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Abstract

This chapter provides an overview of current theories and empirical research on cities and the knowledge economy. Two recent and interrelated streams of literature are discussed: the first focusing on agglomeration economies related to increasing returns and knowledge spillovers of firms in cities and the second highlighting the role of knowledge workers and creativity in identifying new and innovative growth opportunities in cities. We argue that analyses using knowledge production functions to capture knowledge flows in cities do not, as of yet, provide true insight into the generation and transfer of different kinds of knowledge. Only recently are various conceptualizations of distance and knowledge transmission channels able to address the heterogeneity of the actors and processes involved in capturing the respective role of cities in knowledge creation. We conclude that the mechanisms that create and diffuse knowledge in cities should be better embedded into both streams of literature. The current discourse on agglomeration externalities obviously needs such conceptual and

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methodological views to address current impasses. In particular, evolutionary economic geographical concepts are promising in explaining the innovative behavior of growing firms and organizations in cities, carefully addressing the heterogeneity of the actors involved, spatial scale, selection and survival, as well as time and path dependency.

25.1 Introduction

In the 1980s, many people were convinced that cities as centers for social and economic dynamism were disappearing. Wealthier people wanted to live outside the cities, in larger villages, or in suburban areas. The widespread use of the car and the rise of information and communication technologies (ICT's), as well as the concentration of the socially and economically disadvantaged, made many observers think that we would see a complete transformation of communication, spatial configurations, and social and economic structures. The end of distance and spatial concentration seemed near (Gaspar and Glaeser 1998). The current view is completely different; today, views on urban development hold that distance still matters and that urban concentration still continues (Glaeser 2011). At first glance, it seems easy to understand why cities are increasingly the preferred mode of human settlement. They save on infrastructure, reduce trade costs, and enhance interaction. In developing countries, there's nothing particularly new about urbanization as an expression of development. At second glance, however, cities are associated with many costs – land, pollution, and other externalities. We once believed that suburbanization combined the primary advantages of urbanization with these lower land costs and other externalities, but density has returned to many parts of the world.

Examining the arguments behind this modern urbanization view, we find two major approaches. The first is based on the theory of agglomeration economies with increasing returns and easy access to knowledge (Jacobs 1984; Krugman 1995), and the second is based on the idea that (larger) cities are strong because they claim to be the physical concentration of skilled knowledge workers and the creative class (Glaeser 1999; Florida 2002). Both approaches lead to the hypothesis of an expected higher labor productivity. This raise of productivity seems to be the case, although the explanation can differ. In Europe, the largest urban areas, in particular the London-Randstad-Paris-Frankfurt-Milan axis, contribute much more to their national GDPs than could be expected judging by their population sizes (Ciccone 2002). The same conclusion was reached by Glaeser (2011) for the USA.

The question that can be raised is whether knowledge is a decisive factor in explaining (a) higher productivity and (b) the stronger attraction of knowledge workers, or more general, of the creative class. In urban economics, knowledge receives increasing attention as a source of growth. Apart from knowledge, urban growth is explained by many other variables, and by the concentration of creative people, with the expected concomitant development of new knowledge and innovations (Combes et al. 2008). Urban economics focus on properties associated with

agglomeration advantages, external economies of scale, increasing returns, and the development of a variety of producers and consumers. Knowledge, its generation, and its use in innovations are perceived as the principal variables. However, the concept of knowledge in itself is not entirely clear, and neither are the mechanisms of its impact on productivity. It can be seen as a separate production factor or as an attribute, in one way or another, linked to capital goods and labor. Most economic studies emphasize the second interpretation. In endogenous economic growth theory, knowledge is seen as an output of investment in research and development (R&D). This kind of investment can be defined more broadly, as knowledge-intensive inputs, such as in new capital goods and new labor, to increase R&D. To make things more difficult, in the aforementioned case, knowledge can be both an input and an output.

In this chapter, a (non-exhaustive) survey of theories and empirical applications on research focused on cities, knowledge, and innovation is provided. We structure the theories using two recent and interrelated streams of literature: the first focusing on agglomeration economies related to increasing returns and knowledge spillovers of firms in cities and the second highlighting the role of knowledge workers and creativity in identifying new and innovative growth opportunities in cities. [Section 25.2](#) provides an overview of historical and current conceptualizations of knowledge and knowledge diffusion. [Section 25.3](#) provides a discussion on knowledge production function methodologies applied to cities, and concludes, consistent with [Sect. 25.2](#), that future research should increasingly and explicitly focus on the transfer mechanisms of knowledge diffusion. [Section 25.4](#) focuses on the related literature of agglomeration externalities and its link to innovation and urban economic growth. [Section 25.5](#) confronts the central plea for a better embedding of knowledge transfer mechanisms in agglomerations with current agglomeration discourse and methodologies. Conclusions on new and necessary conceptual and methodological views are presented in [Sect. 25.6](#).

25.2 Knowledge Creation and Diffusion

A useful distinction is the one in “data” (facts or unstructured information), “information” (structured data and standardized knowledge) that can be easily transferred via markets, “practical knowledge” (dispersed over economic actors and belongs to particular individuals) that can be used in commercial activities or applied directly in production processes, and “scientific knowledge” that can be applied after further research and development. Knowledge is acquired through the interactive process of learning, based on the cognitive competencies and experiences of the actors. A distinction can be made between “tacit” and “codified” knowledge. Tacit knowledge can be defined as the person-specific knowledge that people have developed through a process of learning-by-doing or learning-by-using, meaning that a person is able to use it but is not, or is not yet, able to codify it in a transferable form, such as a book, patent, or a mathematical formula.

It has to be emphasized that these kinds of knowledge are not fixed. Nonaka and Takeuchi (1995) have emphasized that tacit knowledge and codified knowledge have to be perceived as dynamic attributes that can be transformed into one other. After a period of application, tacit knowledge can be codified and, vice versa; sometimes, codified knowledge can be developed further and can become tied to individuals. The ways in which learning and the transfer of knowledge across organizations and in spatial settings can be investigated and measured have triggered much debate and research.

Codified knowledge (like patents and books) can be transferred to other users and is most often sold in markets. Tacit knowledge is person and context specific; hence, it has to be transferred or sold connected to a person, as with labor mobility. In some instances, knowledge is transferred for free, as in certain teaching situations or in networks, based on friendship. Tacit knowledge can develop into codified knowledge. This happens when, through research, certain skills, feelings, or capabilities are formalized or defined by rules, as has been performed with chess programs and in medical research. The reverse also occurs when codified knowledge becomes “embedded” in behavior and becomes tacit through its implementation in new situations, through experience, or by sharing within a group. Recent questions on the subject involve the possibilities of transferring tacit knowledge not only via interpersonal contacts but also via modern tools such as TV, the Internet, and mobile phones. Another question is whether the use of knowledge for economic goals and its transfer are related exclusively to production and consumption. Additionally, the question arises regarding whether wider opportunities to increase welfare emerge, for instance, in the arts, or whether measures to increase the sustainability of cities are implemented (Glaeser 2011). Finally, the link between knowledge, skills, and creativity is important. The use of knowledge and, in a broader sense, creativity is not always directly related to economic goals of production and consumption. Creativity can be used for solving personal or family problems, or expressed in the arts. However, this also can lead to higher satisfaction or even to the rise of certain forms of consumption, through which the production of goods and services can increase. There are also many indirect links between creativity, knowledge development, and economic growth.

In endogenous growth theory, the generation of new knowledge and innovations is explained by increased investment in R&D. This concept was also described in Schumpeter’s 1942 book, in which he saw the entrepreneurial function of management replacing the risk-taking and innovative individual hero-entrepreneur. In this view, it is possible to create a knowledge production function (KPF), with investments in R&D as input and knowledge and patents as an output. Recent applications at the regional and urban level show that this line of thinking is fruitful for explaining urban growth differentials (Acs 2002; Breschi and Lissoni 2009). However, in this KPF approach, the important other causality, the line starting from the demand side, is often neglected. The failure to meet the preferences and needs of users has been consistently stressed as a major cause of unsuccessful R&D for over 30 years. This is especially important in urban agglomerations, as is emphasized in studies on consumer cities. In modern urban agglomerations,

consumers are increasingly seen as a source of changing demand and new ideas (Glaeser et al. 2001). However, it is not yet clear how the lines of knowledge generation and application can be connected to producers and consumers in urban contexts. It is particularly necessary to investigate the relative importance of markets (prices) and formal and informal networks as carriers of knowledge. Krugman (2009, p. 567) also emphasized the unclear role of spillovers: "it's not at all clear how to think about the spatial limits of spillover. Do you have to be in the same city to reap positive externalities from other producers in the same industry?" However, for cities with a wide variety of different kinds of economic activities and international relations, this question becomes even more important. The analysis incorporating production functions does not provide us with insight of the generation and transfer of different kinds of knowledge (yet). The investigation of knowledge in cities, as well as other kinds of knowledge, such as scientific knowledge, practical knowledge, and Polanyi's tacit knowledge, is in need of receiving greater attention. The generation and diffusion of these heterogeneous kinds of knowledge can vary and need to be considered as having different effects on urban economic variables. In turn, urban contexts can be perceived as having effects on the generation and diffusion of the various kinds of knowledge. Cities can cumulatively specialize in certain kinds of knowledge connected to different economic specializations (Duranton and Puga 2005).

It is generally accepted that geographical contexts, such as agglomerations, influence the generation and dissemination of knowledge, although other mechanisms besides markets are not always included in explanations of urban development. In urban economics, the role of geographical distance as such is reflected in transport costs (both in the old and in the new economic geography), in the impact on social relations, and in the availability of knowledge embedded in labor, as in the popular view on the development of industrial clusters. In theories of urban hierarchy, distance costs are seen as a decisive factor explaining the differences of the quality of services and amenities in centers of different size. Distance is generally translated in terms of costs or in missed opportunities, stemming from the failure to note chances to produce, sell, or purchase goods or services.

Boschma (2005) emphasized that the word "distance" can be interpreted in different ways. Geographical distance is not the only important factor; social and cultural distance can also be important. This distinction is especially relevant in analyzing the geographical sources of knowledge and innovation because in a globalizing world many researchers have connections with people in other places. Nevertheless, it seems that distance costs and perception barriers are important factors in the analysis of agglomeration advantages because closer distance, no matter how it is measured, seems to foster the development of knowledge and innovations (Breschi and Lissoni 2009). One of the strong attributes of closer distances is the easier transfer of knowledge. This is related to the uncertainties that are inherent to the economic process and to the rapid changes that knowledge development has shown in our time. Such changes in knowledge cause the need for continuous adaptations by economic actors and hence the tendencies to locate

generators of knowledge locally, such as in universities and other R&D organizations (Audretsch and Feldman 1996).

The dynamic properties of knowledge are associated with various forms of dissemination and with their applications as innovations, with concomitant changes in supply and demand conditions. Through this process, continuously disturbing effects on equilibrium exist. Markets have to respond quickly to rapidly changing contexts. Metcalfe (1998) even argued that capitalism is restless because knowledge is restless. Innovations can also change market structures by creating new monopolies, as in the case of radical new technologies, especially GPTs (general purpose technologies).

The consequences of the application of knowledge for innovations are important. However, it is also important to examine the sources of knowledge (or its generation), where the cognitive attributes of economic actors and the organizational capacities of entrepreneurs are decisive properties of a knowledge-enhancing urban society. Economic actors vary considerably in their cognitive capacities and other attributes. This heterogeneity is one of the strengths of cities and an important reason for their continuous creativity. Situations involving heterogeneous actors and conditions lead to continuous uncertainties, which offer “gaps in information” for the existent markets, and this, in turn, can give entrepreneurs opportunities for innovative actions. This is particularly the case when new knowledge leads to pecuniary external effects (Metcalfe 1998).

25.3 Mechanisms of Knowledge Production and Diffusion in Cities

Knowledge and innovation are closely associated. Knowledge is not just “given” but has to be generated. Schumpeter (1934) emphasized that the generation of knowledge is the result of a process of wider social significance. The generation of knowledge is important for the development of the quality of labor and capital goods and is decisive for innovation and economic growth. However, the direction of the causality of the relationship between knowledge, innovation, and economic growth is not always clear. Knowledge can be the result of investment in growing sectors of the economy, but it can also be developed by people with inquisitive minds, without the purpose of commercial application. Knowledge and innovation do not only start at the supply side with research and investment. Rather, the causality may sometimes start with changing demand because certain cultural developments alter the structure of demand through concomitant changes in sectoral structures. This can also happen if wealth increases due to the expansion of foreign markets with already-existing kinds of products. All types of change can lead to the demand of new knowledge, products, and production technologies. This section provides a discussion of production function methodologies and concludes by recognizing the need to explicitly focus future research on the transfer mechanisms of knowledge diffusion. The argumentation is neo-Schumpeterian in character.

Being that knowledge is hard to appropriate, as we argued in the previous section, it generates benefits to other agents through several spillover mechanisms. Understanding the geographical structures that underlie these spillover benefits is necessary for any evidence-based innovation policy to stimulate a region's (or collection of regions, such as Europe) transformation toward a knowledge-based society. Recent years have seen many macro studies on the effect of knowledge spillovers on innovation. Such studies generally apply a knowledge production function to differentiate regional innovation outputs from regional knowledge inputs, as well as from knowledge spillovers from other regions. The strength of interregional knowledge flows is generally assumed to decrease rapidly with geographical distance (Acs 2002), while others have attempted to measure spillovers directly by patent citations (Breschi and Lissoni 2009). Despite the fact that previous research has produced a certain degree of empirical coherence (Fritsch and Slavtchev 2007), it has proven difficult to distinguish between different channels of knowledge spillovers; this has subsequently led scholars to rely on specifications that are suggestive of knowledge spillovers without explicitly modeling the mechanisms through which they occur in practice. Understanding the mechanisms that are behind knowledge spillovers is obviously of the greatest importance for designing effective innovation policies.

The step forward to be taken in empirical research on knowledge production and diffusion in cities and city regions is to correctly model spillover mechanisms of knowledge (correctly). This means that, conceptually speaking, one should take into account via a single framework both geographically localized knowledge spillovers (by examining the extent to which regions profit from regions knowledge inputs nearby) and knowledge spillovers stemming from research collaborations (by examining the extent to which regions profit from network connections to other regions). Put differently, one can analytically distinguish between the "space of place" creating geographically localized knowledge spillovers and the "space of flows" creating spillovers in global networks (Castells 1996). In contrast to geographically localized channels of knowledge spillovers, such as spin-off dynamics and informal networking (Breschi and Lissoni 2009), two promising networked channels of knowledge diffusion come to the fore: research collaborations between firms and universities that are increasingly taking place over longer distances and the mobility of globally operating knowledge workers.

The presence of both private and public research organizations, such as universities and the laboratories of multinational corporations, is generally assumed to have a large impact on urban innovation due to their ability to attract knowledge workers and generate localized knowledge spillovers resulting from their research (Acs 2002). Various empirical studies have suggested the presence of localized academic knowledge spillovers for the USA and various European countries. It has been stressed that highly skilled workers can be regarded as carriers of knowledge diffusion and key drivers of regional innovation and growth. Individuals impact knowledge diffusion through two main and complementary channels: on the one hand, their ability to move from one place or one organization to another and, on the other hand, their ability to enter networks. The mobility patterns seem to be

predominantly local, though some evidence indicates that, due to the intrinsic universality of science, researcher's labor markets – in particular academic researchers' mobility – tend to be more international than other labor markets. Motivations for labor mobility could be related to scientific, economic, cultural, and personal factors. It is expected that nonpecuniary scientific factors, such as the quality of the university, the availability of research budgets, personnel and material research infrastructure, and institutional reputation, are more important than economic factors (Jons 2007). Due to the rising demand of specialized scientific labor, a reputation for scientific quality and openness is a critical factor for attracting excellent researchers. However, differences in wage levels, career opportunities, and concentration effects (talent is attracted by talent) are also thought to be relevant. There also exists a relation to soft factors, for example, language, cultural affinity, living environment, and personal motives (Florida 2002). In line with these insights, many countries have implemented regional innovation policies based on the presence of universities and research institutes in a city or region. In particular, initiatives have been set up to attract skilled workers and facilitate their movement. Systematic research on this kind of labor mobility and migration is lacking.

Besides the importance of local labor markets and spin-off dynamics, a growing body of research stresses the role of networks between individuals and between organizations as mechanisms for knowledge spillovers. Informal networking often takes place at the regional level and, as a result, knowledge spillovers are localized to the extent of these networks. Formal networks of research collaboration are an additionally important mechanism of knowledge spillovers; however, empirical research on the spatial dimension of these networks has suggested that they largely occur at the national or even international scale (Ponds et al. 2010; LeSage et al. 2007). The structure of collaboration networks thus needs to be taken into account to fully understand the impact of researchers' knowledge spillovers (Barber et al. 2011). Despite the increase in literature analyzing knowledge flows in different organizations and geographical contexts, little is known about actual knowledge circulation and its impact on community, as well as urban and regional knowledge creation, diffusion, and quality. At least two weaknesses in the existing studies stand out. First, most studies on localized knowledge spillovers claim that knowledge does not circulate freely across regional boundaries because it is tacit; on the other hand, these studies remain elusive on the specific mechanisms of diffusion of tacit knowledge (Audretsch and Feldman 1996). Studies of knowledge diffusion, with some exceptions, tend to focus only on codified forms of knowledge and on formal channels of transmission (i.e., patents, patent citations, publications, R&D). Second, studies on migration and mobility offer important insights into the motivational factors behind the decision of scientists to move. However, this literature is mostly based on anecdotic or only qualitative evidence. Quantitative evidence instead focuses only on selected groups of skilled workers (e.g., graduates, star scientists) and is limited to cases by country. Future research should shift attention from codified toward more tacit forms of knowledge and from stocks of knowledge toward flows and networks of knowledge.

25.4 Agglomeration, Variety, and Pecuniary External Effects

Agglomeration advantages have been connected with increasing returns to scale, external effects, and with the variety of producers and consumers (Combes et al. 2008). New knowledge changes markets, market structures, and production technologies (including organizational structures). Cities can be perceived not only as locations with agglomeration advantages but also as locations of interacting producers and consumers. Interaction occurs not only via markets but also via social networks, sometimes indicated with “buzz” (Storper and Venables 2004). Baumol (2002) argued that markets are predominant in the process of knowledge creation and diffusion, even when other mechanisms of dissemination also exist, such as social networks, labor mobility external effects (externalities), spillovers, and spin-offs. In various publications, the transfer of knowledge is assumed to be different from other goods and services, most often because it is perceived as a public good, freely accessible to anyone, or as given. In traditional growth accounting literature, “technological knowledge” was accepted as exogenous. Most often, the transfer of knowledge, especially codified knowledge such as books and patents, has a price and occurs via markets. This is also the case for labor mobility, where a higher wage is paid to newly attracted experts. The prices do not always completely cover the costs created by the generators of knowledge; subsequently, in many cases, we can highlight market failure or even more pecuniary external effects. In other cases, one could even address unpaid positive external effects; Alfred Marshall indicated this latter effect by asserting that “it is in the air.”

In the case of technological development and expanding or changing demand, new opportunities are created. This can change the relations between firms in different sectors, which are all confronted with an expanding or changing supply and demand. This requires new production methods and products, a good base for an endogenous process of increasing demand for new knowledge and innovations. Adam Smith and Alfred Marshall emphasized the interrelations between firms with the division of labor and industrial districts. In cities, changes could have their origin in new (technological) knowledge, increasing wealth, or new trade relations, leading to new supply and demand and hence to a larger economic base. As Adam Smith said, “the size of a town depends on the size of the market.” The interrelations between trade, the differentiation of consumers, different kinds of firms, and the development of increasing returns have experienced a resurgence in new trade economics and new economic geography. The economic process is influenced by these factors, but in cities, we can also observe the special influence of positive and negative external effects, which in economic theory has been defined as market failures. However, in the case of increasing market size (growing demand within cities and regions through increasing wealth and trade effects) positive pecuniary external effects are related to increasing returns. This leads to the conclusion that pecuniary external effects are not merely market failures but dynamic opportunities for innovators. Allyn Young (1928), then president of the American Economic Society, emphasized the positive impact of the interrelatedness of firms in the production process. In this structure of relations, as well as in the case of the

development of new technologies, pecuniary external effects could develop because entrepreneurs detect new opportunities for higher profits with new products or new technologies. He stressed that in this case, the opportunities to invest in new technology could result in pecuniary external effects and in increasing returns to scale for the entire structure of related firms. Pecuniary external effects offer new opportunities for entrepreneurs by creating “gaps” in the market. Entrepreneurs can establish new firms and produce new products (physical goods or services). Schumpeter (1934) emphasized that innovation is related to this entrepreneurial function of seeing the gaps in the relation of demand and supply by establishing new firms and improving the allocation of resources.

25.5 Knowledge Spillovers in the Urban Agglomeration Literature

Despite this complex and nuanced way of conceptually linking innovation – the introduction and the application of new or existing knowledge – with growth and cities, an ever-growing body of empirical literature on urban externalities remains rather inconclusive on the exact agglomeration circumstances that optimally enhance growth and innovation in cities. In such literature it is argued that externalities or spillovers occur if an innovation or growth improvement implemented by a certain enterprise increases the performance of other enterprises without the latter benefiting enterprise having to pay (full) compensation. Spatially bound externalities are related to enterprise’s geographical or network contexts and are not related to internal firm performance. All discussions of spatial externalities can be linked to a twofold classification in which the sources of agglomeration advantages are grouped. *Localization economies* usually take the form of Marshallian (technical) externalities whereby the productivity of labor in a given sector of a given city is assumed to increase with total employment in that sector. In short, they arise from labor market pooling, the creation of specialized suppliers, and the emergence of technological knowledge spillovers. The strength of local externalities is assumed to vary, such that they are stronger in some sectors and weaker in others. The associated economies of scale comprise factors that reduce the average cost of producing commodities. External scale economies are applicable when the industry to which the firm belongs (rather than the firm itself) is large. An urban system is composed of (fully) specialized cities, provided that the initial number of cities is large enough; such systems occur contingent on further assumptions on crowding (congestion costs that increase with population triggers dispersion), perfect product, and labor mobility within and between locations, not to mention the influence of large agents. Once cities exist, *urbanization economies* that apply to all sectors become equally important. Urbanization economies are often interchangeably mentioned with Jane Jacobs’ diversity externalities, as (sectoral) diversity tends to be larger in cities than outside them. Frenken et al. (2007) showed that a distinction between variety and diversity externalities and urbanization economies is necessary. A large body of empirical literature has grown around testing

these types of externalities in relation to knowledge spillovers using sectoral specialization, sectoral diversity, and density data from cities. The assumption is that if knowledge spillovers are important to growth and firm dynamics, they should be more easily identifiable in cities where many people are concentrated into a relatively small and confined space where knowledge is transmitted more easily. This literature has evolved in a rather polarized discussion on the question of whether sectoral specialization (clusters) or sectoral diversity matter for economic growth and innovation in cities. Three recent meta-analyses and overviews clearly show the limitations of this empirical approach (De Groot et al. 2009; Melo et al. 2010; Beaudry and Schiffauerova 2009); the outcomes of the many empirical analyses using the Glaeser et al. (1992) framework on agglomeration externalities appear to be highly dependent on spatial scale, sectoral detail, time frame, institutional context, and the construction of indicators and variables. Twenty years of research have not convincingly answered the question “Who was right, Marshall or Jacobs?” (Beaudry and Schiffauerova 2009). The answer is ambiguous; both specialization and diversity are related to growth in different aspects and ways.

In principle, this answer is rather unsatisfactory scientifically for understanding the relation between urban growth, spillovers, and innovation. It is very plausible that the prevailing static urban economic modeling approach, confronting the Marshallian versus the urbanization externalities approach, falls short both conceptually and methodologically, and in its present form is unable to test this important issue satisfactorily. In its conceptual sense, this was previously noted by Lambooy and Van Oort (2005), who suggest four heterodox aspects attached to urban and regional economic growth that are currently (still) relatively unaccounted for in research and should be taken more seriously. These are (a) the importance of the life stages and time frames of firms, technologies, and sectors, or development paths of firms, sectors, cities, and systems of cities; (b) specific spatial networks not showing (clear) relations to the forces of contiguous economic agglomeration; (c) specific urban and regional factors explaining why and through which transmission channels agglomeration forces influence sectors and firms differently, depending on the period of economic development and the various technological trajectories; and (d) factors related to forces that cannot be explained using equilibrium approaches, for example, the relation with institutional structures, path-dependent development, the way selection works out for new technologies and firms, innovation, the rise of new technologies and new regional concentrations of firms, spillover mechanisms, and (co-)evolution. These four heterodox aspects of economic theory and empirics are attached to evolutionary economic development trajectories in a wide range of cities, regions, and countries in the same manner (McCann and Van Oort 2009). In the evolutionary geographical research tradition, much more emphasis is placed on the interaction of the relevant urban and regional environment, with locational choices being made by individual firms and investors (Boschma and Martin 2010). In these traditions, a strong preference exists to allow for the differentiation of firms and types of behavior and locations, addressing the heterogeneity in actors and innovation in cities that were signaled in the previous section. The concept of related variety, indicating that successful sectors in regions diversify over time, though mostly in relation to existing competences and

specializations, is an important exponent of new conceptualizations in the agglomeration, innovation, and growth discussion (Frenken et al. 2007).

Together with these conceptual issues, methodological issues arise as well. More emphasis on a firm or consumer's personal agglomeration circumstances requires a modeling approach that takes firms and consumers as starting point. Duranton and Overman (2005) and Combes et al. (2008) argue that many measures of concentration use arbitrary spatial units (such as provinces, municipalities, or postcodes), which may be problematic, as they may lead to biases. Continuous space specifications of agglomeration circumstances of individual firms therefore become more important in present and future research, avoiding the problems of modifiable areal units signaled in the three review articles. Furthermore, issues of causality, endogeneity, selection, and sorting have to be addressed more thoroughly to ensure that the econometric analyses produce reliable outcomes. Both conceptual and methodological renewal are needed to investigate the nature and origin of knowledge creation and diffusion (transfer mechanisms and absorptive capacity of actors), addressing the central issue of heterogeneous actors as well as the varying contexts in the organization of sectors and networks.

25.6 Conclusions

We have provided an overview of historical and current conceptualizations of knowledge, knowledge diffusion, and innovation in cities. We have argued that knowledge is based on processes of learning as well as research and development, that it is both person specific as well as context specific, and that it can be codified and included in the quality of capital and labor. Recently, much empirical research has focused on the creation and transfer of knowledge across organizations in spatial contexts. We argue that analyses using knowledge production functions to capture these flows generally do not provide us with true insight into the generation and transfer of different kinds of knowledge. Only recently have various conceptualizations of distance and knowledge transmission channels been empirically related to knowledge creation and diffusion, addressing heterogeneity in related actors and processes, and capturing the role of cities in them. Our discussion of knowledge production function methodologies applied to cities has concluded that future research should increasingly and explicitly focus on the transfer mechanisms of knowledge diffusion. This is especially true for research on the mobility of (star) knowledge workers and on the evidently fruitful collaborations between firms and universities. To incorporate this in empirical modeling, econometrical knowledge and innovative applications are needed in this field of research. The chapter has further argued that markets remain the most important kind of interaction for economic actors, even in the case of knowledge. This nuances the large focus on nonmarket factors as put forward in the growing literature on urban competitiveness and innovation. We confronted the plea for a better embedding of the mechanisms that create and diffuse knowledge in agglomerations with current agglomeration discourses and methodologies. We conclude that to address the

apparent impasse on the measurement and interpretation of agglomeration externalities, new conceptual and methodological views are needed here as well. In particular, evolutionary economic and geographical concepts are promising for explaining the innovative behavior of growing firms and organizations in cities, carefully addressing the heterogeneity in the actors involved, spatial scale, selection and survival, and time and path dependency. For this, accompanying econometric tools have to be applied, such as continuous space modeling and causality analysis. The future of urban agglomeration research is thus in the interplay of conceptual and methodological renewal, in close relation to already-established insights: what is needed is renewed and related variety in conceptualization and testing.

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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.

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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 in business 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 Européen 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 unconstrained 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:

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

where kF_{ij} represents the knowledge flow (e.g., measured in terms of patent citations) from origin location i ($i = 1, \dots, n$) to destination location j ($j = 1, \dots, n$). X_i^o and X_j^d are origin-specific and destination-specific factors, respectively, and α_1 and α_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 α_3 and α_4 . α_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.

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