Chapter 8

STYLIZED FACTS IN THE GEOGRAPHY OF INNOVATION

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Abstract

The geography of innovation describes the importance of proximity and location to innovative activity. As part of what has been termed the new economic geography, this area of research is less than 20 years old, and is now developed sufficiently so that the discussion can be organized around certain stylized and commonly accepted facts:

- Innovation is spatially concentrated.
- Geography provides a platform to organize economic activity.

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- All places are not equal: urbanization, localization, and diversity.
- Knowledge spillovers are geographically localized.
- Knowledge spillovers are nuanced, subtle, pervasive, and not easily amenable to measurement.
- Local universities are necessary but not sufficient for innovation.
- Innovation benefits from local buzz and global pipelines.
- Places are defined over time by an evolutionary process.

The purpose of this chapter is to summarize recent work on innovation and location in light of these themes, and to consider how these stylized facts shed light on the broader process of technological change and economic growth.

While firms are one venue to organize economic activity, the resources required to generate innovation are typically not confined to a single firm, and geography provides another means to organize the factors of production. Geography is additionally a venue for complex multifaceted social relationships, and human community and creativity that are beyond the economic sphere. Economies are complex: highly integrated, globally interconnected, and highly agglomerated on centers of activity. There is always the temptation to analyze economic institutions and actors individually; however, the new economic geography literature considers the large context. Of course, once the analysis is open to consider geography there is a need to understand history, building a deep contextualized understanding of a place and the relationships that define it. The present review of the literature summarizes the advancements made in this stream of inquiry, but also indicates that many open avenues for research remain, thus encouraging others to contribute to the emerging field of economic geography.

Keywords

agglomeration economies, geography of innovation, knowledge spillovers, localization, new economic geography, urbanization

JEL classification: A33, O11, O18, O31, O33, R11

1. Introduction

Innovation has a decidedly geographic dimension that affects economic growth and technological change. The deliberate and unintended circulation of knowledge between economic actors and the role of physical proximity and colocation are pivotal in understanding the dynamics of the innovation process. The purpose of this chapter is to summarize recent work on innovation and location and consider how this may shed light on the broader process of economic growth and technological change.

Geography and place-specific interactions shape industries. Connoisseurs talk about *terroir*, a French term used to denote the special characteristics that geography bestows. The term can be translated literally as "dirt" but more poetically as a "sense of place." The term captures the total effect that the local environment has on the product, when the total effect is more than the sum of its parts and the effect is difficult to replicate (Feldman, 2009). For wine and coffee, it is the climate, angle of the sun, age of the stock, and growing and harvesting traditions that creates a unique product. Even the best vineyards experience different vintages, reflecting temporal variations. In addition, while quality winemaking is diffusing internationally, wines have become more complex and differentiated rather than homogeneous.

2. Stylized facts surrounding the geography of innovation: A road map

Historically, economic geographers examined the location of economic activity, considering the underlying determinants of the diffusion of innovation (Brown, 1981; Hägerstrand, 1967). Geographers were cognizant of the uneven spatial distribution of economic activity (Amin, 1994), concentrating on industrial restructuring which emphasized the loss of standardized manufacturing due to growing international competition (Harrison and Bluestone, 1988). However, the upside of this restructuring was the growth of technology-intensive industries and an increased emphasis on innovation and entrepreneurship.

This topic of inquiry has expanded to mainstream economics as a result of Krugman's (1991a,b) key observation linking geography and trade. He found that rather than converging, national economies became more divergent over time. This ran counter to the predictions of neoclassical growth theorists. Lucas (1988) and Romer (1990) challenge the assumption of constant or decreasing returns to scale by pointing out that knowledge is subject to increasing returns because of the externalities inherent in its production and use. Rather than diminishing, the value of knowledge actually increased, as a result of network effects (i.e., a larger number of participants increases the utility to any one user). In addition, nonexcludability (i.e., knowledge is accessible to those who invest in the search for it) and nonrivalry (i.e., knowledge can be exploited by many users simultaneously) are features of knowledge that further support the concept of increasing returns.

Porter's (1990) *Competitive Advantage of Nations* introduced geographic considerations to the field of management, exploring how firms benefit from localized competition. Porter extended his work on firm competitiveness to provide a model of a four-factor diamond, which explains "reinforcing supply and demand conditions, industry conditions, and related and supporting industries." Arguably, Porter provides a more formalized view of the national innovation systems literature (Lundvall, 1992; Nelson, 1993), which describes and analyzes the *gestalt* of innovation processes and technological change. Porter's diamond formalized the actors and relationships.

An extensive literature addresses the topic of geography of innovation and describes the importance of proximity and location to innovative activity. This has been termed the "new economic geography," an area of research that is less than 20 years old (Clark et al., 2000). This field is now developed sufficiently so that the discussion can be organized around certain stylized and commonly accepted facts:

- Innovation is spatially concentrated.
- Geography provides a platform to organize economic activity.
- All places are not equal: urbanization, localization, and diversity.
- Knowledge spillovers are geographically localized.
- Knowledge spillovers are nuanced, subtle, pervasive, and not easily amenable to measurement.
- Local universities are necessary but not sufficient for innovation.
- Innovation benefits from local buzz and global pipelines.
- Places are defined over time by an evolutionary process.

Each of these themes is developed in turn.

2.1. *Innovation is spatially concentrated*

Innovation exhibits a pronounced tendency to cluster both spatially and temporally. There is currently an active debate in the literature about whether the world is flat—that is to say whether opportunities are uniformly distributed, or if there are certain places at certain times that offer greater opportunity. Friedman's (2005) view of a flat world focuses on the impact of globalization, which is certainly significant and deserves attention. The argument of a flat world hails back to the neoclassical view that the economic activity takes place on a featureless plane, with the factors of production able to move frictionlessly between places. However, throughout human history we have observed that creative activity has been concentrated in certain places and at certain times; consider Florence under the Medici, Paris in the 1920s, England during the Industrial Revolution, Silicon Valley and even Wall Street in more recent times. For every generation, there is some location that captures the imagination as a locus of creative activity and energy. The activity may change, but the importance of place remains.

Global outsourcing allows firms to lower production costs; however, technologically sophisticated firms compete on the basis of differentiated performance and innovation. While firms are the entities that take ideas to the market and realize value from innovation, even the largest multinationals are embedded in ecosystems that support and sustain their activity (Gassler and Nones, 2008). These systems are globally connected, but the highest value activity is typically focused in certain locations. The literature alternatively defines collection of firms within one specialized industry or technology, concentrated within the same geographic area by a variety of names such as technopoles, clusters, etc. Marshall (1890) noted this tendency, citing three reasons behind it: an infrastructure of related and supporting industries; the presence of deep, specialized skilled labor pools; and the presence of nonpecuniary externalities due to proximity to a strong knowledge base that facilitates knowledge exchange. These factors are often analyzed relative to geographic concentrations.

Of all economic activity, innovation benefits most from location. Innovation is the ability to blend and weave different types of knowledge into something new, different and unprecedented that has economic value. Similar to art, innovation is a creative expression. However, unlike art, the measure of innovation is not in the eye of the beholder, but in acceptance within the marketplace that brings commercial rewards to the innovating entities and returns to society in terms of economic well being, prosperity, and growth.

Innovation is more geographically concentrated than invention, with invention defined as the first stage of the innovation process. Due to the creation of large patent databases, there are many studies that focus on invention, which should not be confused with innovation. The limitations of patents as an indicator are well known (Griliches, 1990; Scherer, 1984). Patents are geographically concentrated reflecting a concentration of research and development (R&D) activity. This does not necessarily translate into economic advantage for those locations. Feldman (1994) finds correlation of 0.8 in the location of new products introduced to the market and broad patent categories and a correlation of 0.7 between innovation and corporate R&D expenditures. Studies that draw inferences about innovation by focusing on invention should be interpreted with caution. Building on Jaffe (1989), Acs et al. (1994) find that new product introductions were more geographically concentrated than patents, with universities and industrial R&D as important inputs. Feldman (1994) demonstrates that the presence of other local factors such as related industry presence and specialized business services are also determinants of the ultimate realization of invention into product innovation.

Innovation is more geographically concentrated than production. Even after controlling for the geographic distribution of production, innovation exhibits a pronounced tendency to cluster spatially (Audretsch and Feldman, 1996a). The seminal dartboard approach of Ellison and Glaeser (1997) reiterates that geographic concentration is ubiquitous, but also demonstrates that most industries are only slightly concentrated. The aim was to capture the random agglomeration that a dart-throwing model would produce and to see if this was differentiated from industry-specific agglomerative forces resulting from spillovers and natural advantages. The findings indicate that some of the most extreme cases of industry agglomeration are mainly due to natural advantages, such as proximity to water, which would be especially the case if cost considerations concerning the shipment of heavy goods enter the equation of locational choice. However, a high degree of heterogeneity exists among the causes that lead to spatial clustering in most of the remaining industries.

Location matters most at the earliest stage of the industry life cycle. Once a good is at a mature stage of its life cycle costs of production become more important. The propensity for innovative activity to spatially cluster is subject to the industry life cycle, which indicates that there is a direct link between the localization of innovation and the maturity level of particular industries within a territory (Audretsch and Feldman, 1996b). Early stages of the industry life cycles are characterized by the importance of tacit knowledge. Once a product has become standardized and demand will support mass production, it is easier for an industry to disperse geographically.

While a distinction between novel and established products on the market is one way to differentiate between varying levels in the intensity of agglomeration forces, distinguishing between physical and service-oriented production units is certainly another useful approach. Traditional manufacturing, especially if it relies heavily on external production inputs is seemingly less footloose than service-oriented sectors where infrastructure demands and external capital investments are frequently low, and the most significant input factors leading to economic gain are highly skilled, mobile workers. A frequently used example of an innovative platform, which is geographically dispersed, is the open source community (von Hippel, 2001). The globally scattered network of members of this community is certainly impressive; however, it should be noted that most of the tools that are utilized to actually generate open source software products rely on hardware, but also on original source codices such as UNIX,[1] which at one point in time have been developed in particular agglomerated production centers. On the other end of the spectrum, even labor-intensive, low-technology sectors that have experienced a tremendous spatial shift away from highly industrialized places to developing countries, exhibit strong tendencies to cluster, once they are re-embedded into their new locational and institutional setting (Scott, 2006a).

New technologies and new industries, while offering the potential for economic growth, do not emerge fully developed, but begin rather humbly as scientific discoveries, suggestions by product users or suppliers or the novel idea from an entrepreneur. Initially, the commercial potential is unknown and only a few experts or lead users may appreciate its significance. Translating the discovery into commercial activity and realizing its economic potential entails a process that involves building an appreciation of what is possible among potential investors, customers, and employees, building a company and creating a value chain. Increasingly, there is recognition that what matters for place-specific industrial development is not necessarily resources or initial conditions, but the social dynamics that occur within a place and define a community of common interest around a nascent technology or emerging industry (Feldman and Romanelli, 2006). Certainly, this is the case for user-defined innovation (von Hippel, 1988, 2005). Community building, as opposed to insular scientific dialog, can be essential to regional industrial development by constructing a shared understanding and appreciation of the emerging technology (Lowe and Feldman, 2007).

When entrepreneurs confront new technological opportunities, they fashion solutions that adapt what they have on hand from what is easily accessible. The solutions they adopt are more likely to come from local sources—either through tapping networks of people working on similar things or through serendipitous encounters. Most importantly, entrepreneurs use local ingredients in creative and adaptive ways, thus entrepreneurship serves a conduit of knowledge spillovers (Audretsch and Keilbach, 2008, p. 1698). Solutions that appeared to work are repeated and fine-tuned, gradually evolving into accepted routines and operating procedures—the industrial recipes for the region. These recipes are adopted by institutions to define common practices and a common vision of the industry. This encourages further experimentation and adaptation. Knowledge of what does not work, what approaches have previously been tried, and led to dead ends, are part of this local knowledge (Eisenhardt and Martin, 2000; Feldman, 2000; Sitkin, 1992).

In contrast to the logic of specialization, there are benefits to cross-fertilization and collaboration (Jones, 2002). The costs of collaboration are simply lower due to geographic proximity. Geographic proximity promotes serendipity and chance encounters that suggest new uses, new solutions, and refinements. Diversity among industrial sectors within a jurisdiction is considered beneficial to innovative output (Feldman and Audretsch, 1999) and economic growth in general (Glaeser et al., 1992; Jacobs, 1969). However, a distinction between discrete and related variety might offer some further insight in this regard. Perhaps the most important influence on geographic proximity is underlying technical commonalities or related variety (Boschma and Iammarino, 2009). Related

[1] The UNIX system was initially developed in 1969 by a group of AT&T employees at Bell Labs (see http://www.unix.org for a detailed history and timeline). It would take until 1975 until it was widely available outside of Bell Labs.

variety is similar to the concept of Jacobs' externalities, or the relevant diversity between industrial activities that would create the transfer of ideas and spawn innovation. Certainly, much discussion of agglomeration economies focuses on industry localization, which may represent a production orientation or reflect the mature stage of an industrial life cycle, neither of which would be association with new ideas and novelty. Related variety on the other hand, which refers to sectors that have low cognitive distance in terms of their input mix (Frenken et al., 2007), is considered to stimulate innovation by means of spillovers between complementary sectors in the traditional sense of Jacobs-type externalities.

One decisive explanation in this context is offered by the increased importance of regionally embedded tacit knowledge (Maskell and Malmberg, 1999, p. 171). The importance of factors that are of implicit local and evolutionary nature, and therefore are not easily describable, such as the institutional setting, firm and market competencies, knowledge and available skills, and in particular the combination of all of these factors, which in a successful jurisdiction add up to more than the sum of the individual building blocks, is exaggerated in a global marketplace where widespread easy access to codified knowledge seems to be obtained universally. This is clearly a resource centric, or supply driven perspective on how an innovative economy is put in place, and suggests that given the right effort it may be possible to copy and emulate a successful example. However, localized learning processes, which are difficult to codify as they are substantially driven by tacit knowledge and thus regionally specific, need to be present in order to accomplish the continuous creation of improved and novel products and processes. It can be argued, *inter alia*, that knowledge is a fundamental resource, and therefore learning is an essential process that shapes the contemporary technological and innovation driven economy (Lundvall and Johnson, 1994, p. 23).

2.2. Geography provides a platform to organize innovative activity

Just as firms are one means to organize economic activity, geography also provides a platform to organize resources and relationships for economic activity. Beyond the natural advantages of resource endowments, proximity to markets, or climate, certain places have internal dynamics that increase the productivity of investments and result in higher innovation and creativity (Feldman and Romanelli, 2006; Rosenthal and Strange, 2003). These internal dynamics are socially constructed and involve a wide variety of actors. Most importantly, as it is difficult to predict future technological change and market evolution, the greater the number of individuals who are able to participate in creative endeavors, the higher the probability that a place, be it a city, region, or nation is able to capture the resulting benefits.

The resources required to produce innovation are typically not confined to the boundaries of a single firm. Firms frequently contract for external resources, and this can be done at great distances. The motivation is typically saving cost, but his strategy may result in a loss of dynamic efficiencies (Pisano, 1997). Contracting out elements of the value chain for innovative products means that any unexpected results that suggest future improvement or new opportunities are lost. When the value chain is more geographically concentrated there are opportunities for observation and interaction. At longer distance, the relationship is strictly contractual.

Three fundamental spatial scales can be considered to shape the geographic platform in which economic activity and innovation is organized: the global, the national, and the local scale. Some aspects that have a direct impact on innovation processes take place along the continuum of these scales whereas other factors are more specific to one particular scale. The shift from Fordism to post-Fordism, the advent of the information age resulting in globalization, the increasing flexibility of production processes and labor, and the change from a local or national to a global dominated marketplace all indicate that economic activity is now coordinated at the global scale (Dicken, 1998). This view encouraged some scholars to pronounced the "death of distance" (Cairncross, 1997), which they supported by the claim that in the future, economic activity will be dominated by global corporations that are footloose in the sense that they have no real home country affiliation and national identity (Ohmae, 1990). Multinational corporations (MNCs) are the focal entities in the investigation of global innovation activities at the firm level (Pavitt and Patel, 1999). It is recognized that both intra- and extra-organizational networks at the global scale significantly contribute to product and process innovations in MNCs; however, it is also noted that despite the apparent footloose character of MNCs, states or multinational organizations such as the European Union intervene and shape its choices regarding location and innovation strategies. While MNCs have the ability to relocate their sites of production and R&D at random, decisions are strongly guided by the availability of local resources, and the result is the actual innovation processes are still carried out predominantly in a few key regions (Rugman, 2000).

The increasing significance of the global scale seems to have eroded the sovereignty of national economies to the point where they are powerless players in a global game (Ohmae, 1995; Strange, 1997). In contrast some of the literature suggests that the role of nation states is now even more significant than in the past since "with fewer impediments to trade to shelter uncompetitive domestic firms and industries, the home nation takes on growing significance because it is the source of the skills and technology that underpin competitive advantage" (Porter, 1990, p. 19). The early development of the Internet offers an example of the potential instrumental role national public entities play in enabling and supporting innovation and technological change (Greenstein, 2007; Mowery and Simcoe, 2002; Rogers and Kingsley, 2004). Prioritized funding for the development of decentralized communication and transportation technologies by the US Department of Defense provided the initial idea, and substantial funding by the National Science Foundation in turn encouraged and expanded the involvement of a multitude of lead users (Kahn, 1994) transferring this potential technology from the public realm to the marketplace. This combined with favorable regulatory, antitrust, and intellectual property policies along with federal capital investment policies that allowed public entities to invest in venture capital are considered to have further added to the development of the WWW and spurred the development of commercial content and applications. The net result has been the creation of a general purpose technology associated with innovation and economic growth in the 1990s, which to a large extent can be attributed to policies at the national scale (Lipsey et al., 1998).

Recent work has established the importance of government investment in infrastructure to economic growth and competitiveness (Klein and Luu, 2003; La Porta et al., 1999). For example, the quality of transportation and communication infrastructures are frequently acknowledged in terms of trade in physical goods; however, they also directly shape the rate and timing of knowledge exchange that takes place between places (Parent and Riou, 2005). Advanced infrastructure potentially polarizes knowledge spillovers estimates to the extent where highly connected places engage and learn from each at a level that is much more intense than their relative spatial distance would suggest. On the other end of the spectrum, even if two places are closely situated to each other, but lack the support of an advanced transportation and communication infrastructures, knowledge spillovers will take place at a lower magnitude than estimated.

Out of all spatial scales that serve as the point of departure in the analysis of territorial innovation systems, it is probably the regional or local scale that has attracted most attention over the past decades, including participants form a wide range of disciplines. Two basic interpretations of the region as an innovation system have been offered. First, the region simply represents a subsystem of national or sector-based systems. Second, and perhaps more importantly, regions, even in the same national environment, primarily depend on local institutional capacity, which often leads to variances in the delivery of educational and regulatory services across nations. It is argued that as a result of specific advantages from locally rooted institutional capacities, in the form of tacit knowledge, the regional innovation system (Cooke, 1996; Maskell and Malmberg, 1999) is the most important factor for localized learning (Howells, 1996). Untraded interdependencies, which include tacit knowledge that is based on face-to-face exchange, routines, habits and norms, conventions of communication and interaction are considered important assets that shape the innovative potential of a region (Storper, 1997).

One of the primary reasons why regions, and in particular cities, have moved to the center of attention is based on the finding that inventors heavily rely on local information or knowledge as input factor for novel products or processes. Local variations in information available to decision makers exist, and in most instances information can be very costly to transfer from place to place. Such information "stickiness" can have a number of causes (von Hippel, 1994). First, this can be due to the attributes of the information itself, such as the way it is encoded (Nelson, 1982, 1990; Rosenberg, 1982). Second, information stickiness may be due to attributes of the information holders or seekers. The lack of "absorptive capacity" (Cohen and Levinthal, 1990) by a particular information seeker could limit their ability to acquire information due to the lack of certain tools or complementary information. Third, the availability of specialized organizational structures such as transfer groups (Katz and Allen, 1988) can significantly affect the information transfer costs between and within organizations.

In addition to the concept of "stickiness," the "communities of practice" literature (Brown and Duguid, 1991; Wenger, 1998) provides further insight into why innovators tend to use local information. This stream of thought recognizes the situated nature of knowledge as it is created by a community of individuals who have a shared practice or problem. One of the main arguments is that the ways people actually work usually differs fundamentally from the ways organizations describe that work in training programs or organizational charts (Granovetter, 1985). Knowledge is not only considered tacit, in the sense of it being not explicit (Nonaka, 1994), but also knowledge and knowing in general cannot be separated from an individual's engagement in the practicing of their practice (Cook and Brown, 1999). Communities of practice exist in a variety of settings and may develop improvements or innovations in products, services, and work practices in environments that have not much in common with the traditional geographic platform of economic organization, including newsgroups, cyber communities, or knowledge forums. This suggests that relational proximity might be a substitute for spatial proximity (Amin and Cohendet, 2004). However, there has to be a clear distinction between knowledge (i.e., technical expertise that leads to the development of a new product) and contents (i.e., random bytes of data or information that is interesting but of no particular economic value). While content is readily available, knowledge is best transmitted via face-to-face interaction. While it is possible for individuals to come together in temporary agglomerations, the more frequent and trusted interaction predominantly occurs in a collective place. Cities are key examples of such places of knowledge exchange, and in addition they are also primary places of creativity (Scott, 2006b) and dense locations of knowledge generation and spillovers (Feldman and Audretsch, 1999).

Innovation is inherently evolutionary, and in its fundamental nature consists of a multitude of socioeconomic interactions across different spaces and scales (Edquist et al., 1998). Geography provides a platform to organize these interactions, and focusing on only one spatial scale will perhaps not be sufficient to fully understand innovation processes (Bunnell and Coe, 2001). There are many distinctive parts that shape economic activity in a particular place (Feldman and Martin, 2005). This includes not-for-profit organizations, such as universities, research consortia, and standards setting organizations that play a significant role in affecting scientific opportunity and the diffusion of innovation, or other public entities, such as foundations that may fund research and help create markets. In addition there are also civil society organizations that create opportunities for discussion and engagement, and may formalize social networks, as well as intangible assets such as the reputation of a place in terms of business climate, or even the geopolitical setting that connects it to other political units. Institutional setting can be investigated at various spatial scales, local, regional, national, and global. Critical to understanding the dynamics of place is the interrelationships between the various spatial scales and institutions as national laws set the agenda for what lower levels of government may accomplish. Any attempts to replicate Silicon Valley are doomed to fail. What is needed is an understanding of the unique geographic platform on which innovation and economic growth is situated.

2.3. Places are not equal: Urbanization, localization, and diversity

The advantages that accrue to specific places are due to external economies of scope or agglomeration economies. When we refer to agglomeration economies, there are three different concepts to consider: urbanization, localization, and diversity economies.

Economic entities strive to obtain maximum output for a given set of inputs in order to gain comparative advantages in the market. Internal economies of scope, that is, improved efficiency due to product portfolio management, and scale, that is, increasing effectiveness in the utilization of the factors of production, to some extent explain variations in the performance of firms beyond a simple profitability framework (Bercovitz and Mitchell, 2007; Henderson and Cockburn, 1996), but what remains are a set of aspects benefiting the performance of such units that occur due to location, providing a comparative advantage that can be attributed to external economies of scope.

Urbanization economies refer to the component of agglomeration economies that focuses on the actual size of a place itself to explain varying levels of productivity, regardless of competition. Research in this stream has produced mixed results, but principally indicates that doubling the size of a city generally creates a productivity increase ranging from about 3% to 8% (Segal, 1976; Sveikauskas, 1975; Tabuchi, 1986). More recently, urbanization economies have been investigated in terms of inventive output rather than overall productivity levels. Bettencourt et al. (2007) find that large metropolitan areas have disproportionately more inventors than smaller ones, and they generate more patents, which indicates that increasing returns to patenting exist as a scaling function of city size. What remains to be validated is if larger metropolitan areas attract or generate more inventors, or both, than their smaller counterparts.

Localization economies on the other hand are attributed to the concentration of an industry at a particular place rather than agglomeration itself. The initial discussion of the advantages that derive from a densely spatial agglomerate of firms belonging to the same industry sector dates back to Marshall (1920). Three specific benefits are highlighted in this context: the spatial concentration of input–output linkages between buyer and supplier networks, the character of local labor pools with a high degree of specialization, and embodied knowledge spillovers that facilitate the diffusion of technical knowledge (Marshall, 1885). When localization and urbanization economies are investigated simultaneously the results point to a stronger impact of the former on productivity, but industry variations seem to exist (Henderson, 2003; Rosenthal and Strange, 2003). While the discussion regarding the relative importance of urbanization and localization economies to productivity and growth remains vibrant, contemporary research on the impact of external economies of scope frequently focuses on questions regarding specialization and diversity (Rosenthal and Strange, 2004).

Contrary to Marshall's findings, relating to urban specialization, Jacobs (1969) points to the significance of urban diversity as a source of external inputs that boost creativity and subsequently economic activity. The main argument in this context is that the diversity found in agglomerations fosters and enhances the cross-fertilization of ideas between industrial sectors. Although Marshall (1920, pp. 273–274) already recognized the inherent risk that a strictly localized industry produces in terms of vulnerability to external shocks in demand, or local labor uniformity that excludes certain segments of the population from participating, it was Jacobs' account that stressed the importance of diversity to economic development. In this context, development is considered growth through diversification, as the cross-fertilization of knowledge and technology between diverse sectors in the economy leads to the differentiation, diversification, and transformation of the underlying processes of production, which in turn directly influences total factor productivity (Ellerman, 2005). Much of the recent literature, which aims to investigate the effects of agglomeration on innovation and productivity, proceeds to situate external economies of scope, that is, localization and diversity, within a dichotomous framework, therefore generating a fundamental division between them (Baptista and Swann, 1998; Feldman and Audretsch, 1999; Glaeser et al., 1992). The results are mixed, and in some cases Marshall–Arrow–Romer (MAR) externalities[2] are considered more prevalent (Baptista and Swann, 1998), while in others, Jacobs' externalities (Feldman and Audretsch, 1999) are thought to dictate local knowledge spillover processes, and in some instances both types of externalities are found to be significant (Capello, 2002). The substantial variations in the findings are unsatisfactory and continue to fuel further research efforts in this context; however, they may also point to the necessity to review some of the underlying principles that guide research efforts on agglomeration economies, in particular we need to reconsider the potential inequality of places.

Marshallian externalities, which are concerned with intraindustry economies of localization, are different from Jacobs' externalities that refer to interindustry exchanges between different technologies and sectors within a particular metropolitan area, and therefore are not a mutually exclusive phenomenon (Ibrahim et al., 2009). Also, while the overall diversity of economic activity, and increasingly cultural activity (Scott, 2006b), within a metropolitan is pivotal in explaining performance resulting from the cross-fertilization of ideas and subsequent economic development, it does not rule out that

[2] Glaeser et al. (1992) formalized the MAR externality, which concerns knowledge spillovers between firms in an industry, based on the findings of Marshall (1890), Arrow (1962), and Romer (1990).

concurrently a progression of specialization, as indicated by a concentration of employment in a particular industry takes place within the very same city. Another aspect that should be considered is that diversity and specialization might play very different roles in terms of which kind of innovation they produce. The potential to generate radical, disruptive innovative output should be higher when very diverse sectoral knowledge bases are combined, while incremental innovation should demand specialized knowledge, which is necessary to improve existing technologies (Schumpeter, 1942). Seemingly the relationship between the relative importance of localized specialization and diversity to economic growth should not be characterized as a continuum from evolutionary to revolutionary innovation, but not as a dichotomous one (Christensen, 1997).

Finally, and most importantly, from a spatial perspective much work that attempts to investigate and differentiate between these two types of external economies of scope relies on aggregate data sources, and while presumably statistically significant, is not able to capture the substantial sectoral and spatial variety that exists at a particular place. Thus, much of the findings are not uncovering fundamental dimensions of innovation, but rather provide secondary results, which warrants caution to generalize and apply conclusions universally to all places (Scott, 2006b). This leads to yet another scope that should be considered in a comprehensive analysis of agglomeration economies, the temporal one (Rosenthal and Strange, 2003). Places are intrinsically evolutionary, which stresses the importance of historic events in shaping local economic activity. Research related to the static or dynamic nature of agglomeration economies provides evidence of the dynamic components of spillovers, but fails to fully address the underlying mechanism that facilitate them (Glaeser and Mare, 2001; Henderson, 1997).

Large metropolitan areas are among the most productive places (Ciccone, 2002; Ciccone and Hall, 1996; Feldman and Audretsch, 1999; Harris and Ioannides, 2000). Glaeser and Mare (2001) provide evidence that an urban wage premium, resulting from a combination of wage level and wage growth effect, exists, which potentially explains why workers in cities earn relatively more than their counterparts in nonurban areas. While it is unclear if a more efficient coordination of labor markets, or factors of accelerated learning, in cities cause higher levels of urban wage growth, this analysis also indicates that the workers who eventually leave cities continue to enjoy relative higher wage premiums. Recent evidence also suggests that cities may experience higher levels of productivity due to the positive relationship between hours worked and the density of professionals within an occupational group, in a particular metropolis. In addition to spatial agglomeration, the presence of rivals among professionals appears to further increase the number of hours worked, and subsequently productivity (Rosenthal and Strange, 2008). While the idea that cities are very vibrant and busy places is indeed not a new one, the actual notion of an "urban rat race," which conceptualizes the relationship between agglomeration and work output was first introduced by Akerlof (1976), not much attention has been given to concepts such as adverse selection processes or competition among professionals, as they relate to the work routines of professionals in urban agglomerations.

2.4. Knowledge spillovers are geographically localized

Knowledge is an ethereal concept that is perhaps best considered as embodied in human capital, which is individuals who are able to comprehend, integrate, and create new knowledge. Individual productivity is definitely influenced by location, that is, individuals with a given set of characteristics will have different levels of productivity depending on their location (Rigby and Essletzbichler, 2002).

The ground-breaking findings of Abramovitz (1956) and Solow (1957), which established that there was a large residual of aggregate productivity growth unexplained by capital accumulation, and Kuznets' (1962) pioneering research on the nature of inventions, have given rise to knowledge being named as the key economic asset that drives long-run regional and national economic performance. In particular, the concept of knowledge externalities or spillovers has become the focal interest in multiple disciplines concerned with research relating to the dynamics of location, and their impact on the processes of agglomeration of innovative activity. Contemporary research regarding knowledge spillovers in a spatial context takes into consideration and builds upon two commonly accepted facts. First, that innovative activity is concentrated in space (Feldman, 1994, 1999; Moreno et al., 2005), and second, that knowledge flows are geographically localized (Bottazzi and Peri, 2003; Branstetter, 2001; Jaffe et al., 1993; Maurseth and Verspagen, 2002; Sonn and Storper, 2008).

The significance of knowledge inputs in the generation of innovation and technological change, which in turn is followed by economic growth, combined with the fact that knowledge spillovers are considerably localized suggests that the performance of a jurisdiction heavily depends on what type and amount of knowledge will be produced internally. Strong connectivity between inventive agents within a regional community essentially benefits diffusion processes, but in more fundamental terms provides the exposure to new knowledge and perspectives that allows for increased creativity and innovativeness (Cowan and Jonard, 2004). In addition, regional network aggregation, that is, the connection of previous separate communities within a spatial cluster, creates opportunities for technological brokerage, which again will increase knowledge spillovers within a particular place (Burt, 2004).

The importance of geographic location as a factor for knowledge creation and innovative activity, in a world that is reliant on technology that provides instant communication may seem irrelevant and even paradoxical. After all, telecommunications technologies have triggered a virtual spatial revolution. Geographically dispersed activities may be linked electronically in real-time transactions. However, in this specific context, a sharp distinction between codified and tacit knowledge inputs has to be made. Codified knowledge is technical information that can be found in publications. It can be easily communicated through conventional media, and therefore has an extended spatial reach. Conversely, tacit knowledge constitutes the specific capabilities of individuals. To a large extent it describes the outcomes produced from social and institutional settings found within a particular place. This type of knowledge is best transferred through face-to-face interactions and, in general, is difficult to exchange over long distances (Gertler, 2003).

However, spatial proximity alone may not be sufficient enough for knowledge spillovers to occur. In addition, cognitive and social distance also has to be overcome by individuals and firms in order to engage in efficient knowledge exchanges that lead to learning processes and subsequent innovation. In other words, knowledge can only spill over if the involved parties exhibit an optimal cognitive distance (Nooteboom, 2000), because only then it will be possible to absorb and implement the external knowledge that in turn results in technological change and enables innovation (Cohen and Levinthal, 1990). Too much cognitive distance, which is the case when individuals or industries operate in very different knowledge bases and/or institutional settings, might prohibit communication and therefore entirely eliminate knowledge spillovers. On the other hand, too much cognitive proximity, which exists among firms that work in similar product portfolios and rely on related problem solving techniques, may result in spillovers that possess minimal value added, and in the worst case perhaps even diminish possible inventive advantages a firm may enjoy over its competitors. Related variety, not necessarily regional diversity or regional specialization, which refers to an optimal cognitive distance, is considered to be the most supportive factor for effective knowledge spillovers that actually lead to increased innovative output in a particular locality (Boschma and Iammarino, 2009; Frenken et al., 2007).

2.5. Knowledge spillovers are nuanced, subtle, pervasive, and not easily amenable to measurement

Significant considerations need to be taken into account in any investigation concerning knowledge externalities. First and foremost knowledge spillovers are nuanced in the sense that different variations exist. A broad distinction originates from Griliches (1979), who differentiates between two types of knowledge spillovers. On the one hand there are knowledge spillovers that are associated with the exchange of goods, they are labeled "rent spillovers," and refer to knowledge that is rival and excludable in nature. Alternatively there are those that arise purely from the process of R&D, which are identifies as "pure spillovers" or "idea-creating spillovers." This type of knowledge spillover refers to knowledge that is characterized by its nonrivalry and nonexcludability as it can be utilized by many users at the same time and is freely available. Due to these specific qualities, the nature of this type of knowledge is considered to resemble that of a public good (Arrow, 1962). There are some important implications resulting from these two particular properties of pure spillovers, which were first pointed out by Arrow (1962) in the context of public goods. First, nonexcludability implies that it is impossible to prevent someone from consuming it. In other words, if research results are disseminated through the regular channels of communication, for example, by means of publication in journals or books, or Web sites, knowledge enters the public realm, and therefore becomes available to anyone who searches for it. Second, nonrival knowledge or goods may not only be consumed by many individuals at the same time, but additional users of said knowledge, will not decrease the amount or quality available to others. In essence, readily available research results constitute a nonrival good, as their utility is not influenced by the size of the actual user group.

The intricate nature of knowledge and its associated spillovers pose a challenge when trying to draw such a strict dichotomous distinction. Upon closer examination pure knowledge externalities, frequently claimed to be the primary focus in this stream of research, turn out to be mediated by market mechanisms (Geroski, 1995), and therefore influence local firms' innovation opportunities indirectly through pecuniary rather than pure knowledge externalities (Breschi and Lissoni, 2001a). The complexities involved in describing true knowledge spillovers, that is, ideas that benefit research efforts in one industry or firm that originates from the results of previous undertaken research in another industry or firm, is reflected in the lack of a universal definition in the literature. In general, knowledge spillover can be considered, "intellectual gains by exchange of information for which no direct compensation to the producer of the knowledge is given or for which less compensation is given than the value of the knowledge" (Caniëls, 2000, p. 6).

Knowledge spillovers, while pervasive in shaping innovation, are also inherently subtle, making it a difficult phenomenon to identify and to measure. A general skepticism concerning the difficulty of measuring spillovers is reflected in Paul Krugman's statement "knowledge flows [. . .] are invisible; they leave no paper trail by which they may be measured and tracked, and there is nothing to prevent the theorist from assuming anything about them that she likes" (Krugman, 1991b, p. 53). Contrary to this view, Jaffe et al. (1993, p. 578) indicate that "knowledge flows do sometimes leave a paper trail, in the form of citations in patents," and, by this, suggest the research potential of this method as a means of studying the complex Webs of knowledge spillovers across locations, technologies, and time. Patent citation analysis, the study of citations made to previous patents, provides the opportunity to gain insights into the process of knowledge flows rather than just present a proxy measurement (Jaffe and Trajtenberg, 2002). Also, patent citations provide a way of exploring pure knowledge spillovers as they correspond to the nonrival property of knowledge that forms the foundation of endogenous growth, rather than pricing or pecuniary externalities that derive from the exchange of goods (Griliches, 1979).

The computerization of patent data by national patent offices, such as the United States Patent and Trademark Office (USPTO) or the European Patent Office (EPO) and further the provision of these data by commercial data vendors such as the Derwent World Patents Index offered by Thomson Reuters, have made patent data widely accessible to researchers. However, it was the first NBER US Patent Citations Data File (Hall et al., 2001),[3] and the original method presented in the seminal paper by Jaffe, Trajtenberg, and Henderson (1993, hereafter referred to as JTH), which especially enabled and inspired both geographers and economists to carry out a series of investigations that demonstrate the localization effect of knowledge spillovers, thus making patent citation analysis the most commonly used approach in this context. The goal set out in the original JTH experiment was to test whether knowledge spillovers are localized, by comparing the geographic location of patent citations with that of the cited patents. Further, the goal was also to measure the extent, it at all, that localization was present. To adjust for uneven patent output growth and varying levels of technology focus between spatial entities, a control sample was constructed. For each patent that cited a sample of original patents, a corresponding control patent was identified belonging to same technology class and as near as possible to the application date, to assure that the control patent closely resembled the citing patent in terms of technology and timing of the invention. The control patents, which are geographically matched with the original or cited patents, were then used as a baseline or reference value in the comparison of the frequency of geographic matches between the actual citing–cited patent pairs. The rational was to compare the localization of citations with that of similar patents that were not linked through citations to the original patents. The results confirmed that knowledge spillovers as indicated by patent citations are indeed localized. At the city[4] level citations were two to six times as likely to come from the same jurisdiction as control patents if self-citations were excluded from the analysis.[5]

The JTH control technique, which in its own class has somewhat become the standard methodology in the exploration of knowledge spillovers through patent data, has been employed in numerous similar studies since its inception (Almeida, 1996; Almeida and Kogut, 1997; Hicks et al., 2001), and it still applied today (Sonn and Storper, 2008), but has also been subject to substantial critique, in particular by Thompson and Fox-Kean (2005, henceforth TFK). The main concern put forward by TFK is that JTH's matched case-control methodology might not adequately control for existing patterns of industrial activity, which induces a systematic bias in the results, thus potentially portraying evidence that supports the localization of knowledge spillovers where really none exists. In essence, TFK outline two significant problems in this regard. First, matching of control patents to their citing counterparts is

[3] The National Bureau of Economic Research (NBER) is working on a major National Science Foundation (NSF) funded update and extension of these data; the new NBER patent data file is scheduled to be released in 2010.

[4] Cities refer to SMSAs, which are based on 1981 Standard Metropolitan Statistical Area definitions.

[5] Self-citations in Jaffe et al. (1993) refer to citing patents that are owned by the same organization as the originating patent; they do not represent an externality.

done by the broad three-digit USPTO technology classification, which suppresses "within-class" heterogeneity due to aggregation. Second, most patents contain several distinctive claims, each of which is assigned a different technology code in addition to the primary code used in the matching process. Again this makes matching a control patent a random task as it may not resemble the citing patent that is associated with the original patent. In summary, TFK question the level of precision by which the control patents eventually match their paired citing patents in terms of industrial similarity, something that could have a substantial effect on the final results as the derived "control frequency," which is used as a reference value in the evaluation of a geographic match between the citing and paired control patent to the original patent, might be erroneous. The results obtained by TFK, by applying subclasses rather than just the main three-digit classification in the selection process of control patents, show that there is no statistical support for intranational localization effects, but verifies JTH's earlier findings of localization at the country level. The reassessment concludes that in principal the JTH methodology is capable of indentifying the localization of knowledge spillovers, but only if controls are carefully selected based on the suggested detailed technology subclass classification (Thompson and Fox-Kean, 2005).

Henderson et al. (2005) provide comments on the reassessment of the JTH methodology carried out by Thompson and Fox-Kean (2005), in particular they point to the possibility that the lack of localization effects in the results, at the intranational scale, are due to a possible sample selection bias induced in the final step of the TFK test, where the sample is restricted to control patents whose primary subclass matches the primary subclass of the citing patent. The key problem, identified by Henderson et al. (2005), with the methodology applied in the TFK experiment relates to the missing justification as to why spillovers should only occur within the narrowly defined subclasses. An analysis that relies fundamentally on intratechnology flows would follow the argument of specialization, but at the same time would certainly exclude any possible evidence pertaining to knowledge spillovers from other technology sectors in the process of invention, thus rendering arguments for diversification inadequate. If knowledge spillovers are mainly intrasectoral, the impact of industrial specialization, and consequently the pattern of knowledge flows, is very different than in a system where technology spillovers flow easily between industries (Lucas, 1988). Controlling for the geographic and temporal distribution of "technology in order to identify knowledge spillovers is very tricky, and [. . .] the exercise in JTH can hardly be regarded as conclusive in that respect" (Henderson et al., 2005, p. 463). This suggests that further research is warranted.

Maurseth and Verspagen (2002) offer an alternative approach for capturing technological linkages, which has been an area of criticism in the JTH methodology, by constructing a regional compatibility index for all regions across Europe; however, they derived similar results, which also indicate that geography matters. Furthermore, studies that examine whether or not the strong proximity effect of knowledge spillovers found in macrolevel studies also holds true in a microcontext, generally confirm the proximity effect on spillovers, and find significant negative coefficients on the geographical and technological distance variables (Verspagen and Schoenmakers, 2004).

Patent citation analysis is not the only research framework that may be utilized to quantify knowledge externalities. An alternative stream of analysis focuses on the movement of people, and is based upon the idea that knowledge is embedded within an individual. In contrast to patent citation analysis, which focused on the mapping of codified knowledge, research undertaken in this context attempts to measure the flow of tacit knowledge (Polanyi, 1958), which is an equal pervasive but different part of knowledge spillovers. This type of knowledge is not only considered tacit, in the sense that it is not explicit (Nonaka, 1994), but there is also the understanding that knowledge is embedded in the individual, and cannot be separated from a person's functionality (Cook and Brown, 1999). For example, a study carried out by Zucker and Darby (1996) found that the agglomeration of star scientists (defined as highly productive individuals who have discovered a major scientific breakthrough) in the biotechnology field, directly results in a high concentration of new biotech ventures at the same location. In a similar study, Almeida and Kogut (1997) show that mobility patterns of star patent holders in the semiconductor industry match the transfer of knowledge, and therefore directly influence the geographic patterns of knowledge spillovers.

One of the problems that occurs when the mobility of individual (skilled) workers is used to demonstrate knowledge spillovers, is actually verifying how much pure knowledge spillovers, that is, appropriate knowledge that benefits the new firm to be more innovative, is generated. The seemingly tacit character of knowledge is questionable, because knowledge is actually embodied in human capital. In other words, what actually occurs when an individual moves from one firm to another is more of a knowledge transfer rather than a knowledge spillover. The literature surrounding *evolutionary economics* (Nelson and Winter, 1982) is particularly informative in this context.

This work discusses the forms of organizational knowledge that is embodied in firms' organizational routines, but not in individuals. Firm capabilities, in particular once they have demonstrated innovative success in the past, are eventually standardized, and therefore create an internal path dependency that is frequently rooted in local practices. However, at the same time that a firm develops greater path dependency, it also exhibits a lower receptivity to external knowledge sources. Thus, the effectiveness of knowledge sourcing in the form of highly skilled mobile workers relies on the degree of path dependency. Song et al. (2003) illustrate that mobile engineers who join a firm with stronger path dependence are less likely to build upon the knowledge of their previous firms, especially if the engineer's key area of expertise lies inside the core technology areas of the new firm. Furthermore, workers that embody relevant knowledge may tend to move locally for a number of reasons, such as risk aversion, localization sunk costs, and existing social ties, but because they are already embedded into local practices, regardless if they are concerned with technical or organizational routines, may not provide the desired knowledge transfer which is capable of inducing structural changes that lead to increasing levels of innovative output.

Of course, noncompete and nonsolicitation covenants, which are common practice in certain localities, potentially influence highly skilled labor mobility in that it becomes mainly of a cross-border nature, and therefore indirectly affect the quantity and direction of local knowledge spillovers (Stuart and Sorenson, 2003). Saxenian's (1994) work on Silicon Valley, which discusses some of these agreements, has shown that the absence of such covenants may result in a high rate of mobility between firms, something that is now considered a central contributing factor to the supportive entrepreneurship culture that has developed in Silicon Valley. Notably, the California noncompete provisions were not a strategic entrepreneurship policy enacted by California lawmakers. Gilson (1998, p. 5) notes, "Rather, the California prohibition dates to the 1870s, a serendipitous result of the historical coincidence between the codification movement in the United States and the problems confronting a new state in developing a coherent legal system out of its conflicting inheritance of Spanish, Mexican, and English law."

Of course, not all communities are defined by physical proximity. Recent studies suggest that members of scientific disciplines form epistemic communities, where they develop a great level of trust and communicate more frequently regardless of distance. An epistemic community is defined as a collective of individuals dedicated to the production of knowledge, with recognized expertise and competence in a particular domain, and who share a common understanding and language pertaining to problem solving within this specific area (Amin and Cohendet, 2004). The need to communicate about scientific findings that are relevant to a small spatially dispersed group indicated that there is greater interaction with this specific community than with other unrelated individuals in close physical proximity. Thus, social proximity potentially explains a significant share of knowledge externalities, and it is actually the borders of epistemic communities that define the scale of investigation rather than local or national borders when studying knowledge spillovers (Breschi and Lissoni, 2003; Singh, 2004). However, this does not explicitly imply that geography does not matter anymore in terms of knowledge diffusion and spillovers, as interpersonal networks are actually embedded in physical space (Singh, 2005). These may be considered the remnants of the prior geography–social relationships that were established by previous proximate contact (Bercovitz and Feldman, 2010).

In a more direct measure of knowledge spillovers, Feldman et al. (2009) employ indicators of knowledge sourcing provided by inventors obtained through survey data, rather than secondary sources such as patent citations. This type of analysis mimics closely the idea of Marshallian knowledge spillovers by investigating the underlying geographic distribution of knowledge generating agents. The findings show that even after controlling for the existing distribution of inventive activities, knowledge spillovers benefit from geographical proximity. This analysis provides further evidence for the breadth of knowledge spillovers at the microlevel, that is, individual inventors who are actually utilizing spillovers in the process of stimulating technological change.

Another approach used to explore knowledge spillovers is based on the finding that knowledge can be embodied in goods. As a result, knowledge externalities can be mapped using trade patterns (Feldman, 1999). However, trade pattern data is, in most cases, not available on a subnational level, which confines this stream of analysis to the international level (Coe and Helpman, 1995). In addition, trade patterns, even if they are considered in an international context, focus on what might be described as technology diffusion rather than knowledge diffusion (Jaffe and Trajtenberg, 1998), therefore this approach is interpreted as a reduced form of evidence of knowledge spillovers across international boundaries. It is acknowledged that bilateral trade flows are strongly correlated with various forms of communication and information transfer making it difficult to "distinguish the effect of pure knowledge flows from the effect of technology flows embodied in advanced capital goods sold from one country to another" (Jaffe and Trajtenberg, 2002, p. 200). In Chapter 19, Keller discusses in detail how import, export, and foreign direct investment (FDI) data can be employed in an analysis of international technology spillovers.

Certainly, we believe that receptivity to knowledge declines as physical space increases. Similar to the manner that Van Thunen's urban rent gradient decreases from the city center, we expect that the transmission of knowledge declines over physical space. Face-to-face contact, social and cultural commonalities, a shared understanding and language in a specific technology field, are all attributes that hint at the localized character of knowledge spillovers. There is a broad consensus over the significance and the widespread use of the concept in the literature, but the inherently nuanced, subtle and pervasive character of the phenomenon, combined with the complexity to measure it, continues to generate disagreement, and therefore it seems that knowledge spillovers to a certain extent remain a black box, whose contents needs to be further investigated in order fully comprehend the localization of innovation processes (Breschi and Lissoni, 2001b).

2.6. Local universities are necessary but not sufficient for innovation

Universities are increasingly viewed as engines that are able to drive innovation and economic growth. In the knowledge economy universities are perceived as important input suppliers, both in terms of providing skilled labor and innovative ideas, but also as instrumental institutions that shape technological progress through various mechanisms as outlined by Salter and Martin (2001):

- Increasing the stock of knowledge
- Training skilled graduates
- Creating new instrumentation and methodologies
- Facilitating the formation of problem solving networks
- Increasing the capacity for problem solving
- Creating new firms

Universities have provided economic advantage to the regions they are located in since their onset, and reducing them to a simple factor of production ignores the fact that they have long been places of contemplation and exploration, unfettered inquiry, free expression, and public discourse, significantly shaping the sociocultural environment of regions and nations, thus building quality of place. Gertler and Vinodrai (2005) describe universities as anchors of creativity with the ability to attract highly skilled talent in the form or researches and students. These individuals potentially add to existing local knowledge assets in a region, which in turn strengthens local innovative competences.

The historical conceptualization of innovation, that portrays technological change as a linear process, places universities at the earliest stage of knowledge creation (Bush, 1945). However, since the shift from a closed innovation system to a more open one (Chesbrough, 2003), which is increasingly visible in the contemporary knowledge-based economy, universities are increasingly considered advanced production sites of applied research rather than just a provider of basic science findings. This has a significant impact on local economic growth as university spin-off firms are frequently acknowledged as one of the key drivers of technological change and subsequent economic growth, leading to the development of economic successful regions (Bercovitz and Feldman, 2006). Today, most advanced national economies strive to generate economic wealth by exploiting and diffusing public research by means of commercializing university research (Clarysse et al., 2005). In many cases, however, such endeavors have experienced limited success (Callan, 2001), and although comprehensive case studies of Silicon Valley, Route 128, and Research Triangle Park (RTP) highlight the supportive role of local universities, the literature points to the finding that research universities are a necessary, but not sufficient, condition for regional economic development.

Although universities are frequently considered one of the engines of growth (Feller, 1990; Miner et al., 2001), there are examples of prolific institutes that have either not been successful or do not actively participate in the pursuit of commercializing research findings, and yet their contribution to the advancement and dissemination of knowledge is profound and should not be underestimated (Feldman and Desrochers, 2004). After all, universities produce both the new ideas and skilled workers that are essential to innovation and economic growth, although the path is indirect. In contrast to commercial firms with a relatively simple profit motive, universities have complex objective functions that involve a variety of educational and societal objectives, as well as the interests of faculty members, students, politicians, and the larger scientific community. Also, the rate and direction of knowledge transfer and the actual strength and importance of linkages leading to university–industry partnerships vary significantly among industry sectors. In sectors where science plays a major role, as is the case in the biotechnology and information technology fields, the significance of university knowledge inputs, which preferably are readily accessible at a particular locality in order to gain a competitive advantage through localized knowledge spillovers, are certainly stronger than in other less knowledge-intensive sectors.

One particular important, and highly localized, transfer mechanism through which knowledge spillovers are realized is through knowledge exchanges that take place between people. Ideas embodied in individuals who possess particular skills, specific knowledge, and valuable know-how, have the potential to significantly influence the rate and direction of technological change at a particular locality. Universities play an important role in this context as they employ and train highly skilled scientific personnel. Of particular interest in this context are star scientists, which are defined by Zucker and Darby (1996) as highly productive individuals who discovered a major scientific breakthrough. Employing this criterion and based on the premise that such individuals embody the intellectual capital to enable the commercialization of advanced research findings, Zucker et al. (1998) investigate the impact of star scientists in the formation of New Biotech Entities (NBEs). The results show that the startup rate of NBEs is considerably higher in regions where the intellectual capital resides, that is, where outstanding scientists as measured by research output are located. Strong linkages between stars and NBEs are indicative of higher levels of productivity compared to regions where such linkages are missing. Overall, intellectual capital, as indicated by the number of stars and their collaborators in a given area, is considered the main determinant of where and when the US biotechnology industry developed (Zucker et al., 1998). In a similar attempt, Almeida and Kogut (1999) follow intellectual capital through interfirm mobility patterns of major patent holders in the semiconductor industry. One of the primary findings is that interfirm mobility of these highly skilled intellectuals significantly influences the transfer of knowledge, and that these transfer mechanisms are embedded in regional labor networks. However, Almeida and Kogut (1997, 1999) also show that the localization of knowledge diffusion displays considerable regional differences, thus variations in the spatial patterns of knowledge externalities exist. Particular strong localization effects are observed in Silicon Valley, one of the industry's most prolific regions. The investigation emphasizes the role small firms play, and in particular startups, as they display higher levels of research productivity than larger entities, which is more evident in the United States compared to other countries, and then again more so in specific industries (Pavitt et al., 1987; Scherer, 1984), as these entities are in particular sensitive to university research inputs that mostly take place in spatial proximity (Feldman, 1994). Following this argument, the impact of local university research may be a universal phenomenon, but is amplified in the context of firm formation, which in turn represents an integral segment of the economy driving technological change and subsequent economic growth.

The fundamental question regarding the role universities should play in an advanced economy is certainly accompanied by the concern that the current high level of emphasis on university–industry partnerships may be to the detriment of the significant role these institutions play for longer-term economic growth (Nelson, 2001). Chapter 6 provides an in-depth discussion of the significant role university research and public–private interaction play on innovation and economic growth.

2.7. Innovation benefits from local buzz and global pipelines

One of the main advantages to firms of locating in a cluster is that spatial proximity allows for a better exchange of tacit knowledge, an essential component in an innovative economy (Saxenian, 1994). However, recent empirical studies have begun to question the seemingly superior character of local versus global knowledge flows (Gertler, 2003; Malecki and Oinas, 1999), which indicates a certain dissatisfaction with the above line of reasoning. Based on this, Bathelt et al. (2004) have developed a concept that recognizes both the existence of a local buzz dynamic, which demonstrates the importance of just being there (Gertler, 1995), but also the significant role of extralocal sources of knowledge, that is, the pipeline structure (Owen-Smith and Powell, 2004). A significant benefit arising from urbanization economies is the inevitable exposure to a range of local knowledge bases of varying degrees of cognitive distance to a firm's core capabilities. Spatial proximity to a diverse set of activities initiates interactive learning processes along several dimensions (Malmberg and Maskell, 2006), namely through learning by interaction and by monitoring. Knowledge exchange in this context is frequently unintentional and serendipitous rather than mediated through market transactions. It is regular encounters and frequent face-to-face contact, facilitated through an organizationally and institutionally local embeddedness, which is further enhanced by shared socially constructed norms and conventions among the actors involved, that especially excels local learning processes and in turn creates what is labeled a buzz (Storper and Venables, 2004), or noise (Grabher, 2002), in a particular locality. In the context of localization economies, which are characterized by a high level of activities in a variety of rather closely related functions, as is the case in specialized clusters, the level of interaction is even further increased due to relational proximity of the actors involved. While local knowledge sourcing is certainly one of the determining factors affecting the performance of knowledge-intensive industries, competitive pressure and forces of globalization, among other factors, point to the necessity to harvest knowledge pools outside the local environment. Global knowledge search processes, however, are much more structured, formalized, and planned than in the case of localized learning (Bathelt et al., 2004). Determined by the spatial concentration of knowledge production in certain localities, the search for distant knowledge inputs by individual or firms is a conscious process that is only directed to specific places considered to possess particular competencies in a particular core activity (Bathelt, 2005a). To a certain extent this leads to a buzz-and-pipeline dichotomy where local knowledge flows are associated with tacit forms of knowledge, while global knowledge corresponds to more formalized or codified knowledge types. However, these arguments rest on a small base of empirical evidence (Gertler and Wolfe, 2006), and have been questioned more recently, especially in the context of particular industry sectors (Moodysson, 2008). In essence, while the search for new and useful knowledge inputs is a universal process, the way this is carried out at the local and global scales differs significantly.

Long-distance collaborations are certainly part of knowledge creation. As creative activity has become more complex teamwork has become more prominent. But does the fact that individuals collaborate over great distance indicate that distance is not important? Certainly new technologies have lowered the cost of long-distance collaborations. This begs the question of how such collaborations form. Bercovitz and Feldman (2010) examine teams of inventors to discern if collaboration is driven by prior employment relationships, prior social relationships or star attraction. They find that the majority of external members had some prior social relationship with internal members of the team—either as former colleagues or students or as long-time coauthors. These collaborations reflect the footprints of a former geography—that is to say that the collaboration reflects prior colocation. In only about 25% of the cases did the team come together without any prior working relationship such as previously being at the same institution or being a long-time coauthor. In the cases without a prior relationship what matters most was the star attraction of the external member. Highly cited individuals were more likely to be engaged in long-distance relationships. As found by Mansfield, industry collaboration was more likely to be local while academic collaboration took place at greater distance, confirming the relevance of epistemic communities. Moreover, having an external member was more likely to results in a producing economically valuable knowledge. This suggests that external members are brought in to address specific requirements. However, the most productive teams were internal to the organization and included novel combinations of inventors.

In the worst case scenario individuals and firms operate in a local vacuum, that is, they exhibit no, or very low levels of, local interaction with other actors working on similar problems in the same local setting, and, in addition, they also display a global void as they have limited capabilities in accessing geographic distant specialized knowledge pools that are relevant in their respective sector. The result is an inevitable decline of innovative output, resulting in a loss of productivity gains, and eventually economic stagnation. For example, Bathelt (2005b) illustrates that the lack of extralocal firm linkages and market relationships in the Leipzig media sector, combined with limited local networking and interactive learning activities within the cluster, have led to the actual decline of one of Germany's secondary media agglomerations, despite a favorable growth potential partially grounded in a historical context and recent national economic restructuring processes.

2.8. Places are defined over time by an evolutionary process

The remarkable growth of Silicon Valley, which is considered the archetype of high-tech industrial clusters, has made it the prototype for a wide range of policy initiatives aiming to replicate this success story in other regions. In a historical account, Moore and Davis (2004) emphasize that learning was the key process that led to the transformations that built Silicon Valley rather than specific institutions, single events, or even chance. Particular importance is attributed to the interplay of general and regional-specific growth factors as exemplified by the evolution of scientist-managers, which at the time was a nation-wide trend, but was especially amplified in the region due to the fact that many scientists learned about management at establishments such as Fairchild. These spatially concentrated learning processes caused a significant shift in business aptitude, and ultimately created an increased number of opportunities where the usually adverse task of risk-investment became an important regional quality resulting in a strong economic growth performance. Learning, in the perspective of industrial cluster formation, is considered a regionally embedded activity that is best facilitated in dense local social and institutional networks, where regional competition leads to severe selection processes, and in turn to efficiency by means of adaptation of enhanced production methods, as well as an accelerated rate of innovation. More importantly, learning is also an inherently evolutionary, cumulative, and most importantly, dynamic activity, and therefore any type of static cluster policy initiative is doomed to fail, especially if it does not incorporate local context, in which important processes such as the development of regional absorptive capacity are accentuated in a path-dependent fashion.

When considering the development of industrial clusters there are two diametrically opposing models. One model, practiced in China, relies on government dictating the growth of designated science cities (Hu, 2007). This is a very top-down approach to economic development that has been successful in Singapore and Taiwan: the central government dictates that a specific location will have a concentration of R&D and accomplishes this in a relatively short period of time. The verdict is still out as to whether these locations will be successful at creating a sustained competitive advantage given that innovation is more complex than simply conducting R&D. The other model occurs in the United States and other market economies and relies on self-organization and local initiative. In market economies the central government cannot dictate the actions of private companies but may only offer incentives to encourage firm location decisions and investments in R&D. The closest that we have to a government-induced clusters is RTP in North Carolina, which was the result of state and local government actions. RTP was a very long undertaking beginning in the 1920s and is now the largest research park in the world (Link, 1995). While there are many other examples of government trying to build clusters in market economies, the results typically look very different from what was originally intended (Leslie and Kargon, 1994).

Given that innovation is about the flows of people and ideas then institutional dynamics and political context certainly matters. In RTP, over time entrepreneurs left large firm employment or returned to the area to start firms, filling in a vibrant industrial landscape (Avnimelech and Feldman, 2009).

Causality is always difficult to discern: the attributes associated with fully functioning clusters are the result of their success, not the underlying cause. While it is always difficult to attribute causality and many policymakers search for the recipe for industrial cluster development and economic vitality there is evidence that cluster genesis is a social process (Braunerhjelm and Feldman, 2006). Indeed, many of the factors associated with success clusters such as venture capital or active university involvement lag rather than lead industrial viability (Feldman, 2001). What matter most is the entrepreneurial spark that takes hold and transforms a region. In the most successful places, entrepreneurs build institutions and shared resources that develop the cluster building the firm (Feldman and Francis—Building cluster while building a firm). Over time a social consensus develops about the potential of a new idea or a technology, new business models emerge and the place becomes about doing something unique and not easily replicated by other places (Lowe and Feldman, 2008). There are many attempts to model the stages of cluster formation (Avnimelech and Teubal, 2004; Maggioni et al., 2007).

Even Silicon Valley, the archetype of a technology-intensive cluster started from humble beginnings. Lécuyer (2005) examines the history of Silicon Valley to 1970 and documents how faculty and administrators at Stanford used proximity to local firms to build a major research program in solid-state electronics, which was the ultimate basis for the development of the computer industry in Silicon Valley. Levuyer offers a skill-based interpretation of the formation of Silicon Valley, noting that local entrepreneurs developed a unique know-how in the production of vacuum tubes and semiconductors. Important social innovations such as stock options provided a mechanism to attract and retain skilled workers.

While economic development officials and government planners want to define long term strategies, it is difficult, if not impossible to predict scientific discoveries, new technologies and new opportunities. IBM, an industry leader, underestimated the potential of the computer industry, creating an opportunity for new firms to create personal computers. Few people predicted the potential of the Internet and how it would change the way we access information and communicate. Moreover, successful entrepreneurs make their own luck, adjusting and adapting to survive. Instead of wisely considered, farsighted solutions, entrepreneurial activity is by necessity messy, adaptive and unpredictable. Economic development strategies need to be equally adaptive. The biggest problem is that it is impossible to predict which technologies are going to yield any payoff. By the time a new industry, for example, biotech or nanotechnology, has a defined name and is on its way to becoming a household name, it is probably too late for other places to decide that they will participate as major centers. Creating a cluster in a market economy is a messy social process. Designing an effective economic development strategy may be the ultimate local innovation.

3. Conclusions

Students in introductory classes are told that economics consists of three major questions: what to produce, how to produce, and for whom to produce. A fourth question that is increasingly important in the global economy is where to produce—where to locate the factors of production so that they are most efficient and productive. The study of the location of innovation is a subset of the question of where to locate; however, the character of place is not static and is constructed by the economic actors who locate there. While firms are one venue to organize economic activity, the resources required to generate innovation are typically not confined to a single firm, and geography is another means to organize the factors of production. But we should remember that geography is additionally a venue for complex multifaceted social relationships, and human community and creativity that are beyond the economic sphere.

Economies are complex: highly integrated, globally interconnected, and highly agglomerated on centers of activity. There is always the temptation to analyze economic institutions and actors individually; however, the new economic geography literature considers the large context. Of course, once the analysis is open to consider geography there is a need to understand history, building a deep contextualized understanding of a place and the relationships that define it.

This chapter has considered stylized facts related to the geography of innovation. While much is known there is still much to be done and many open avenues for research remain. We hope that this review will encourage others to contribute to the emerging field of economic geography.

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