malerba 2004) with varied knowledge bases and heterogeneous micro-agents compete for resources within regionally as well as sectorally bounded selection environments. Jointly, these interacting components give rise to the meso-level of innovation systems which may vastly diverge from the national level and incrementally transform the latter thus generating novel macro-structures (Cooke 2012).

5.1 Sectoral systems of innovation

The concept of sectoral systems of innovation provides a basis for explaining and empirically investigating the question why different sectoral regimes emerge under one national institutional framework (Strambach 2010). This concept accommodates the notion that "innovation systems…tend to be sectorally specific" (Nelson 1992: 371). Malerba (2004: 16) defines sectoral systems of innovation as a "set of activities unified by some linked product groups for a given or emerging demand and characterized by a common knowledge base". Knowledge bases differ across sectors in terms of their specificity, tacitness, complexity and interdependence (Breschi et al. 2000). A central premise of the sectoral systems of innovation (SSI) framework is that innovation patterns tend to display commonalities across countries. These cross-national contingencies are attributed to sector-specific technological regimes, knowledge bases, actors, networks and institutions.

Drawing on the concept of technological regimes by Nelson and Winter (1982), the SSI approach emphasizes the importance of the technological

environment for the organization and evolution of industries. Technological regimes are defined by the specific composition of opportunity, cumulativeness and appropriability of innovation, which represent central economic properties of technologies. These in turn greatly affect the incentives and requisite organizational capabilities in innovation processes. Technological opportunity conditions relate to the potential with respect to the likelihood of generating innovative activities for the invested amount of funds. These conditions are found to vary considerably across technological regimes. Moreover, the appropriability conditions, that is, the mechanisms by which firms safeguard their innovations from competitors as well as technological cumulativeness referring to the extent to which the generation of novel knowledge builds on extant knowledge may also strongly vary across technological regimes (Malerba 2002). These, in turn, give rise to specific learning processes, structural patterns of innovation (e.g. industrial concentration, the rate of entry and exit) as well as the transformation of sectoral systems of innovation (Breschi et al 2000). In the SSI-framework, technological regimes thus account for much of the cross-country invariance in terms of innovation patterns. The different elements of SSI, i.e. knowledge bases, actors, networks and institutions co-evolve giving rise to distinct patterns of innovation (Coriat et al. 2004). A parsimonious distinction of innovative activity across industries is made between Schumpeter Mark I and Schumpeter Mark II industries. This distinction focuses on the systematic distribution of innovative patterns among entrants and incumbents. The former constitute learning regimes in turbulent environments with great amounts of entries, entrepreneurial activity and processes of 'creative destruction' constantly challenging and eroding incumbent's positions. By contrast, a distinct feature of Schumpeter Mark II industries are processes of 'creative accumulation', by which dominant industry incumbents 'deepen' their competitive positions by way of accumulating capabilities over time in relative stabile environments with relatively high barriers to entry (Breschi et al. 2000; Malerba/Orsenigo 1997).

The SSI-framework holds that heterogeneous micro-agents in similar technological regimes display common behavioural characteristics and organizational forms (Malerba 2002). It is assumed that these regularities also apply to the transformation of industries. However, while some of the conditions underpinning technological regimes are held to be constant across countries, it is conceded in the SSI-framework that the capacity to exploit and create technological opportunities varies substantially across countries relating to national institutional frameworks. The SSI-framework is also attentive to the notion of heterogeneous micro-agents and sector-specific networks of innovators (Malerba 2004). However, the integrated analysis of actors, networks and institutions found in this framework has tended to underrepresent micro-diversity and the processes by which organizational capabilities and networks evolve. This is closely connected to the level of analysis of this framework: Although the SSI framework recognizes the impact of institutions and the heterogeneity of micro-agents, the focus of this framework has been on the relation between technological regimes, industrial structure and evolution in an aggregate perspective. In doing so, the specificities of national systems of innovation are frequently regarded as 'residuals'. It is argued here that understanding the interplay between the institutional features and sectoral patterns of innovation and their manifestation at the micro-level is key for understanding the factors inhibiting or driving industrial performance. More generally, little is known about the extent to which sectoral sys-

tems of innovation are shaped by national institutional settings such as financial systems, labour markets, science and education systems on the one hand and the evolution of organizational capabilities on the other. For instance, as entrant's requirements of finance also varies markedly across industries, nation-specific financial systems may impact the evolution of certain organizational capabilities which give rise to specific industries that in turn disproportionately contribute to aggregate economic growth (O'Sullivan 2005). In addition to heterogeneity at the sectoral-level, a growing literature points to the great scope of variety at the regional level.

5.2 Regional systems of innovation

An extensive of body of literature has highlighted the importance of the regional level for innovative performance (Asheim/Gertler 2005; Audretsch/Feldman 1996; Braczyk/Heidenreich/Cooke 1998; Camagni 1991; Porter 1990) and the scope for variation of economic systems at the regional level (Voelzkow 2007). Rather than eroding the importance of local proximity, globalisation forces as well as the shift towards the knowledge-based economy (OECD 1996) seem to accentuate the importance of localised production systems (Asheim/Gertler 2005; Porter 1990). Regional concentrations of "interconnected companies, specialized suppliers, service providers, firms in related industries, associated institutions in particular fields" (Porter 1998: 199) lay the geographical foundation from which innovation emerges. The driving forces that give rise to the spatial clustering of economic activity have been elicited by Marshall (1890) and more recently formalised by Krugman (1991), namely in terms of three different types of externalities, i.e. the development of a local pool of specialised labour, local provision of non-traded inputs specific to an industry in greater variety and at lower cost as well as the flow of information, ideas and technological spillovers in spatial proximity. Particularly the last type of localised externalities have been shown to facilitate the transmission of knowledge and the generation of innovation among interacting micro-agents embedded in regional systems of innovation (RSI) (Cooke 1992).

Recent approaches in economic geography have focused on evolutionary aspects of economic development (Boschma/Martin 2010) in general and cluster life cycles (Menzel/Fornahl 2010) in particular. One of the central points raised by these strands of literature is that economic development is affected by constant structural change and upheaval forces; throughout history new industries have emerged and mature industries have declined or relocated in non-predetermined path-dependent processes (Martin/Sunley 2006) which have in turn laid the foundation for upswings as well as the decline of regional economies. Audretsch and Feldman (1996) link the notion of industrial life cycles to the geography of innovation. That is, the propensity of innovative activity to cluster spatially is closely linked to the evolution of industry life cycles; while particularly in early industry life stages the share of tacit knowledge is highest (Audretsch/Feldman 1996), newer findings indicate that as industries mature an increasing codification of knowledge takes place which in turn leads to a dispersal of economic activity. In these mature stages of cluster life cycles, positive agglomeration effects are offset by congestion effects. Thus, micro-agents primarily benefit from co-location within clusters between two distinct junctures, namely after the emergence of clusters, that is, when the regional concentration has reached a critical mass and until the heterogeneity of a cluster is exhausted due to mutual learning processes and the subsequent convergence of regional competencies (Menzel/Fornahl 2010). Upon depletion of micro-diversity, maturity or stagnation of

cluster growth may set in thus turning the benefits derived from clustering into liabilities locking regional economies into downward spirals of development.

Regional systems of innovation are thus faced with the challenge of constantly having to adapt to changing environments by generating micro-diversity and renewing their knowledge bases (Cooke 2012). RIS may facilitate localized learning processes by way of providing an institutional support infrastructure on the basis of which micro-agents may import, recombine, generate and diffuse highly complex tacit knowledge (Cooke 2008: 402; Polany 1966). The accumulation of these idiosyncratic resources may continuously deepen and widen the regional knowledge base (Asheim/Coenen 2005) and thus form the foundation for ''localized capabilities' (Maskell 1997) and 'competitiveness' (Porter 1990) at the firm and regional level. More particularly, localized learning processes are facilitated by regionally embedded subsystems (Cooke 1997). On the one hand, RIS are comprised of knowledge generation and diffusion subsystems engaged in the production and dissemination of knowledge and skills within regional institutions such as public research institutions, technology mediating organizations as well as education facilities. On the other hand, RIS are shaped by knowledge application and exploitation subsystems encompassing firms, clients, suppliers, competitors, financing institutions, industry associations and government agencies (Tödtling/Trippl 2011).

Although the literature on regional systems of innovation has made extensive progress on the factors underpinning the geography of innovation, the framework has only recently begun to shed light on the micro-processes by which RIS emerge and evolve (Boschma/Martin 2010; Cooke 2012). Similar to comparative institutional analysis, this shortcoming may be attributed to economic geography's concern for populations of firms. In most studies on the geography of innovation, geographical proximity among micro-agents is equated with different kinds of innovative outputs such as knowledge externalities and localized learning. More recently, geographical proximity as such has been proven to be insufficient for explaining innovative outcomes (Boschma 2005; Doloreux/Parto 2005). Moreover, the RIS literature has by and large contended that dense networks of inter-firm cooperation are favourable to regional economic performance. However, this notion neglects the processes and structure underpinning these networks (Giuliani 2010). In sum, the notion of proximity is increasingly deemed insufficient for understanding the complex interactions among micro-agents. That is, the notion of 'proximity' treats interactions among micro-agents as a black-box reading-off micro-actor's properties from meso-structures. Therefore, a framework that is attentive to the micro-mechanisms by which RIS emerge, adapt or fail to adapt to changing environments may elucidate a more nuanced view in this context.

6 Towards a micro-theoretical framework of multi-level systems

In the final chapter of this paper, the outlines of the MMLS will be elucidated. This model is informed by the fundamental finding of the literature review provided above relating to the insufficient treatment of the micro-mechanisms that underpin the co-evolution of actors, networks and institutions that produce the fluctuations of aggregate variables and institutional structure (see also Cooke 2012). Drawing on some of the major tenets of complexity-based approaches (Ahrweiler 2010; Kaufmann 1993; Prigogine/Nicolis 1989; Saviotti 2009; Pyka/Scharnhorst 2009), the co-evolution of structure and agency is afforded a central position in this framework. At the heart of this process is one of the most important evolu-

tionary concepts, notably co-evolution. Co-evolution is one of the fundamental mechanisms driving evolutionary change of economic systems. It captures the interactions and feedback loops between two components within a given system over a certain period of time (e.g. Murman 2003). While co-evolution and multi-level theory have in common their concern for interaction effects among different interacting components and different levels respectively, co-*evolution* adds to this type of analysis the time dimension[2]. The last section will briefly sketch out some of the major dynamics of such interaction effects.

6.1 The co-evolution of structure and agency

Complexity theory (e.g. Kaufmann 1993) offers a fruitful starting point to address the co-evolution of structure and agency (Fuchs 2003). This relates to one of the fundamental explananda of evolutionary economic development, that is, the emergence and transformation of order. Even though in the course of economic development micro-diversity increases, economic systems do not tend to display higher levels of randomness. On the contrary, bifurcations, that is, discontinuous and radical changes to structure notwithstanding, economic systems display considerable stability with incremental, rather than radical variation (Saviotti 2009). Bifurcations are a consequence of the inherent propensity of socio-economic systems to transformation which has qualitative components giving rise to new types of entities and interactions as well as quantitative underpinnings, referring to growing efficiency and increasing micro-diversity, that is, an increasing number and heterogeneity of entities within economic systems (Saviotti 2010). Understanding how such micro-diversity is generated and how it co-evolves with its institutional selection environment is the central question a micro-theoretical perspective of multi-level systems of innovation (MMLS) seeks to address. Complexity theory offers at least two important processes by which such evolution takes place, that is, autocatalysis and the above described process of co-evolution.

Autocatalysis is a central concept from complexity theory that provides a meaningful explanation to processes by which small initial differences are scaled-up into macro-level phenomena (Padgett/Powell 2012). Autocatalysis refers to a cyclical concatenation of processes that engenders and stimulates growth of its constituent components until a certain threshold is reached (Ulanowicz 1997). In this process, autocatalysis promotes competition and selection in specific directions towards autocatalytic sets[3]. Originally, autocatalytic sets were used to describe chemical reaction networks that if provided with the required energy inputs would reproduce over time. These reproductions may be carried forward even in the event that some of its constituent components (e.g. network nodes) are removed by mechanisms of self-repair and resilience (Padgett/Powell 2012). Moreover, autocatalysis is not limited to a single loop, it "transfers its influence to the wider systemic environment via con-

[2] Co-evolution is itself a multi-level phenomenon (Cooke 2012); for instance, innovation system scholars have focused on the co-evolution of institutions and technologies (Nelson 1993), whereas business scholars have investigated the co-evolution of different levels of organizations (Klein/Kozlowski 2000). More recently, the co-evolutionary nature of network development (Doreian/Stokman 2005; Lewin/Volberda 1999; Volberda/Lewin 2003) and industries (Ter Wal/Boschma 2005; Kudic/Pyka/Günther 2012) as well as regional specificities of network evolution (Glückler 2007) have gained attention.

[3] Autocatalytic sets are defined as a "set of nodes and transformations in which all nodes are reconstructed through transformations among nodes in the set" (Padgett/Powell 2012: 8)

nections that exist among assemblages of autocatalytic loops" (Matutinovic 2005). Thus in economic systems autocatalytic sets refer to patterns at the micro-level (e.g. organizational capabilities) that by way of reproduction may become prolific over time thus generating and transforming meso- and macro-structures. With respect to the evolution of structure and agency, one of the principle problems emerging from this notion is connected to the processes by which micro-agents self-organize into self-replicating autocatalytic sets and how these sets co-evolve with institutional selection environments.

Evolutionary economic geography (e.g. Boschma/Martin) shows that variation at the meso-level plays an important intermediate role in generating and transforming institutional structure (Cooke 2012) by absorbing interregional knowledge spillovers (Giuliani 2005) and incrementally building regional knowledge bases as well as by disseminating novel combinations and endogenous resources (Bathelt/Malmberg/Maskell 2004) by the workings of a number of interacting heterogeneous micro-agents. Moreover, regional systems of innovation are conceptualized here as dynamic selection environments within and across which micro-agents engage in the competition for resources the outcome of which determines the creation and destruction of micro-diversity. In this process, the region's properties co-evolve with the deliberate attempts of micro-agents to modify meso-institutional environments (Essletzbichler/Rigby 2010). Indeed, these modifications must not be commensurate with incremental or radical transformations of structure, but may also relate to strategies of auto-protection locking regional economies into protracted periods of institutional stagnation (Grabher 1993). More generally, in the proposed framework, macro-institutional structure is thus conceptualized as an emergent property of autocatalytic micro-level processes which may be strongly mediated at the meso-level. This underscores the central position agency is afforded in the MMLS framework.

6.2 Central pillars of a micro-theoretical framework of MLS

We propose to conceptualize and empirically analyze agency as the highly varied organizational capabilities of micro-agents to generate and leverage resources and to adapt to evolving institutional selection environments. These capabilities are the outcome of micro-agents' knowledge bases and resources which may span organizational boundaries (networks) and may include higher-order latent institutional resources, that is, resources at the meso- and macro-level. Thus at the basis of the proposed model are micro-agents conceptualized as heterogeneous factors bundles with varying resources, strategies and absorptive capacities (Baum/Rowley 2008; Cohen/Levinthal 1990; Penrose 1959; March 1991) embedded into a direct environment comprising the ego-centered network of the focal firms as well as an intermediate meso-level shaped by sectoral (Malerba 2004) and regional systems of innovation (Cooke 1992) and a macro-level comprising the national institutional framework (Hall/Soskice 2001).

Rather than merely 'selecting' those kinds of organizational capabilities that fit a specific selection environment, institutional structure provides a specific set of what is here referred to as 'latent institutional resources' (cf. Murman 2003). 'Latent' denotes that these institutional resources are potentially available to micro-agents, that is, they are not accessible and interpretable to the same degree by all micro-agents as these exhibit heterogeneous capabilities in terms of transforming these resources into resource generating and leveraging mechanisms. Given the heterogeneity of organizational capabilities, micro-agents

may engage in networks to access complementary stocks of resources (Pyka/Küppers 2002). In doing so, micro-agents are contended to display the capacity of circumventing and adapting to impoverished institutional environments by modifying latent institutional resources and creating endogenous resource bundles. In this process, networks play an important role. These networks may be extremely clustered generating localised externalities which are conducive to the formation of highly idiosyncratic resource bundles not supported by the macro-institutional environment (Voelzkow 2007). Firms may also engage in institutional arbitrage by way of internationalizing their activities in highly dispersed networks providing functional equivalents of institutions (Ahrweiler/Gilbert/Pyka 2006) or combine both institutional arbitrage and local clustering (Bathelt/Malmberg/Maskell 2004).

More particularly, organizational capabilities are conceptualized as an outcome of the configuration of activities and resources across the focal firm's internal value chain as well as the properties and the management of the focal firm's network relations embedded in a specific network structure. On the interior resources relate to financial assets and the technological knowledge base as well as organizational competence referring to e.g. recruitment of qualified personnel and management capability. To leverage these resources, firms may draw on their relational exterior. Firms also display varying relational capabilities, that is, the ability to build and sustain relations with other firms (Dyer/Singh 1998). Moreover, the focal firm as well as the network nodes may pursue complementary or non-complementary proprietary as well as network strategies. With respect to the types of proprietary strategies firms pursue, a parsimonious distinction is made between exploration and exploitation (Lavie/Rosenkopf 2006; Levinthal/March 1993; March 1991). Exploration refers to "search, variation, risk taking, experimentation, play, flexibility, discovery, innovation" (March 1991: 71), whereas exploitation may be described by "refinement choice, production, efficiency, selection, implementation, execution" (ebd.). To safeguard survival, firms need to balance these activities both internally and within their networks (Lavie/Rosenkopf 2006). That is, micro-agents are conceptualized here as primarily interested in attaining these proprietary strategies, while network nodes may facilitate or constrain these attempts by providing complementary resources.

Balancing these activities requires the focal firm to build and sustain appropriate portfolios of relational ties and to capture promising network positions. Relational ties between the focal firm and network nodes represent the channels through which various types of resources may be exchanged (Hite 2008). These ties may have multidimensional properties (Hite 2003), which in turn may increase competitive advantage (Dyer/Singh 1998). To leverage proprietary strategies, focal firms and nodes may pursue varied network strategies (Baum/Rowley 2008; Doreian 2008). Drawing on Kudic et al. (2012), these network strategies may relate to progressive, moderate and conservative relational orientations, where progressive strategies refer to the rapid expansion of network ties to gain access to resources, while moderate strategies relate to more gradual expansion and conservative strategies aim at retaining the existing stock of resources.

The interplay of the firm, relational, node and network level create a complex and evolving network structure with specific properties (e.g. density, homophily) which in turn give rise to network trajectories (Kilduff/Tsai 2003). These trajectories are the outcome of the strategic orientation of

focal firms and network nodes at point t_0 which in turn impacts the type of cooperation options in the future at t_1 (Kudic/Pyka/Günther 2012). Jointly, behavioural patterns of focal firms and nodes give rise to specific patterns of network change[4] (Koka/Madhavan/Prescott 2006).

Moreover, organizational capabilities may be reproduced or modified over time via adapting firm-level, node- or network-level properties, that is, variables endogenous to networks. To illustrate this point consider for instance the evolution of a dyadic relation D_1 between a present (t_0) and future (t_1) point in time between the focal firm F_1 and the network node N_1 that provides specific sets of resources DR_1 to F_1 and DR_2 to network node N_1. While benefits derived from D_1 are distributed equally at the inception of the relation, for purposes of illustration, F_1 extracts larger relational rents as a result of F_1's superior absorptive capacity and relational capabilities. Moreover, although resources derived from DR_1 and DR_2 exhibit positive, albeit diminishing returns, upon reaching an inflection point IP_1 and IP_2 respectively the benefits obtained from DR_1 and DR_2 decline sharply in this exemplar. First, resource accumulation between t_0 and t_1 disproportionately increase resource stocks of F_1. However, upon reaching IP_1 it may be rational for F_1 to alter its relational tie to N_1, whereas N_1 may then still have an interest in the relation in view of the resource gained from DR_2. F_1 may decide to dissolve the relation. This in turn modifies network structure. Moreover, F_1 may not be aware of the changing nature of its relation to N_1 (Simon 1959) or deliberately choose to maintain its relation in view of switching costs. More generally, the focal firms' complex portfolio of discretely evolving relations impacts the amount of resources available for F_1, which in turn impacts network structure. These sets of resources must not necessarily be superior to the one at t_0. Indeed, it is widely accepted that network relations may become liabilities (Hagedoorn/Frankort 2008) and exhibit diminishing returns (Deeds/Hill 1996). However, the processes by which this takes place and how this relates to network structure remains less clear.

In the above described relation between F_1 and N_1, the changing quality of institutional selection environments may also play a central role as these changes may impact the level of latent institutional resources available for the focal firms' and network nodes' strategic action. For the sake of parsimony and in reference to Koka et al. (2006) as well as Hall and Soskice (2001), we distinguish between resource abundant and resource impoverished institutional environments (cf. Fig. 1). While resource abundance describes institutional environments that offer favourable bundles of latent institutional resource (e.g. access to finance, qualified labour) and thus hospitable conditions for growth, impoverished institutional environments provide limited amounts of resources and may thus inhibit growth. This raises the question whether and how micro-agents adapt their organizational capabilities and network relations to changing institutional selection environments (Saviotti 2009: 21) and how this affects network structure as well as performance (e.g. outputs such as innovation, revenues). The interrelation between institutional environments at multiple levels of innovation systems represents another central analytical dimension of the MMLS framework.

[4] These patterns of network change include expansion, churning, strengthening and shrinking.

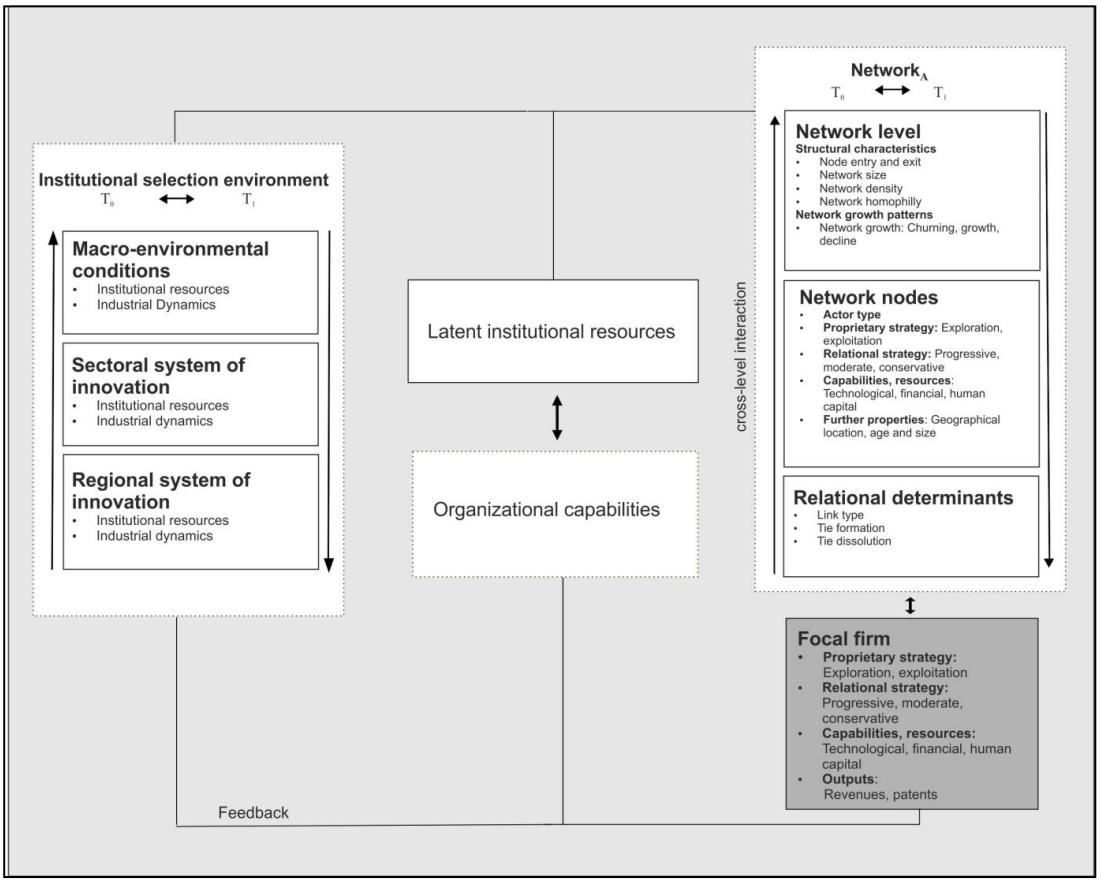

Figure 1: A framework for the analysis of the co-evolution of actors, networks and institutions

Drawing on Hite and Hesterly (2001) we thus seek to analyze the evolution of organizational capabilities embedded in inter-organizational networks as adaptation to changing resource requirements and resource acquisition challenges of the focal firm. Moreover, following these authors we conjecture here that resource challenges do not unidirectionally affect network evolution; network evolution also impacts the set of resources available to the firm in the future. That is, the relation between firms and their networks is co-evolutionary as is the relation between the focal firm and networks (Soda/Zaheer/Carlone 2008) as well as the institutional selection environment.

6.3 Cross-level effects

Having introduced some of the most relevant components of the proposed MMLS-perspective, the last section briefly turns to the expected cross-level effects that this framework seeks to address. One basic assumption underpinning multi-level theory is that understanding outcomes at one level of analysis requires researchers to account for the interrelations of this level with higher and lower levels of analysis (Kilduff/Tsai 2003). The directionality of interaction effects relates to top-down and bottom-up effects (e.g. Moliterno/Mahony 2011)[5]. Moreo-

[5] Due to space constraints, the notion of lateral interaction effects referring the interplay between entities within a single level, for instance, interaction effects

ver, these interaction effects may be self-reinforcing over time. For instance, Klein and Kozlowski (2000) argue that top-down effects at a certain point in time (t_0) may change the structure of lower levels, thus altering the magnitude of bottom-up effects at a later point in time (t_1). Over time this may cause self-reinforcing feedback loops (Arthur 1990) thus transforming small initial differences into macro-level transformations (Hite 2008: 136).

The most important cross-level effects are briefly sketched out here. Micro-level bottom-up effects refer to the interplay between the focal firm and network nodes. In this case, research may target the ways in which the focal firm leverages its resources across a dyadic tie to pursue its proprietary strategy addressing the question how this affects performance of both interacting parties as well as network structure. In turn, network structure and growth patterns emerge from the multitude of relational ties the focal firm builds and adapts. Conversely, a first-order top-down effect relates to the alterations to the network nodes' properties that may impact the focal firms' stock of resources. For instance, a change in the nodes' relational strategy from progressive to conservative may impact the amount of resources that are available for exchanges with the focal firm. The focal firm may then not be able to pursue its proprietary strategy requiring it to make a strategic decision in terms of amending its own relational strategy and acquiring new stocks of resources by way of changing its portfolio of network ties.

Higher-order top-down effects relate to meso- as well as macro-level top-down effects affecting F_1[6]. Both levels relate to the impact of industrial dynamics as well as the abundance or scarcity of latent institutional resources on F_1 and its $Network_{F1.}$ For instance, high levels of entry in turbulent sectoral environments may translate into a higher rate of network entries thus changing network properties such as size, density, homophily and growth patterns and ultimately the set of resources available for F_1. Moreover, an impoverished macro-institutional environment may have a bearing on the structure of $F_{1's}$ network, possibly causing pockets of network nodes in said network to atrophy. From a MMLS perspective, one of the fundamental questions in this context relates to the ability of the focal firm to adapt to these changing environments and reproduce its organizational capabilities embodied in its proprietary and network-based resource generating and exploiting mechanisms.

7 Conclusion

The starting point of this paper has been the insufficient treatment of micro-diversity and agency in the literature on the varieties of capitalism (Hall/Soskice 2001). The varieties framework theorizes economic actors as homogeneous entities thus adopting a highly-stylized and static perspective of economic development reducing the scope of individual manoeuvre as well as the inherent tendency towards change in socio-economic systems drastically (Prigogine/Nicolis 1989; Saviotti 2009). This is unsatisfactory inasmuch as innovative action, which may be seen as the "real expression and explanation of life force" (Cooke 2012: 5) as well as the central mechanism promoting adaptation and renewal of systemic structure, emerges from complex interactions of

among networks or among varied sectoral systems of innovation which are central to the notion of 'transversality' (Cooke 2012) cannot be addressed.

[6] For the sake of parsimony and to maintain coherence, this model does not refer to the interrelations between the macro- and meso-level. Moreover, questions concerning the bottom-up structuring of these respective levels cannot be taken into consideration here. These may be more adequately captured by simulation models.

heterogeneous agents at the micro-level embedded in innovation networks (Ahrweiler 2010; Pyka/Scharnhorst 2009). In search of an adequate analytical and conceptual framework that alleviates the tension between micro- and macro-analyses as well as static and evolutionary perspectives, networks were identified as the most promising candidate analytical device.

However, it has been argued that network approaches that focus primarily on structural elements to explain network evolution lack a convincing explanation of the mechanisms by which these structures come into existence and how they change. While these network analyses have engendered a variety of valuable insights, their constituent components have been analyzed as homogeneous entities thus replicating the above delineated structuralist determinism. For this reason, the analysis of agency in networks requires different analytical tools (Ahrweiler 2010). A recent review of some of the 'grand theories' of system change argues in a similar vein (Cooke 2012), that is, extant theoretical approaches including co-evolutionary transition theory (Geels 2004), resilience approaches (e.g. Folke 2006) as well as approaches in evolutionary economic geography (Boschma/Frenken 2003), lack explanatory power concerning the upward and downward causality of changing systemic properties as well as the micro-mechanisms that produce the fluctuations of aggregate variables and systemic structure.

This paper has sought to develop a tentative analytical framework that captures micro-diversity and agency on the one hand as well as incorporating processes at higher levels of aggregation on the other. It has been argued that agency and structure co-evolve generating as well as incrementally altering multi-level systems of innovation. While acknowledging the bearing of institutional forces on micro-agents, this framework relaxes the structuralist determinism of institutional analysis. Indeed, the main research interest of the proposed MMLS lies in unpacking the co-evolution of micro-diversity within multi-level systems of innovation. In this context, organizational capabilities play a central role. These capabilities may be embedded in network trajectories that are shaped by geographical factors (Glückler 2007) as well as institutional selection environments (Essletzbichler/Rigby 2010; Hall/Soskice 2001; Malerba 2004; Cooke 1992). This approach thus draws attention to the nonlinearity of the co-evolution of capabilities, networks and institutions, wherein organizational capabilities are emergent properties of firm-internal as well as latent resources available at the firms' exterior. The interplay between the firms' direct environment relating to its network relations and its more remote environment referring to the meso- (sectoral and regional systems of innovation) as well as the national institutional framework at the macro-level, is afforded an important position in this framework. To avoid deterministic interpretations of the resources provided by institutional structure, the notion of latent institutional resources directs the analytical focus towards the variegated sets of resources that are potentially available at different levels of innovation systems. In the competition for these resources, micro-agents exhibit heterogeneous capabilities. This in turn causes a considerable degree of heterogeneity at the micro-level. Moreover, as a means of survival micro-agents pursue varying proprietary and network strategies to build and sustain their resource generating and leveraging mechanisms in competitive environments. Micro-agents and their organizational capabilities as carriers of the competitive process (Saviotti/Noteboom 2000) thus co-evolve with institutional selection environments. The meso-level and in particular, regional systems of innovation,

may play a central role as selection environments and resource facilitators by jointly fostering the emergence of micro-diversity. Moreover, autocatalytic processes may turn micro-level differences into meso-structures and promote the transformation of entire systems.

Clearly, the framework outlined here is at its inception. With regards to methodology, in-depth comparative case studies (Eisenhardt 1989) may supplement quantitative ego-centered network analyses by providing detailed analyses of individual components of the framework sketched out here. For instance, these systematic case studies could address the evolution of a focal firm's proprietary and network strategy and its resource generating and leveraging mechanisms and their impact on network structure across different environmental settings. These analyses may provide very detailed information on the behavioural patterns of specific micro-agents which may elucidate the ample scope of strategic manoeuvre feeding into actor-based simulation models (Ahrweiler 2010).

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