Networks in the Innovation Process

26

Emmanouil Tranos

Contents

Abstract

This chapter reviews the importance of networks in the innovation process from a spatial perspective. Such networks are part of different scale systems of innovation and are essential to the creation of knowledge externalities. It is well established in the extant literature that innovation does not occur in isolation, and furthermore, interorganizational networks facilitate innovation creation. Social networks, trust, and local embeddedness play key roles in the formation of such networks. In addition, relational perspectives, such as non-geographical proximities, are also vital factors for the creation of innovation networks, the main objective of which is knowledge creation. Important enough, the latter can be approached as crucial production factor in the frame of the knowledge economy. Moreover, scale is an important attribute of such networks, as both local and global links are important in the innovation process.

E. Tranos
Department of Spatial Economics, VU University, Amsterdam, The Netherlands
e-mail: e.tranos@vu.nl

M.M. Fischer, P. Nijkamp (eds.), *Handbook of Regional Science*,
DOI 10.1007/978-3-642-23430-9_24,

26.1 Introduction

This chapter aims to review the importance of network formations in the innovation process adopting a spatial perspective. The starting point for this journey is the systemic understanding of the innovation process: innovation does not occur in isolation but is the outcome of systemic interactions among various actors. The spatiality of such systems of innovation (SI) and more specifically networks of innovation is the main focus of this chapter. Unavoidably, such an analysis is underpinned to some extent by evolutionary processes, which capture the change of organizations, institutions, and their ties over time. Importantly, SI highlight the role of interactions between actors in the innovation process and the related feedback mechanisms. Thus, innovation activity is a collective process, which is based on actors interacting together to transfer, exchange, and create knowledge (Edquist 1997). Such knowledge is a necessary input for the *innovation* production. It needs to be stressed here that despite the great interest from academics and policy makers in understanding the mechanisms behind innovation creation, there is still not a commonly accepted definition for innovation. For the needs of this chapter, the following definition is adopted: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method inbusiness practices, workplace organization or external relations" (OECD and Eurostat 2005, p. 46).

The systemic understanding of the innovation process was initiated by the introduction of the concept of national innovation systems (NIS). Pioneers in this conceptual formation were Christopher Freeman and Bengt-Åke Lundval, who introduced the idea that different innovation actors are linked together forming a knowledge exchange network structure. Such a systemic understanding of innovation is based on three components: (a) the actors of the innovation system, which are private (individuals and firms) and public organizations (universities or state authorities), the affiliation of which with the SI defines the boundaries of the system; (b) the relations and interactions among these actors for knowledge creation and diffusion; and (c) the attributes of the actors.

Soon after the systemic view on innovation was established, this approach was then transferred to a regional scale known as the regional innovation system (RIS) (Cooke 1992). This scalar change came as a response to empirical evidences that innovative activity is neither uniformly nor randomly distributed across geographical space. The main explanation is that knowledge, especially tacit – that is, the non-codified part of knowledge – can only be transferred via face-to-face interactions and within an atmosphere of trust. Thus, geographical proximity can act as a facilitator for the innovation production. However, as it will be highlighted later in this chapter, geography is not the only proximity dimension useful in this context. During 1990s, the RIS concept was developed as an analytical framework for policy makers and academic researchers to understand the innovation process in regional economies (Cooke 1992). RIS focuses on interactive networks of nodes and linkages on a regional scale to understand a city or region's innovation performance. Thus, the spatiality of interactions among innovation actors becomes an important element of the innovation production.

The last point leads the discussion to the core of this chapter. Innovation is a systemic process, which is facilitated by networks of actors. The latter is a systemic representation of interactions among innovation actors. However, such systems are anything but *a*-spatial as spatial and territorial dynamics facilitate interactions and directly affect innovation actors. After analyzing the systemic nature of innovation in the introduction section, this chapter then focuses on further understanding innovation networks. Then, Sect. 26.3 highlights the importance of networks in knowledge creation and in the frame of the knowledge economy. Sect. 26.4 focuses on the impact of different proximities in network formations, and Sect. 26.5 reviews the main current methodological challenges in modeling spatial innovation networks. Finally, the chapter ends with a conclusion section.

26.2 Networks and Associated Concepts

Owing to Cooke and Morgan's (1993) seminal work on the network paradigm, the importance of networks in regional economic growth is well established among academics and practitioners. Although the starting point was limited to the micro-scale, the spatiality of such links gained importance over time. Initially the focus was on interfirm links, usually representing buyer–supplier relationships. The dominant economic school of thought, grouped here for simplicity reasons under the term mainstream economics, incorporated space as "transaction cost." Thus, proximity, mostly in terms of geographic proximity among actors of local production systems, can result in transaction cost reduction. Such a proximity effect decreases the locational disadvantage of peripheral, but still agglomerated regions when compared with the core urban areas, which represent the nodal points of the Fordist production system. A similar effect can be generated by the so-called Marshallian externalities. According to Alfred Marshall's argumentation on an *industrial atmosphere*, small and agglomerated firms in *industrial districts* can benefit by scale economies and the resulted cost decrease in human capital training, information and knowledge sharing, and the collective use of infrastructure (Marshall 1927).

However, the introduction of the *innovative milieu* concept by the French group GREMI (Groupement de Recherche Europeen sur les Milieux Innovateurs) turned the interest to more dynamic and territorially embedded conceptualizations of the innovation production. Indeed, proximity is in the center of the discussion around innovation production, not only because it decreases transaction costs, usually expressed in the form of transportation cost, but mostly because it eases information exchange usually through frequent face-to-face interactions and cultural similarity.

In more detail, there are two main characteristics of an innovative milieu. Firstly, a milieu, in order to enhance the innovation production, needs to be characterized by a *collective learning process*. Such an attribute improves local creativity, technological development, and adaptation and, in total, supports the innovation production. Secondly and in the same spirit, a local milieu reduces uncertainty as it enables a better understanding of firms' decisions given the easiness it provides in interpreting technological transformation (Camagni 1991).

At the same time, Porter (1990) introduced the notion of *clusters* and defined it as a group of interconnected companies from more than one industry and the related institutions, which are all located in geographic proximity. The notion of the industrial district differs from the regional cluster as the latter mostly consists of firms from the same or related industries as well as supporting institutions. Although he did not explicitly focus on networks, the distinctive point of his conceptual proposition was the interconnectedness of regional actors and how such network-like structures can benefit firms. The mechanism behind this argument is summed up by the following: once a specialized industrial cluster is formed, then demand for suppliers and other supporting services is generated. This demand acts as an incentive for suppliers and service producer firms to locate within the cluster to take advantage of the emerging economies of scale and the lower transaction and transportation costs. Consequently, dense transaction linkages should be expected within a cluster (Bathelt et al. 2004).

In total, various closely or less closely related concepts have been introduced in the new regionalism tradition including, apart from the innovative milieu and Porter's cluster notion, concepts such as local knowledge communities and learning regions. Even when the discussion moves to older conceptualizations such as Marshallian industrial districts, an important element for the success both of the firm and the district is the density of social networks among organizations. In both conceptualizations of local and regional networks, economic and social relations play a key role in innovation facilitation.

Therefore, given the wide acceptance of the above conceptualization, the spatiality of networks between actors came to the forefront of academic research, and in addition, such a network framework was further expanded to include non-firm actors. Examples include links between firms and other noncommercial organizations such as universities, research institutes, technology transfer agencies, and regional and governance bodies. Despite the different conceptualizations found in the literature, there are some common characteristics in respect to the mechanisms related with spatial innovation network formation (Giuliani 2011):

- Market relationships or *traded interdependencies* using Storper's (1997) terminology. Such networks are formed utilizing market mechanisms, and examples include user-producer links, spin-off companies, and highly skilled human capital mobility. Spatial proximity is an important facilitator of knowledge and most importantly tacit knowledge exchange.
- Social ties or *untraded interdependencies* (Storper 1997). More often than not, interpersonal networks provide the necessary basis to build market linkages. Examples include the importance of social relationships in the formation of

Italian industrial districts as well as their role in the success of Silicon Valley (Saxenian 1994).

- Policy-driven ties, which are the outcome of specifically designed (usually regional) policies, the main objective of which is to enhance the density of local interorganizational ties. The policy-related discussion around RIS tends to include such measures.

Despite the growing interest on networks, the relevant literature is still missing a universally accepted definition. As a summary of the above discussion, Tijssen's (1998, p. 792) definition is adopted here. According to him, a network is

> an evolving mutual dependency system based on resource relationships in which their systemic character is the outcome of interactions, processes, procedures and institutionalization. Activities within such a network involve the creation, combination, exchange, transformation, absorption and exploitation of resources within a wide range of formal and informal relationships.

The discussion around networks is usually related with interfirm interactions. Firms benefit by participating in such regional innovation networks. Firstly, firms profit from the informal exchange of resources including knowledge and know-how, which is difficult to be facilitated by formal market mechanisms. Secondly, owing to an already adopted network perspective from a firm, the creation of new links is easier to take place, indicating a cumulative advantage. And thirdly, such networks carry trust and reciprocity – qualities that were usually excluded from mainstream economics, which enable the preservation of ties over long periods of time (Giuliani 2011).

Different typologies can be built for such networks. From a managerial perspective, innovation networks can be identified as the summation of interfirm linkages. Fischer (2006) distinguishes five different network types. *Supplier networks*, apart from intermediate goods purchase, reflect mostly subcontracting relationships between firms. The latter differs from the former as subcontracting relationships are ruled by formal contracts which define the order specifications, instead of simply obtaining final products from an upstream supplier. *Customer networks* represent the effort spent by companies to gain feedback from their customers to better customize their products and services. At the same time, the opposite direction of such a relationship is also important as customers – in this case firms – need to obtain information for new products from their suppliers. *Technological cooperations* is the third type of interfirm networks. The main objective of such networks is to share scientific knowledge and the outcome of R&D processes as well as to facilitate joint technology production and process development. *R&D cooperation networks* represent a well-established framework for interaction between firms and other actors such as universities and research centers, the main characteristics of which are fundamental or applied research. What used to be depicted as informal networks between firms and universities, nowadays, is mostly reflected in formal agreements between such actors. Finally, *production networks and strategic alliances* represent interfirm collaboration agreements for joint production. The main motivation for such agreements is the achievement of economies of scale and also surplus or scarcity in production capacity. While the first two types of interfirm networks can be characterized as vertical networks, the last three represent horizontal collaborations (Fischer 2006).

From a functional point of view, interfirm networks can fulfill three different corporative needs: (a) problem solving by assistance networks; (b) lack of information such as whom to contact for specific reasons through information networks; and (c) entrepreneurship and product development (Mønsted 1993). The above networks are vastly based on interpersonal relationships and trust found in local communities. Although these networks are mostly interfirm networks, the driving force for such structures is interpersonal relations. In general, such regional innovation networks are always based on preexisting personal social networks which carry the necessary trust (Lechner and Dowling 1999). Thus, to the extent that such networks are related with regional innovation production as a necessary condition for firms to innovate and thrive, then trust, which is a necessary condition for the creation and maintenance of such interpersonal links, can be approached as an important mechanism for regional innovation processes. However, trust is a complex notion and can be approached as a socially embedded notion which is based on friendship, kinship, and repeated interaction (Boschma and Frenken 2010). Although such relationships are primarily social, they also carry information about potential partners, and because of this attribute, they increase the ability of organizations to get involved with innovation networks.

What also needs to be highlighted here is the interrelation between regional networks and regions per se. Regions do not only contain and shape network formation, but at the same time social interaction among actors in regional networks also affect its geography (Storper and Walker 1989). The above interrelation can be further intensified by the evolutionary nature of regional networks. For instance, the existence of large firms in the development stage of a region might prevent the development of extensive regional innovation networks or even an industrial district (Lechner and Dowling 1999). The explanation behind this influential role of large companies on regional networks is the power that large firms hold in terms of bargaining power against their supplies (Porter 1980). The utilization of such power has negative effects in developing interpersonal to innovation networks. A well-known example is the comparative discussion between Silicon Valley and Route 128. While in the former, the existence of one large firm, that is, Fairchild, supported the establishment of innovation networks, and the presence of multiple large firms in Route 128 prevented the creation of innovation links (Saxenian 1994).

26.3 Knowledge Networks in a Knowledge-Based Economy

Knowledge exchange is the main incentive behind the formation of networks. Knowledge production does not solely depend on isolated for-profit firms and nonprofit institutions. Knowledge comes as the outcome of unconstraint exchange of information between a plethora of actors organized formally or informally in systemic ways creating networks at different scales. Such networks tend to be more and more inter-sectoral, interorganizational spanning over a variety of actors from firms to universities and also international (Autant-Bernard et al. 2007).

The importance of knowledge in the current economic framework is depicted in the discussion around the *knowledge economy*. Knowledge is directly linked to information because "knowledge is more than information as information is more than simply data" (Malecki and Moriset 2008, p. 29). The relation between these notions is hierarchical as one step higher in the hierarchy reveals a higher level of sophistication, codification, and consequently value. Leydesdorff (2006, 17; original emphasis) further explains the notion of knowledge and distinguishes it from information:

> Knowledge enables us to codify the meaning of information. Information can be more or less meaningful given a perspective. However, meaning is provided from a system's perspective and with hindsight. Providing meaning to an uncertainty [. . .] can be considered as a first codification. Knowledge enables us to discard some meanings and retain some others in a second layer of codifications. In other words, knowledge can be considered as a meaning which makes a difference. Knowledge itself can also be codified, and codified knowledge can, for example, be commercialized.

This last point is the key characteristic of the knowledge economy: knowledge, as a commercialized entity, has become a production factor, in advance of capital and labor (Drucker 1998). According to the OECD's (1996, p. 7) definition, knowledge-based economies are economies "which are directly based on the production, distribution and use of knowledge and information."

The notion of knowledge is tied with the notion of learning. The latter, as a collective ability of a society or a locale, appears to be central in the development process (Lundvall 1992). Advances in information and communication technologies (ICTs) resulted in the acceleration of codification and digitization of "codifiable" knowledge and thus in improvements in knowledge accessibility. These drastic changes in knowledge codification process resulted in the transformation of knowledge into a market commodity. The part of knowledge which is not codifiable is identified as tacit knowledge and is embodied in practices, people, and networks (Maignan et al. 2003).

Given the current knowledge economy framework, the importance of innovation and knowledge networks becomes more evident both at the micro- (firm) and meso- (city) level (for a city-level discussion around the knowledge economy, see Geenhuizen and Nijkamp 2012). *Knowledge spillovers*, which are defined as the positive externalities that a firm benefits from in terms of knowledge as a result of the environment it operates within (for a discussion, see Capello and Faggian 2005), are essential elements for knowledge generation and most importantly for the innovation creation process. Knowledge spillovers can be understood as incentives for the formation of formal and informal networks. Simply put, knowledge creation and innovation production are not just the product of one actor, but on the contrary are facilitated by spillover effects and efforts taking place outside the individual actor. Network structures support this process as they provide the necessary platform for utilizing such spillovers (Fischer 2006). Knowledge and innovation creation can be approached as interactive processes in which actors, which possess different types of knowledge, interact together in order to overcome technical organizational, commercial, or intellectual problems (Bathelt et al. 2004).

Of equal importance in understanding the role of networks in innovation process is the distinction between tacit and codified knowledge and how these different types of knowledge are tied to specific localities. The distinctive point between them is the easiness to be transferred. For instance, codified knowledge can be digitized and transferred through ICTs over long distances without the need for intensive interpersonal interaction. Especially nowadays, owing to the digital revolution and the pervasive character of ICTs, codified knowledge can be very easily transferred or even downloaded via digital networks. Therefore, the spatial ties of this type of knowledge are loose. However, this argument applies less for tacit knowledge. The latter is characterized by a higher level of sophistication and complexity which does not allow for its codification (It needs to be highlighted here that the borderline between codification and non-codification is not fixed and may change over time). As a consequence, tacit knowledge transfer is heavily based on interpersonal interactions. Therefore, tacit knowledge has a higher degree of local embeddedness as proximity is a crucial factor for transmission of such knowledge. The role that ICTs play in supporting distant, face-to-face interactions via teleconference applications needs to be highlighted here. Face-to-face communication can be divided into two components: the *conversation* and the *handshake*, with the former being the "metaphor for simultaneous real-time interactive visual and oral messages" while the latter for the physical co-presence (Leamer and Storper 2001, p. 4). ICTs can only lower the cost of the conversation component of the face-to-face communication, which enables up to a certain extent the transmission of tacit knowledge via global networks.

The above argumentation can be crudely summarized on the preposition that the more codified knowledge is, the less spatial dependent is. On the other hand, the more tacit characteristics knowledge has, the more its transfer is based on spatial proximity between the involved actors. This spatial distinction of knowledge and the knowledge transfer process also reflects the debate between global connectivity and local network intensity. The discussion in this chapter has been mostly focused on the latter, which refers to Marshallian externalities, clusters, and innovative milieu. All of these notions highlight the value of local networks in innovation generation and growth. What has not been yet discussed in this chapter is the value of global links in achieving the above objectives. Such global *pipelines* can be understood both as open channels and more closed conduits. The former approaches interorganizational links as open systems that diffuse knowledge to all the loosely connected actors in a way that facilitates knowledge spillovers. This type of linkages can be understood as weak links. The latter type of links functions in a more restricted way so that knowledge only flows among these connected actors that are part of the alliance. Such strong links are used to protect sensitive issues such as intellectual property rights. Based on this, it can be said that access to knowledge is not only the result of interactions among collocated actors in local or regional networks, but it can also be the outcome of partnership and linkages at an interregional or international scale (Owen-Smith and Powell 2004).

The interplay between local and global linkages can also be seen as the outcome of the transformation that our society is going through due to the extensive use of ICTs. From an urban perspective, the underlying new techno-economic paradigm is related with drastic social changes. The starting point for understanding these changes is the seminal work of Castells on the *network society* (Castells 1996), where he illustrated the emergence of a new spatial form due to the structural transformation that society is undergoing because of the extensive use of ICTs. He identified this new spatial form as *the space of flows*, and he defined it as the "managerial organization of time-sharing social practices that work through flows" (Castells 1996, p. 442). Such flows are "purposeful, repetitive, programmable, sequences of exchange and interaction" between detached socioeconomic actors (Castells 1996, p. 442). Castells presented this new spatial form as a three layer system. The first layer consists of the technical network infrastructure, upon which the flows of Castells' network society are transported. Examples of such infrastructure include the digital infrastructure upon which the Internet function is based as well as aviation networks which are responsible for transfer of people between places. Most importantly from the innovation network viewpoint, the second layer refers to the nodes and the hubs of the space of flows. These are the real places with "well-defined social, cultural, physical, and functional characteristics" (Castells 1996, p. 443). These places – cities in reality – are interlinked through the first – infrastructural – layer of the space of flows upon which real flows, such as knowledge, are transported. From this perspective, global pipelines can be understood as part of the space of flows. Lastly, the third layer of the space of flows refers to "the dominant managerial elites" and analyzes the spatial organization of these privileged social groups, which are increasingly located in isolated communities, but at the same time in highly connected places (Castells 1996, p. 433).

What would be a mistake here is to approach the above discussion on the scale of interorganizational linkages as preference toward local or global links. The argument that innovation cannot occur in isolation is only valid from a multi-scalar perspective in the contemporary world economy. It is well established nowadays that local economies are dependent upon global corporate processes. Thus, localities cannot exist anymore as local and regional economies only linked with the global economic system via trade flows, following a Marshallian logic. From a policy point of view, strategies to support local economies using a Marshallian framework targeting only the intensification of local links ignore global interdependencies, and their success is anything but given (Amin and Thrift 1992). Such local strategies should be multi-scalar in nature and promote cross-fertilization between global and local links.

26.4 Innovation Networks and Different Types of Proximity

The discussion in the previous section took place on two axes. On the one axis, different knowledge types were analyzed. The focus was on tacit and codified knowledge and how these "distinct" types of knowledge flow between organizations. On the other axis, the scale and the spatiality of interorganizational linkages, which facilitate these flows, were examined. As it was explicated, the range of such links varies from local to global links. Despite the importance of the above approach in understanding the mechanisms behind the formation of knowledge and innovation interorganizational links, it is still a simplification to assume an absolute correspondence between tacit knowledge and geographic proximity, on the one hand, and codified knowledge and long distance links, on the other hand. Firstly, the separation of both knowledge types is not always clear. Secondly, face-to-face interactions and geographic proximity are not the exclusive facilitators of tacit knowledge flows. For instance, ICTs, as mentioned before, can also play a role as such a facilitator. Most importantly though, it is important for innovative firms to establish links with nonlocal partners to obtain knowledge and ideas which are not accessible locally (Torre 2008).

In order to shed more light in this complex relation, this section takes a relational turn and introduces other non-geographic components of proximity. Thus, apart from the geographical proximity denoted by Euclidean distance, other relational proximities, including cognitive, organizational, and institutional proximity, will also be assessed. These proximities are defined in a *relational space* which can be defined as “the set of all relationships – market relationships, power relationships and cooperation – established between firms, institutions and people that stem from a strong sense of belonging and a highly developed capacity of cooperation typical of culturally similar people and institutions” (Capello and Faggian 2005, p. 78). The starting point for defining the different dimensions of proximity lies in the French school of proximity. The main objective of this group of industrial economists was to endogenize space in economic analysis and, more specifically, to incorporate space and other territorial proximity elements in a research framework, which aims to better understand the dynamics of innovation (for a review of the French school of proximity, see Torre 2008). A second development in further decomposing and analyzing the different components of proximity was studies related to innovation and territorial learning in the broader framework of evolutionary economic geography. In recent years, we have experienced an increased interest in factors which explain how firms and regions interact as part of a “collective learning process,” since learning and knowledge creation are an essential component of the firms’ and regions’ competitive advantage. The notion of proximity and its different components is juxtaposed with ideas about knowledge transfer and creation, tacit knowledge, and learning regions (Boschma 2005).

The common basis of these approaches is the importance of non-geographic types of proximity in innovation creation. Starting from the French school of proximity, two different types of proximity can be identified: geographical and organized (Torre 2008). The former type is more straightforward and usually represents physical distance and collocation. Nonetheless, different conceptualizations of geographic proximity could also be utilized, as physical proximity might be affected not only by Euclidean distance but also by the transportation cost between two places and their accessibility. In addition, the temporal continuity of geographic proximity is also important. As Torre (2008) suggests, geographic proximity and face-to-face interactions are necessary only during specific stages of the innovation process.

Unlike physical proximity, organized proximity is a relational notion and refers to the ability of an organization to enhance interaction between its members. The main point behind this concept is that members of the same organization will interact together more easily than actors outside the organization. This is based on two different logics (Torre 2008): (a) adherence logic, according to which actors, who are close in organizational terms, such as a firm and network, are part of the same relational space, and (b) similarity logic, according to which the organizationally close actors tend to be alike. In a nutshell, while geographical proximity reflects separation in space regarding physical distance, organized proximity is considered as the overall framework in which different actors interact. In the same vein, Boschma defined organizational proximity "as the extent to which relations are shared in an organizational arrangement, either within or between organizations" (Boschma 2005, p. 65).

Building upon the French school of proximity findings, Boschma (2005) approached proximity as a five-dimension notion. Cognitive proximity is the point of departure for his conceptual framework and is defined as the level of similarity of the knowledge base of different organizations. Organizations collaborate and form links and networks using as criteria the knowledge background of the potential partners, as people and organizations, which share the same knowledge background and expertise, may learn from each other. The complexity of the learning process is reflected in the nonlinear effect of cognitive proximity in learning. In order for knowledge to be transferred, gained, or created, there is a need for optimal cognitive proximity, since too high cognitive proximity will eliminate any novelty from the interaction, while, vice versa, too high cognitive distance will result in communication difficulties (for a detailed discussion, see Boschma 2005).

Despite the effort spent in the relevant literature, cognitive proximity is still a rather fuzzy concept, and it is difficult to quantify. Strong links can be identified between cognitive proximity and technological similarity. While some authors distinguish these two, more often than not, these notions are used interchangeably in an empirical context. While cognitive proximity represents the similarity of the knowledge bases of two organizations or regions, technological proximity reflects the similarity between the technological knowledge among economic actors (Dangelico et al. 2010).

In addition, institutional proximity is also proposed as another proximity dimension. Following North's (1990) definition, institutions are the amalgamation of formal rules and informal constraints including behavioral and social standards, while organizations can be approached as a group of agents performing the same activity. Put simply, organizations define agents' practices and strategies in the overall context provided by the institutional ecosystem in which they are positioned (Kirat and Lung 1999). Therefore, one would expect that collocation in the same institutional environment would result in increased interaction.

The analytical value of the multidimensional approach of proximity is now well established in the relevant literature as a tool for understudying structurally interorganizational innovation networks. Apart from the above discussed proximity dimensions, different proximity components can be introduced such as social or linguistic proximity. Most importantly, in a quantitative framework, a multidimensional understanding of proximity will enable researchers to compare the impact of different proximity measures in the formation of linkages. Such a framework provides researchers with the necessary tools and flexibility to model the explanatory value of different proximity dimensions in network formation. For instance, it can be claimed that the different proximity dimensions in innovation networks are in reality substitutes rather than complements (Boschma 2005).

Despite the increased complexity that the inclusion of relational proximities introduces to the discussion on interorganizational spatial innovation networks, the above proximity components reveal interesting dimensions of organizational behavior. Thus, the inclusion of these relational dimensions of proximity should not be interpreted as a diminishing factor of the importance of the spatiality of interorganizational networks. It might be the case that geography, in terms of collocation and geographical proximity, is not the (only) determinant for the innovation networks formation, but on the other hand, the spatiality of the other relational dimensions of proximity might reveal interesting geographies as well. For instance, path dependency could explain organizational proximity between geographically distant actors. Although geography could not explain this phenomenon, a study of the spatiality of such networks and the underlying relational proximities, which do not correspond with the geographical one, could be of interest per se.

26.5 Innovation Networks: Some Methodological Approaches

The centrality of spatial innovation networks in economic geography and regional science can be depicted on the numerous different methodologies adopted by researchers in their effort to understand and model innovation activity and innovation networks in space. In this section, some recent methodological advances will be presented. On the one hand, "traditional" econometric modeling is enriched with spatial econometric concepts to understand innovation in space. Although this strand of research is less associated with network structures, it still provides insights on the spatiality of the innovation process and therefore is briefly presented here. On the other hand, the network structure of innovation activity is the key focus on studies having a starting point on *network science*. Despite the fact that space and geography is not the key focus of this field, recent developments incorporate this dimension as well in the search of the innovation networks driving forces.

A starting point for the first strand of methodological approaches is *the knowledge production function* which relates regional knowledge output with R&D by industry and university research in a Cobb-Douglas framework. The original work of Zvi Griliches and Adam B. Jaffe was further expanded by the developments in the spatial econometrics (for a discussion, see Anselin et al. 1997). The latter enabled an in-depth investigation of the spatiality of knowledge spillovers. For instance, the work of Anselin et al. (1997) confirmed the significant positive relationship between university research and innovative activity, both directly and indirectly, through its impact on private sector R&D. Most importantly, the spatiality of university research spillovers on innovations was confirmed and quantified.

Moving to models addressing the relational character of interorganizational links, gravity models, an important model class in regional science, may be used to measure the impact of different types of proximity or distance on knowledge flows. These models typically rely on three types of factors: (i) origin-specific factors that characterize the ability of origin locations to generate knowledge flows, (ii) destination-specific factors that represent the attractiveness of destination locations to absorb knowledge flows, and (iii) origin–destination factors that characterize the way spatial separation of origin from destination locations constrains or impedes the interaction (Fischer and Wang 2011). Suppose that we have a spatial system of n locations representing network nodes, then the following (lognormal) knowledge flow model may be taken as a framework for the analysis:

$$\ln kF_{ij} = \alpha_0 + \alpha_1 \ln X_i^o + \alpha_2 \ln X_j^d + \alpha_3 D_{ij} + \alpha_4 BD_{ij} + \varepsilon_{ij} \qquad i, j = 1, \ldots, n \tag{26.1}$$

where kF_{ij} represents the knowledge flow (e.g., measured in terms of patent citations) from origin location i $(i = 1, \ldots, n)$ to destination location j $(j = 1, \ldots, n)$. X_i^o and X_j^d are origin-specific and destination-specific factors, respectively, and a_1 and a_2 denote the associated coefficients. D_{ij} is a continuous distance (proximity) measure, for example, geodetic distance or travel time from i to j, and BD_{ij} is a binary distance measure representing, for example, institutional proximity between the locations, with the corresponding distance sensitivity coefficients a_3 and a_4. a_0 is the constant, and ε_{ij} is the error term, generally assumed to be identically and independently distributed. For model estimation issues, and econometric extensions of the lognormal gravity model to account for spatial or network dependence in flow data, see Fischer and Wang (2011, p. 47–70).

Finally, network science is shaping the latest developments in modeling the structure and the evolution of innovation networks, also from a spatial perspective. From a descriptive point of view, network analysis provides a plethora of metrics which can assist researchers to understand the topology of innovation networks. Examples include different *centrality* indicators, which depict the position of an actor and the roles it performs in the overall network, the *clustering coefficient*, which indicates the tendency of a network to create clusters of dense internal connections, and the *average path length*, which is a measure of network distance. From a modeling point of view, complexity science provides a plethora of tools to model innovation networks from a structural and evolutionary perspective. The distinctive point of this strand of research is that instead of adopting an explanatory modeling strategy as reflected in fitting regression lines in observed data (e.g., the gravitation family of models discussed above), stochastic models are utilized to understand the underlying mechanisms of the network formation and to simulate the evolution of the (observed) network. A wide range of such modeling applications – from agent-based models to statistical physics and social network analysis – can be found in the book edited by Pyka and Scharnhorst (2009).

To sum up, spatial innovation networks are curved by a two-level complexity: a network level complexity which reflects the topological characteristics of k interacting actors and a spatial level complexity which represents the peculiarities of geographical space where innovation interactions are embedded. Despite the difficulty to model these mechanisms, studies focusing on such issues are currently at the forefront of regional science. Nonetheless, the incorporation of both level complexities is still a challenging task despite the developments in modeling presented in this section.

26.6 Conclusions

The objective of this chapter was to highlight the importance of networks in the innovation process. From the above discussion, it became apparent that innovation does not occur in isolation and that interorganizational networks facilitate innovation creation. Such networks are usually based on interpersonal relations characterized by a high level of trust. Moreover, these social networks are embedded in places. This reflects the importance of the spatiality of such networks. In addition, such innovation networks can be understood as knowledge networks and knowledge externality catalysts. Actors interact to gain knowledge, a crucial production element of the knowledge economy. Broadly speaking, two different types of knowledge and two scales of interaction can be identified: tacit and codified knowledge and local and global interaction. Although there is no absolute correspondence, it can be said that tacit knowledge is facilitated by geographic proximity, while codified knowledge can be easily accessed remotely. Counterarguments to the above statement are the increased use of teleconferencing applications via desktop computers and the necessity for firms to establish long-haul links to gain knowledge which is not available locally. These arguments advocate toward the adoption of a relative proximity perspective. The latter enables researchers to understand the determinants of innovation activity and networking not only in the Cartesian but also in relative space. Finally, effort was spent to approach innovation networks from a systemic perspective. Innovation networks are vital parts of multi-scalar systems of innovation, and this systemic attribute should also be reflected in attempts to model such networks as well as their dynamics.

To conclude, despite the inherent complexity for understanding and modeling such networks, especially from a spatial perspective, the research community should continue its efforts for two reasons. Firstly and from an analytical perspective, we are still lacking a generalized understanding of how actors interact together in order to innovate. From a spatial perspective, it is essential to understand the role places perform in this process. Secondly, such analytical gains can be utilized to better design local and regional policies. In the current network society, it is important for policy makers to propose tools for increasing network intensity in a multi-scalar, targeted, and efficient way.

References

Amin A, Thrift N (1992) Neo-Marshallian nodes in global networks. Int J Urban Reg Res 16(4):571–587

Anselin L, Varga A, Acs ZJ (1997) Local geographic spillovers between university research and high technology innovations. J Urban Econ 42(3):422–448

Autant-Bernard C, Mairesse J, Massard N (2007) Spatial knowledge diffusion through collaborative networks. Pap Reg Sci 86(3):341–350

Bathelt H, Malmberg A, Maskell P (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Prog Hum Geog 28(1):31–56

Boschma R (2005) Proximity and innovation: a critical assessment. Reg Stud 39(1):61–74

Boschma R, Frenken K (2010) The spatial evolution of innovation networks. A proximity perspective. In: Boschma R, Martin R (eds) The handbook of evolutionary economic geography. Edward Elgar, Cheltenham

Camagni R (1991) Innovation networks: spatial perspectives. Belhaven Press, London/New York

Capello R, Faggian A (2005) Collective learning and relational capital in local innovation processes. Reg Stud 39(1):75–87

Castells M (1996) The rise of the network society. Blackwell, Oxford

Cooke P (1992) Regional innovation systems: competitive regulation in the new Europe. Geoforum 23(3):365–382

Cooke P, Morgan K (1993) The network paradigm: new departures in corporate and regional development. Environ Plann D: Soc Space 11(5):543–564

Dangelico RM, Garavelli AC, Petruzzelli AM (2010) A system dynamics model to analyze technology districts' evolution in a knowledge-based perspective. Technovation 30(2):142–153

Drucker PF (1998) From capitalism to knowledge society. In: Neef D (ed) The knowledge economy. Butterworth-Heinemann, Woburn, pp 15–34

Edquist C (1997) Systems of innovation approaches—their emergence and characteristics. In: Edquist C (ed) Systems of innovation: technologies, institutions and organizations. Pinter, London, pp 1–35

Fischer MM (2006) Innovation, networks and knowledge spillovers. Springer, Berlin/Heidelberg

Fischer MM, Wang J (2011) Spatial data analysis. Models, methods and techniques. Springer, Heidelberg/Dordrecht/London/New York

Giuliani E (2011) Networks of innovation. In: Cooke P, Asheim B, Boschma R, Martin R, Schwartz D, Tödtling F (eds) Handbook of regional innovation and growth. Edward Elgar, Glos/Northampton, pp 155–166

Kirat T, Lung Y (1999) Innovation and proximity: territories as loci of collective learning processes. Eur Urban Reg Stud 6(1):27–38

Leamer EE, Storper M (2001) The economic geography of the internet age. J Int Bus Stud 32(4):641–665

Lechner C, Dowling M (1999) The evolution of industrial districts and regional networks: the case of the biotechnology region Munich/Martinsried. J Manage Gov 3(4):309–338

Leydesdorff L (2006) The knowledge-based economy: modelled, measured, simulated. Universal Publishers, Boca Raton, FL

Lundvall B-A (ed) (1992) National innovation systems: towards a theory of innovation and interactive learning. Pinter, London

Maignan C, Pinelli D, Ottaviano GIP (2003) ICT, clusters and regional cohesion: a summary of theoretical and empirical research. http://www.ssrn.com/abstract=438507. Accessed 13 Jul 2011
Malecki EJ, Moriset B (2008) The digital economy. Routledge, New York
Marshall A (1927) Industry and trade. a study of industrial technique and business organization; and their influences on the conditions of various classes and nations, 3rd edn. Macmillan, London
Mønsted M (1993) Regional network processes: networks for the service sector or development of entrepreneurs? In: Karlsson C, Johannisson B, Storey D (eds) Small business dynamics. Routledge, London, pp 204–222
Geenhuizen MS, van Nijkamp P (eds) (2012) Creative knowledge cities: myths, visions and realities. Esward Elgar, Glos/Northampton
North DC (1990) Institutions, institutional change and economic performance. Cambridge University Press, Cambridge
OECD (1996) The knowledge-based economy. OECD, Paris
OECD and Eurostat (2005) Oslo manual: guidelines for collecting and interpreting innovation data. OCED and Eurostat, Paris
Owen-Smith J, Powell WW (2004) Knowledge networks as channels and conduits: the effects of spillovers in the Boston biotechnology community. Organ Sci 15(1):5–21
Porter M (1980) Competitive strategy. Free Press, New York
Porter M (1990) The competitive advantage of nations. Free Press, London
Pyka A, Scharnhorst A (eds) (2009) Innovation networks: new approaches in modelling and analyzing. Understanding Complex Systems. Springer, Berlin/Heidelberg
Saxenian A (1994) Regional advantage: culture and competition in Silicon Valley and Route 128. Harvard University Press, Cambridge, MA
Storper M (1997) The regional world. The Guilford Press, New York
Storper M, Walker R (1989) The capitalist imperative: territory, technology, and industrial growth. Blackwell, Oxford
Tijssen RJW (1998) Quantitative assessment of large heterogeneous R&D networks: the case of process engineering in the Netherlands. Res Policy 7–8(26):791–809
Torre A (2008) On the role played by temporary geographical proximity in knowledge transmission. Reg Stud 42(6):869–889