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# Economic geography and the evolution of networks

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## Abstract

An evolutionary perspective on economic geography requires a dynamic understanding of change in networks. This article explores theories of network evolution for their use in geography and develops the conceptual framework of geographical network trajectories. It specifically assesses how tie selection constitutes the evolutionary process of retention and variation in network structure and how geography affects these mechanisms. Finally, a typology of regional network formations is used to discuss opportunities for innovation in and across regions.

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## 1. Introduction

The limited explanatory value of neoclassical growth theory to understand unequal rates of regional growth and the geographical agglomeration of innovation has inspired an evolutionary approach to economic geography (Boschma and Lambooy, 1999; Boschma and Frenken, 2006). An evolutionary take on economic geography is committed to the integration of growth and innovation theories and to endogenous explanations of regional economic development (Frenken and Boschma, 2007). The project is ambitious and far from being coherently established (Martin and Sunley, 2006; Essletzbichler and Rigby, 2007). While endogenous growth theory has advanced our understanding of sustained growth through the simultaneous production of new technologies and accumulation of knowledge (Romer, 1990)—geographers are interested in understanding how innovation is actually performed and why innovative practice often concentrates in geographical proximity. Interestingly, research on evolution in economics has attracted much attention to geography. A lot of the economic evidence on path dependence and lock-in has actually been exemplified in the context of geographic clusters and agglomeration economies (see Martin and Sunley, 2006 for illustrations of the argument).

One way of analyzing regional economic development is to look at the economy as interactions in networks. Economists have become increasingly receptive to social network concepts, since there is now plentiful evidence of the manifold ways in which social networks affect economic outcomes (Granovetter, 2005). Similar to evolutionary economics, social network theory often draws on regional clusters to study the conditions, outcomes and dynamics of network structure. More generally it seems,

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organization theory has discovered geography as a major contingency for organizational change (Owen-Smith and Powell, 2004; Freeman and Audia, 2006). In economic geography, networks have celebrated an exceptional career over many years and they have coined terminology in theories of geographical clusters, global cities, international production systems and globalization. Following a recent critical review, however, much of the use of networks in economic geography has been rather selective, often metaphorical and little formalized (Grabher, 2006).

This article is exploratory of the long neglected development of formal network theory and analysis in economic geography. It explores the only recently emerging research on network evolution (McPherson et al., 2001; Baum et al., 2003; Kilduff and Tsai, 2003) and aims at integrating concepts from network evolution with economic geography. This analysis has three objectives: first, to develop the concept of a geographical network trajectory which defines the evolutionary approach to network dynamics and which permits the study of network evolution in and across regions; second, to examine mechanisms of retention and variation in network structure which are endogenous to network evolution; and third, to assess models of variation in network trajectories with respect to regional innovation. The article argues that regional growth and innovation largely result from the bridging and brokering of unconnected networks or network clusters. After defining the basic concepts in section two, section three will discuss in detail the potential mechanisms which constitute the evolutionary principles of selection, retention and variation mechanisms (and in this sequence). It closes with a discussion of potential sources of innovation for regional growth.

## 2. Defining the elements of a geographical network trajectory

### 2.1. Evolution

There are at least two forms of change which are not evolutionary (Nelson, 1995): First, when change is random, future events are independent from previous events such that there are no inferences from a given course of development on the future. Second, when change is determined, the outcome of a certain development is also independent from the sequence of events. More radically, even, equilibrium theory determines a stable equilibrium which as a final outcome is both independent from the start conditions as well as from the sequence of events (Martin and Sunley, 2006). In contrast, change is evolutionary when future events are not independent from past events and when the sequence of events makes a difference for the outcome. Evolutionary change is a function of path-dependence and contingency. Path-dependence is a concept of cumulative causation in which a certain sequence of events creates unequal propensities for future events. Though path-dependent change allows for inferences from a present on future states of development, it is subject to contingency. Economic processes are at the same time contingent in that the agents' strategies and actions may deviate from existing development paths. Economic action in open systems is not ex-ante determined and cannot be predicted through universal spatial laws (Sayer, 2000). If evolution is neither random nor determined, the academic interest should focus on both, the mechanisms that create cumulative causation and lead to path-dependence and those mechanisms that produce contingency and lead to the emergence of new variety and potentially path destruction.

### 2.2. Network

Looking back at 20 years of research on networks in the social sciences there are all kinds of different conceptions and uses of the term. One irritating use of network occurs in the governance literature, for instance, where a strategic alliance between two firms is often referred to as a network. In the language of network theory a strategic alliance is a dyad or relation of a specific type, not yet a network. Moreover, institutional economists would object to call a market or a firm a network. However, network theory conceives all systems of interactions as networks, and would thus be able to study markets as networks (White, 1981; Baker, 1990) or firms as networks. This article subscribes to the basic understanding of a network put forward in one of the most widely cited definitions: a social network is 'a specific set of linkages among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behavior of the persons involved' (Mitchell, 1969, 2).

This definition has two important implications. First, it implies that relations rather than actors are in the focus of analysis and that the specific structure of relations may be used to draw inferences and expectations on individual and collective action (Mizruchi, 1994; Gulati, 1998). Structure is not conceived as something virtual, but as concrete social interaction. This view helps to bridge the dualism between structure and agency since structure is treated in such a way that it can be studied empirically and in direct association with economic interaction. Second, empirical networks are always socially constructed analytical reductions based on conceptual criteria (Marsden, 1990) such as pointed out in Mitchell's definition: the kind of relationship and the set of relevant actors. For the purpose of this article, the discussion focuses on networks as formal or informal relationships between individuals (e.g. entrepreneurs, employees) or organizations (e.g. firms, projects). Third, since a network so defined implies the same kind of relationship for each tie, analytical emphasis is put on the structural effects of network position on behavior and opportunity.

### 2.3. Geography

The relation between geography and networks can be theorized in (at least) two ways: First, *proximity affects network formation*. The most widely used approach in economic geography aims at assessing the latent effects of physical proximity/distance on economic processes. Sometimes these effects are abbreviated in unfortunate terms of 'spatial causation'. Space, however, is not a necessary cause of human action. Instead, there are at least two underlying social technologies implicit in any account of the geography of economic relations: communication technology (Storper and Venables, 2004) and transport technology (Marquis, 2003). Only with respect to the actors' communication preferences and mobility opportunities may the contingent relation between physical space and economic interaction be established. In other words: the constraints of proximity only rule if face-to-face is the only mode of communication and if travel is prohibitive. In any other case, proximity is contingent on the underlying social technologies.

Second, *place makes a difference*. Borrowing the notion of the resource bundle from the theory of the growth of the firm (Penrose, 1959), a place may be conceived as a bundle of resources and opportunities with the additional characteristic of spatial contiguity. A place-specific resource profile conveys a source of contextuality,

difference and contingency for economic development (Sayer, 1991; Bathelt and Glückler, 2005). This localized resource profile comprises the structural aspects of relationships (e.g. social capital, structural holes) as well as the material, social and institutional resources that these relationships access and transfer. The association between the region and the network is by no means unidirectional. Places do not only constrain network formation but social interaction in networks also shape its geography (Storper and Walker, 1989). Both views of geography matter in a concept of geographical network trajectory.

### 2.4. Geographical network trajectory

The essential starting point for any theory of network evolution is the question of 'how do structural dimensions of an interorganizational communication network at Time 1 affect the interactions among member organizations – specifically, their formation of ties to other organizations – at Time 2?' (Kenis and Knoke, 2002, 277–78). The network trajectory (Kilduff and Tsai, 2003) is an appropriate concept in the analysis of network evolution which combines the notions of evolution, network and geography: it describes a geographically and historically specific development path of a network in which the formation and dissolution of ties in earlier stages generates cumulative propensities for the formation and dissolution of ties in the future and in which the mechanisms of path-disruption and variation are endogenous. This perspective explicitly moves beyond the dyadic analysis of single relations to the analysis of entire networks of relations. A theory of network evolution, thus, looks at the changes that every new tie produces in the existing structure and, conversely, at the impact that the structure imposes on the formation of the next tie. Note that the unit of analysis is always *dyadic* tie formation, whereas the object of knowledge is *network structure*.

Any evolutionary system may be characterized by the principles of selection, retention (continuity) and variation (Nelson and Winter, 2002). The next section discusses these principles in the context of networks. After defining the *selection* principle of relationships, the effects of retention and variation of tie formation are discussed in more detail. *Retention* focuses on those cumulative structural mechanisms that cause new ties to reproduce and reinforce an existing network structure. Path-dependence is only half the story. Similar to earlier efforts (Boschma and Lambooy, 1999), this article explores *variation* as a set of mechanisms that enables novelty and path-disruption. An evolutionary theory which is interested in an endogenous understanding of the production of variety needs to go beyond the exogenous assumption of variety by random or chance events. Instead, this article emphasizes the process of endogenous network *variation* to explain the emergence of novelty from existing paths. Finally, this article aims at exploring the contribution of network evolution to an evolutionary economic geography. Complying with the discussion above, the geography of network trajectories may be inquired in two respects: one is to examine the latent effect of geography on the network trajectory; the other is to explore the effect of localized network evolution on regional innovation. The following section explores in more detail the nature of the selection mechanism in inter-firm networks, as well as the role of geography in processes of network retention and variation.

## 3. The evolutionary process in the geographical network trajectory

### 3.1. Selection: competitive selection of relational advantage

Selection mechanisms are often attributed to the environment. While in biology the natural environment selects biological fitness (natural selection), in evolutionary economics it is market competition that selects firms (competitive selection), correspondingly (Knudsen, 2002). Since, in the context of networks, selection refers to the formation of linkages between members of a network (Gulati, 1995; Stuart, 1998; Gulati and Gargiulo, 1999; Ahuja, 2000; Venkatraman and Lee, 2004), a number of particular conditions seem to require a revised notion of the selection principle.

First, in contrast to the selection of firms, routines or technologies, which are *entities*, the linkages in a network are *relations* between pairs of actors. This has an important consequence, namely, that the selection of a tie is subject not only to an external selective environment, but also to the decisions of the mutual members involved. This implies a dual conceptualization of selection mechanisms. Selection may be a function of exogenous change with respect to the degree of adaptation of relationships but also a function of endogenous incentives and strategies to choose and change relations by both parties involved in a relationship.

Second, new relationships may occur between incumbent firms which have a history of linkages in the network or new firms without any previous relationship. A complete theory of network evolution would thus have to theorize both, the emergence and disappearance of ties *and* nodes. This article focuses on the dynamics of relationships and makes selective reference to the interrelation with the dynamics of node entries and exits.

Third, interaction is costly and as such a scarce resource. This article treats tie selection as a problem of the efficient allocation of relationships because empirical networks of firms are impossible to be fully connected. The law of *N*-squared states that the number of possible contacts increases roughly as the square of the number of actors in a network (Krackhardt, 1994). In other words: 'most choices are impossible for most people' (McPherson et al., 1992, 168). Though the number of potential relations depends on the actors' resource endowment and the kind of relationship, there is always a limit to a firm's capacity to relate with other firms.

Fourth, from a utility perspective, a firm's set of connections may yield differential returns on the invested relationships. One of the key motives to engage in enduring relationships with other firms is to access external resources (Pfeffer and Salancik, 1978). This, in turn, increases or decreases a firm's attractiveness for future alliance partners. Tie selection may then be conceived as the competitive allocation of scarce relationships where the commitment dedicated to one relationship invokes opportunity costs for each unrealized contact. These conditions suggest tie selection to be a competitive process which depends on exogenous changes as well as endogenous dynamics. To give an example: a relationship between two firms may be more attractive because of exogenous changes (e.g. market regulation) but also because of endogenous changes in the network (e.g. one partner has become more attractive because of her alliance with a third party). While many evolutionary approaches stop at the exogenous factor, this article explicitly seeks to explore endogenous mechanisms of network evolution that produce retention and variation of existing network structures.

### 3.2. Retention: place-dependence and network trajectory

Network retention refers to the structural effect of past choices on the propensities for future tie selection within the network. Retention mechanisms result either from the persistence of ties, that is, slow decay, or the path-dependent formation of new ties. Research on the decay of personal relationships between employees suggests that relationships last longer, the more prominent employees are in the social hierarchy, the more similar their work, and the stronger their relations are. Following Burt, decay is a power function of time in which the probability of decay decreases with tie age and node age (Burt, 2000, 23). A review of the organizational literature on networks suggests, more generally, that homophily is a significant driver of tie selection and retention (McPherson et al., 2001; Sorenson, 2003). While studies on the decay of existing relationships ask how long a given tie will sustain, another approach is to ask where the next tie will most likely emerge. A network might experience a massive turnover of decaying and emerging linkages between its nodes and still display the same degree of centralization, density and fragmentation. Whenever new ties replicate or reinforce a given network structure this indicates the operation of path-dependence. From the organization literature, three alternative mechanisms are particularly interesting:

First, the *preferential attachment*-hypothesis expects firms with many ties at one point in time are more likely to receive new ties in the future than those with fewer ties (Barabási and Reka, 1999). There is obviously accumulative advantage for well positioned actors on the one side and a liability of unconnectedness for peripheral actors on the other (Powell et al., 1996). The concept is based on the observation that the degree distribution of a network is scale-free, i.e. follows a power-law (Barabási et al., 2002). Empirical research supports this hypothesis. The alliance behavior of multinational corporations suggests that with increasing experience and connectedness, firms will be more likely to have further alliances in the future (Gulati, 1999). However, since firms are limited in the number of relationships they can maintain, the process of centralization of ties is empirically finite (Holme et al., 2004). Second, the *embedding*-hypothesis expects that future ties form around strong ties by processes of trust and indirect referrals. This cumulative interconnection leads to processes of social embedding (Gulati and Gargiulo, 1999). Persistent network structures emerge from cognitive embeddedness and the formation of mental models within clique-like groups of interconnected actors (Baum et al., 2003). Third, the *multi-connectivity*-hypothesis expects that networks expand through a process in which firms seek diversity of relations and form multiple independent paths among each other to enhance a multiple reachability of partners. In an exemplary study, Powell et al. (2005) are amongst the first to explicitly test alternative hypotheses on the emergence of new relationships in an expanding network of inter-firm alliances in US biotechnology. Their research supports the cumulative advantage of multi-connectivity and demonstrates that new alliances were more likely to form between those firms that were more multiply or more diversely linked to each other at a previous stage (Powell et al., 2005). Following this evidence, new linkages reinforce an existing multiple cohesion and, over time, cohesive subgroups will emerge. Another empirical analysis of the alliance network in biotechnology corroborates the operation of retention mechanisms (Walker et al., 1997). A year-to-year comparison of structural equivalence for each pair of actors showed that if two firms were structurally equivalent, i.e. they were connected to the same other

companies, they most likely remained so throughout the subsequent expansion of the network. This finding leads Walker et al. (1997) to argue for path dependence in network growth. In sum, preferential attachment, embedding and multi-connectivity are cumulative retention mechanisms that induce path-dependence in networks. Network retention mechanisms do not operate independent of geography. Geographical location is a non-relational condition that may strongly affect the evolution of the network trajectory. Two classes of processes are important for place-dependent effects on the network trajectory: local externalities of communication and organizational inertia:

#### *3.2.1. Local externalities of communication*

Externalities of communication render additional local ties more likely than the formation of extra-regional relations. (Stuart, 1998; Sorenson and Stuart, 2001; Powell et al., 2002). Geographical proximity is, of course, a matter of scale: two firms may be co-located in the same office building but also in the same country. The empirical impact of co-location, however, is often limited to the regional level where repeated face-to-face communication is not prohibitive. Powell et al. (2005), for instance, found unequivocal evidence for a strong geographical bias on strategic alliances in biotechnology. New ties as well as repeat ties were more likely when two firms were co-located. Another study on the same sector emphasizes the role of knowledge spillovers in local firm alliances and found that co-location and local membership in the network compensates for the lack of centrality of a firm's position in the alliance network (Owen-Smith and Powell, 2004). 'Being there' compensates for the disadvantage of low centrality. Information spillovers which are typical of serendipitous networks provide cumulative advantage for co-location and cluster growth in technology and knowledge-intensive industries. The notion of local network retention is further supported by empirical evidence for local entrepreneurial relationships to become more persistent and beneficial after start-up than more remote relations (Schutjens and Stam, 2003). One explanation for this effect is the mechanism of local institutionalization. Doreian and Woodard (1999) identified networks in which extra-local forms of institutionalizing relations were not duplicated but local relations institutionalized into network structures dedicated to the same pool of clients.

Geographical proximity also affects the entry of nodes in a network. In addition to the cumulative formation of local ties in response to communication externalities, relocation mechanisms further enhance place-dependent agglomeration. Since the difficulty of accurate transmission and interpretation of knowledge increases with its complexity, spatial proximity often locks-out remote actors from the knowledge flow and thus forces them to (re-) locate in spatial proximity in order to participate in the cluster communication (Fleming and Sorenson, 2001). Empirical research illustrates that the more complex the knowledge in a particular industry, the more do industries agglomerate (Sorenson, 2005). Since the propensity to get in contact with someone is very low but increases with spatial proximity (McPherson et al., 1992), regions with cumulative locational advantage might select talent and knowledge by migration and relocation. These findings indicate that networks do not only evolve in terms of the geographical mobility of existing relationships but also in terms of entries and exits of nodes (firms). Entrepreneurship, new firm foundations and spin-offs (node entry) are

also an important element of local network retention. Finally, geography is also a significant constraint on search behavior: when people need intermediate contacts to reach a (socially) remote target, they choose contacts in geographical proximity of this target to transfer information (Dodds et al., 2003).

#### *3.2.2. Organizational inertia*

According to the theory of organizational inertia the change of core features in organizations requires adaptive cascading processes of reorganization which expose organizations at a higher risk of unfitness and mortality (Hannan et al., 2004). If this is applied to the alliance behavior of firms, some degree of persistence in previous network structures can be inferred (Li and Rowley, 2002). Institutions may persist because they favor distributional claims on resources of those who exert the power to maintain institutions. This resistance to change may be transferred through the network when certain actors exert relational power upon others to prevent certain types of new ties. Moreover, the interrelatedness of institutions may render the costs of changing one out of a set of institutions prohibitive (Frankel, 1955). There is an illustrative evidence for retention mechanisms on networks in a geographical perspective. Marquis (2003) compared the development of the largest urban community systems of interlocking directorships in the US. He demonstrates that the business networks in cities established prior to the advent of air travel technology were significantly more locally bound than networks in younger cities. Despite the availability of modern travel technologies in all cities today, even new corporate board positions were filled with local directors. This persistence of geographical network structure in older communities illustrates the basic argument of imprinting theory (Stinchcombe, 1965): organizations adopt organizational characteristics in response to the environmental conditions during their period of foundation. This imprinted pattern sustains through the evolution even if in later periods the environment changes. Since the social technology of large distance travel was not available before air transport, local business communities were constrained to assign local directors on their corporate boards. This imprinted practice constitutes a 'locally legitimate template of action' (Marquis, 2003, 656) which is continuously emulated and thus preserves network structure over time. Social networks between individual economic actors as well as between firms convey aspects of cumulative, path-dependent evolution over time. The sum of these retention mechanisms may ultimately lead to situations of local lock-in (Hassink, 2005; Martin and Sunley, 2006), in which previously selected patterns of relations are preserved to a degree that new alternatives are prohibitive or do not enter the network. States of lock-in are a problem which can only be overcome by a continuous momentum of contingency and the emergence of new variation.

### 3.3. Variation: path-destruction and the structural sources of innovation

A comparison over a large number of different empirical inter-firm networks conveys an intriguing observation: inter-firm networks often look the same. They display evident patterns of small worlds which are essentially characterized by high local clustering and short global separation (Watts, 1999) and display a high degree of robustness (Kogut and Walker, 2001). This observation provokes the question if there is a possibility for network trajectories to experience variation endogenously.

In Darwinian terms, variation is defined as a random mutation process which fundamentally treats novelty as an exogenous circumstance. The study of the economy, however, is dedicated to the exploration of mechanisms that generate novelty and new development paths. Hence, variation should be conceived as the result of endogenous mechanisms of network formation and dissolution. In the organization literature, the major source of contingency and variation in network structure is the bridging of unconnected network clusters. Variation in a network refers to the differential selection of new ties which countervail against an existing trajectory. Hence, variation is defined at the level of tie selection but refers to the change in network structure.

Tie selection affects the flow and recombination of resources in the network. Knowledge, preferences and routines enter a cluster of interconnected actors through the bridging of structural holes between unconnected clusters (Burt, 2004). Whether this new variety is selected into a local cluster depends on processes of adoption and adaptation. Empirical research in the context of the social composition of voluntary groups found that when group members maintained ties to non-members they were likely to leave the group whereas ties within the group and the size of the group increased the likelihood for enduring membership in that group (McPherson et al., 1992). In short: a link outside the group shortens membership duration in the group. It is this contingency of establishing boundary spanning relations which renders variation inherently likely in any open system of social and economic relations. Empirically, there seems to be a tendency for some new relations to bridge a network cluster which essentially countervails the retention mechanisms outlined above. In the context of firms, empirical evidence suggests that strategic alliance behavior shifts from socially embedded, cohesive or 'identity-based networks' in early stages of firm emergence to more sparse, rationally managed or 'calculative networks' in later stages (Hite and Hesterly, 2001; Baum et al., 2003; Lavie 2004). This process offers relational variation and the possibility to channel novelty in the established small worlds. At the same time and once a bridge is established, the cumulative retention mechanisms of preferential attachment, embedding and multi-connectivity increase the odds for further external links and thus counter existing patterns of path-dependence.

But who bridges the cliques: the core or the periphery of a cluster? In a longitudinal analysis of the evolving Canadian investment bank syndicate network, peripheral firms were found to be more likely to span clique boundaries than core firms (Baum et al., 2003; Rowley et al., 2005). This finding may be interpreted in the language of competitive tie selection: retention mechanisms cumulate into embedded social structure and favor early advantage of some actors who become core players in their small worlds. Over time, however, peripheral players aim at improving their competitive position by spanning small worlds and by sourcing otherwise unconnected clusters within the overall network. Notwithstanding, the evolutionary occurrence of boundary-spanning ties is to a considerable degree also subject to chance events (Baum et al., 2003). Networks are topological associations between actors without an inherent geography. Strong ties may be distant or local as well as clique-spanning may be remote or close by. In order to avoid an implicit dualism of strong-local ties and weak-global linkages, Figure 1 illustrates some of the potential geographies of network topologies and their specific variation opportunities. In a geographical perspective, then, there are three different concepts of (permanent) geographical place and one concept of temporary place with specific opportunities to convey variation during network evolution.

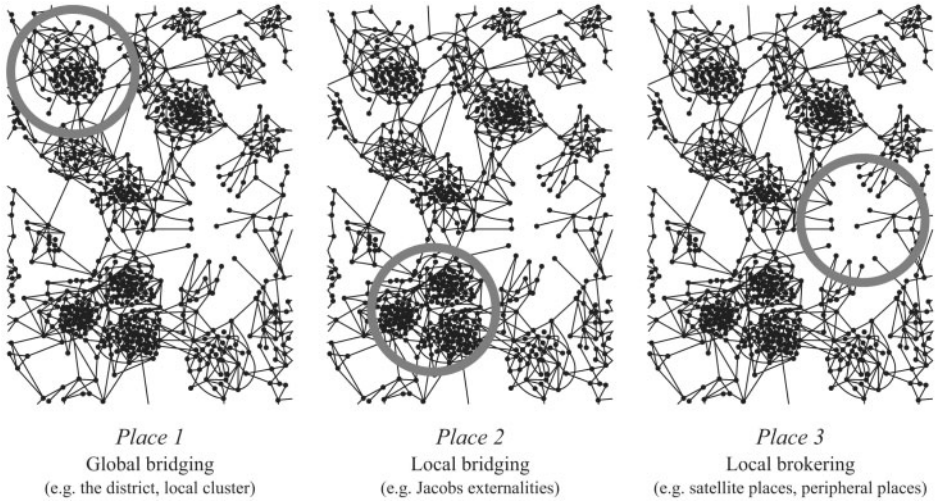


**Figure 1.** Alternative geographies of small world topologies.

### *3.3.1. Global bridging*

The default of innovation in regional clusters is the notion of a densely connected localized inter-firm network which generates variation by establishing bridges to extra-regional network clusters in search of new knowledge and complimentary resources. This notion is well documented in the literature on neo-Marshallian nodes (Amin and Thrift, 1992) which combines Marshall's logic of a local division of labor with non-local exchange relations forward and backward the value chain. Research on the global interrelations of the Londoner media industry, for instance, has illustrated empirically, that firm networks sustain innovative potential by economizing on local proximity and selective access to knowledge external to the urban cluster (Nachum and Keeble, 2003). The logic of local clustering and global bridging is also implicit in the literature on global cities. Generating variation by sourcing extra-regional assets through boundary spanning ties thus corresponds with the illustration of place 1 (Figure 1). If the regional economy is dominated by just one interconnected cluster, variation through external linkages becomes crucial to avoid technological lock-in and subsequent economic decline.

### *3.3.2. Local bridging*

Another possibility is the bridging between different but co-located network clusters as represented by place 2 (Figure 1). Local bridging corresponds with notions of the learning region and endogenous regional development (Hassink, 2005), where variation is generated by recombination and interconnection between distinct clusters of relations. The range and scope of variation largely depends on the degree of local diversity of network clusters. This perspective fits with the notion that cities are conducive to innovation because of local variety (Jacobs, 1969). Urban variety increases the serendipity for spillover-effects between industries or subclusters of networks and enhances regional growth (Glaeser et al., 1992). However, novelty may not only result from the bridging of unconnected parts *within* but also *between* different networks.

In early organizational ecology and contingency approaches, network change is seen as an adaptive process responding to exogenous environmental change (Lomi et al., 2005; Koka et al., 2006). In contrast, community ecology approaches (Freeman and Audia, 2006) surmount the network-environment dualism by conceiving a more systemic framework of an ecology of networks (Carley, 1999). A view of the network ecology permits to analyze the recursive feedback loops between a set of interrelated networks as a co-evolutionary process, i.e. evolutionary changes in one network affect the direction of evolutionary change in interrelated networks which together form ecological community. A perspective of a region as a localized ecological community allows for an understanding of innovation as the contingent interaction and causal feedbacks between social networks and their material and institutional resource endowment, as for example, in the concept of the localized creative field (Scott, 2006). Geographers should, however, not fall into the trap of limiting their focus on the region and the local community. A recent analysis emphasizes the need to study the interplay between community and the wider institutional foundations of (non-local) society to understand real regional economic change (Rodríguez-Pose and Storper, 2006). Strategically, the long-term sustainability of regional network trajectories can be enhanced by supporting diversity. Following the principle of 'compartmentalization' (Grabher and Stark, 1997) the co-existence of distinct networks or subclusters offers future options for bridging and recombination.

### *3.3.3. Local brokering*

In a third perspective, one may conceive only the weak ties to be co-located while the linkages in a topological cluster are all geographically separated (cf. place 3 in Figure 1). In the case of network peripherals that are geographically co-located, the interlocking of these weak ties may yield maximum variation because of the higher degree of diversity in the pool of knowledge and other resources of the local firms. The local brokering of separated and diverse network clusters may thus convey a real novel recombination of knowledge. Empirical examples are the so-called satellite platforms (Markusen, 1996) where multinational firms co-locate to benefit from territorially bounded location advantages (e.g. tax conditions, state subsidies, expertise). While these firms are well connected internationally, they often remain isolated from each other in the satellite location. Though this geographical network formation may have been regarded exceptional, it has certainly gained prominence in the global economy. On the one hand, there are high technology research and development activities that multinational competitors assign to global centers of excellence in close geographical proximity to each other (Zeller, 2004). On the other hand, the global offshoring of manufacturing and increasingly of services creates new satellite places where multinational corporations co-locate specialized business processes (UNCTAD, 2004). The agglomeration of similar activities at these peripheral places offers opportunities for innovation through the local brokering between the operations. Learning from offshore operations might become indispensable in the future, when new processes and standards are developed there. In addition, peripheral satellite places may be appropriate locations to filter contested innovation into multinational organizations. An interesting series of computer simulations supports a viscosity model of innovation (McGrath and Krackhardt, 2003): controversial innovation may be more likely to

diffuse successfully across a network when seeded in the periphery of an organization and when the organization is only loosely connected.

#### *3.3.4. Mobile brokering*

Geographical proximity is often conceived under conditions of permanent location. However, changing travel technologies and induced patterns of mobility also permit co-presence in ephemeral encounters. A final way of generating novelty and variation in tie selection breaks with the notion of fixed locations and assumes a network cluster of interconnected firms (or firm managers) to be geographically distributed and who meet repeatedly in temporary clusters, i.e. trade fairs, conventions or other arrangements of physical encounter. The more mobile managers become the more likely are they to find non-fixed, temporary contexts of mutual encounter and serendipitous tie formation. The concepts of 'ba' (Nonaka and Konno, 1998) or temporary clusters (Maskell et al., 2004) illustrate the notion that face-to-face communication, networking and interpersonal referrals are equally facilitated in trade fairs and conventions as in contexts of permanent co-location. The extending international mobility of business will certainly spawn new opportunities for tie formation which countervail against the traditional mode of permanent locational proximity. In the movie industry, for instance, producers and studios participate in film festivals around the globe on repeated annual travel and thus come close to form a transnational community. While a core of actors may be well connected among each other, each place offers new opportunities to bridge and broker the core with local but yet unconnected firms. Bridging relations in these ba-forms of temporary encounter are serendipitous and thus highly contingent on the actual place. As networks increasingly stretch space and form permanent and temporary trans-local networks, the mapping of these relationships is anything but a trivial geometrical task. Since this concept abandons the geometry of fixed location it can no longer be represented in a static map.

## 4. Conclusion

Evolutionary network change is subject to cumulative mechanisms of retention which create path-dependent network trajectories. Apart from the established types of path-dependence discussed in the literature (i.e. technological lock-in, increasing returns to scale and institutional hysteresis, cf. Martin and Sunley, 2006), the emerging literature on network evolution suggests additional network-specific mechanisms. Preferential attachment, embedding and multi-connectivity also induce path-dependence in inter-firm relationships. Moreover, and instead of simply presuming novelty, an appropriate evolutionary theory of economic growth should be able to explain innovation endogenously. This article has not only looked at the path-creating effects of tie selection but also on its path-disrupting effects. Network variation results from the process of bridging and brokering between unconnected networks or parts of networks. A recombination of network topology with geometrical place has offered alternative models of innovation in regional economic development.

Given the recency and simultaneity of evolutionary theory in economics, organization studies, sociology and geography, this article can only be explorative at this stage. Rather than supplying a coherent theory of regional network evolution, above all, it is lead by a strong curiosity for the benefit that formal network theory offers to an

evolutionary perspective in economic geography. A fruitful application of network evolution to economic geography depends on both conceptual and empirical advance with respect to a number of questions. Network structure, for example, is not an end but a means of facilitating economic growth and innovation. It represents the architecture through which productive resources, social values and economic interests circulate. Therefore, the nexus between structure and the actual content of the flows merits particular attention in future research, as for example the role of technological overlap between firms (Cantner and Graf, 2006) or firm-specific aspects of integration in a network (Giuliani, 2006). Moreover, network structure should not be conceived as deterministic. More research is needed to find out about the drivers and effects of boundary spanning activities at the micro level: why do which firms bridge network gaps and what are the real effects for them and for the network structure as a whole? Another research challenge addresses the role of place as context for network evolution. Apart from the endogenous mechanisms of retention and variation, environmental changes may alter crucial conditions. How, for instance, do changes or differences in the institutional arena of a locality affect network evolution? Since institutions such as conventions and routines define the rules of interaction they certainly influence the trajectory of inter-firm networks (Maskell and Malmberg, 2007). Finally, network evolution is a complex matter because both, relationships *and* nodes may emerge or disappear simultaneously. While current network theory prioritizes tie formation, the causes and consequences of changes in network size should also be addressed. Geographical cluster theory suggests that regional agglomeration enhances the rate of firm foundation, spin-offs and relocation. So what is the causality and direction of the relationship between a path-dependent network trajectory and the growth rate of new nodes? Apart from this brief selection of empirical research questions, there are considerable practical problems to be overcome. Relational data are only scarcely available for industries, organizations and regions. An evolutionary analysis of network change in and through regional development requires not only relational but also longitudinal data over considerable time periods which are even more difficult to obtain (Baum et al., 2003). Network evolution is still in its infancy and the project is in search for innovative ideas and methods—isn't this a good time for geography to join?

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