

Knowledge Spillovers and the Geography of Innovation

Prepared for the Handbook of Urban and Regional Economics, Volume 4

Revised May 9, 2003

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Acknowledgements: We acknowledge the comments of Vernon Henderson, Jacque Thisse, Will Strange and the participants at the CEPR Meetings in December 2002. We are also grateful to the comments and suggestions made by Luigi Guiso. Feldman acknowledges financial support of the Connaught Fund at the University of Toronto. Comments are welcome and appreciated.

1. Introduction

In proposing a new theory of economic geography, Paul Krugman, (1991, p. 55) asks, “What is the most striking feature of the geography of economic activity? The short answer is surely concentration...production is remarkably concentrated in space.” Feldman (1994a) provided evidence that what Krugman observed to be true for production was even more pronounced for innovative activity. This finding helped trigger a new literature with the goal of *understanding the spatial dimension of innovative activity*, specifically the determinants and mechanisms that underlie the propensity of innovative activity to cluster spatially. Knowledge spillovers figure prominently in addressing these issues. This chapter in the Handbook introduces the reader to the path that scholars have taken to understand the geographic dimensions of knowledge spillovers.

The starting point on this intellectual journey is the literature that analyzes the economics of innovation and technological change. This tradition, reviewed in Section 2 focused on the innovation production function however it was *aspatial* or insensitive to issues involving location and geography. However, empirical results hinted that knowledge production had a spatial dimension. Armed with a new theoretical understanding about the role and significance of knowledge spillovers, and the manner in which they are localized, scholars began to estimate the knowledge production function with a spatial dimension.

As Section 3 makes clear, *location and geographic space have become key factors in explaining the determinants of innovation and technological change*. There is a long and insightful literature that considers the spatial dimension of innovative activity and the factors that influence industrial clustering. A piece that had been missing in this older tradition was the role that knowledge spillovers play in providing access to new economic knowledge and increasing the productivity of economic actors.

The fourth section examines studies that have sought to penetrate the black box of geographic space by addressing a limitation inherent in the model of the knowledge production. These studies follow a rich tradition dating back at least to Hoover (1936) of analyzing the role of both localization and urbanization economies, by extending the focus to the organization of economic activity within a spatial dimension and examine how different organizational aspects influence economic performance.

While identifying the importance of geographic location in general, and agglomeration in particular, was a significant step in generating innovative activity, it provided little insight as to *how and why knowledge spills over*, nor did it illuminate the mechanisms that serve as conduits for the transmission of knowledge. Section 5 considers various potential spillover mechanisms and studies that examine these different mechanisms.

Section 6 examines one spillover mechanism which has generated a large body of research – entrepreneurship. Just as entrepreneurs have been found to originate in locations with strong knowledge assets, empirical evidence suggests that high rates of entrepreneurial activity contribute to higher growth performance. Finally, the last section provides a summary and conclusion.

2. The Knowledge Production Function

The traditional starting point in the literature on innovation and technological change for most theories of innovation has been the firm (Baldwin and Scott 1987, Cohen and Levin 1989, Scherer 1984 and 1991, and Griliches 1979). In such theories firms are exogenous and their performance in generating technological change is endogenous (Scherer, 1984 and 1991, Cohen and Klepper, 1991 and 1992). For example, in the most prevalent model of technological change, the model of the knowledge production function (Griliches 1979), incumbent firms engage in the pursuit of new economic knowledge as an input into the process of generating innovative activity. The most important input in this model is new

economic knowledge. As Cohen and Klepper (1991 and 1992) point out, the greatest source generating new economic knowledge is generally considered to be R&D. Other inputs in the knowledge production function have included measures of human capital, skilled labor, and educational levels. Thus, the model of the knowledge production function from the literature on innovation and technological change can be represented as

$$I_i = \alpha RD_i^\beta HK_i^\gamma \varepsilon_i \quad (1)$$

where I stands for the degree of innovative activity, RD represents R&D inputs, and HK represents human capital inputs. The unit of observation for estimating the model of the knowledge production function, reflected by the subscript i , has been at the level of countries, industries and enterprises.

The logic of the production function held: innovative output was a function of innovative inputs. However, empirical estimation of the model of the knowledge production function, represented by Equation 1, was found to be stronger at broader levels of aggregation such as countries or industries. For example, at the unit of observation of countries, the empirical evidence (Griliches 1984) clearly supported the existence of the knowledge production function. This is intuitively understandable, because the most innovative countries are those with the greatest investments to R&D. Less innovative output is associated with developing countries, which are characterized by a paucity of new economic knowledge.

Similarly, the model of the knowledge production function was strong at the level of the industry (Scherer 1982; Griliches 1984). Again, this seems obvious as the most innovative industries also tend to be characterized by considerable investments in R&D and new economic knowledge. Not only are industries such as computers, pharmaceuticals and instruments high in R&D inputs that generate new economic knowledge, but also in terms of innovative outputs (Scherer 1983; Acs and Audretsch 1990). By contrast, industries with little

R&D, such as wood products, textiles and paper, also tend to produce only a negligible amount of innovative output.

Where the relationship became less robust was at the disaggregated microeconomic level of the enterprise, establishment, or even line of business: there is no direct deterministic relationship between inputs and innovation.¹ Thus, the finding that the knowledge production model linking knowledge generating inputs to outputs holds at the more aggregated levels of economic activity suggests the presence of an externality.

The model of the knowledge production function also became less compelling in view of a wave of studies that found that small enterprises were an engine of innovative activity in certain industries. For example, Acs and Audretsch (1988 and 1990) found that while large enterprises (defined as having at least 500 employees) generated a greater number of new product innovations than did small firms (defined as having fewer than 500 employees), once the measures were standardized by levels of employment, the innovative intensity of small enterprises was found to exceed that of large firms.² These results are startling, because as Scherer (1991) documented, the bulk of industrial R&D is undertaken in the largest corporations; and small enterprises account only for a minor share of R&D inputs. This raises the question of *how small firms obtained access to R&D inputs*. Either the model of the knowledge production did not hold, at least at the level of the enterprise (for a broad spectrum across the firm-size distribution), or else the appropriate unit of observation had to

¹ For example, while Acs and Audretsch (1988 and 1990) found that the simple correlation between R&D inputs and innovative output was 0.84 for four-digit standard industrial classification (SIC) manufacturing industries in the United States, it was only about half, 0.40 among the largest U.S. corporations.

² The innovation rates, or the number of innovations per thousand employees, have the advantage of measuring large- and small-firm innovative activity relative to the presence of large and small firms in any given industry. That is, in making a direct comparison between large- and small-firm innovative activities, the absolute number of innovations contributed by large firms and small enterprises is somewhat misleading, since these measures are not standardized by the relative presence of large and small firms in each industry. When a direct comparison is made between the innovative activity of large and small firms, the innovation rates are presumably a more reliable measure of innovative intensity because they are weighted by the relative presence of small and large enterprises in any given industry. Thus, while large firms in manufacturing introduced 2,445 innovations, and small firms contributed slightly fewer, 1,954, small-firm employment was only half as great as large-firm employment, yielding an average small-firm innovation rate in manufacturing of 0.309, compared to a large-firm innovation rate of 0.202.

be reconsidered. In searching for a solution, scholars chose the second interpretation, leading them to move towards spatial units of observation as an important unit of analysis for the model of the knowledge production function.

3. Geography and the Role of Spillovers

As it became apparent that the firm was not completely adequate as a unit of analysis for estimating the model of the knowledge production function, scholars began to look for externalities. In refocusing the model of the knowledge production to a spatial unit of observation, scholars confronted two challenges. The first one was theoretical. What was the theoretical basis for knowledge to spill over yet, at the same time, be spatially within some geographic unit of observation? The second challenge involved measurement. How could knowledge spillovers be measured and identified? More than a few scholars heeded Krugman's warning (1991, p. 53) that empirical measurement of knowledge spillovers would prove to be impossible because "knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked."³

In confronting the first challenge, which involved developing a theoretical basis for geographically bounded knowledge spillovers, scholars turned to the emerging literature of the new growth theory. In explaining the increased divergence in the distribution of economic activity between countries and regions, Krugman (1991) and Romer (1986) relied on models based on increasing returns to scale in production. By increasing returns, however, Krugman and Romer did not necessarily mean at the level of observation most familiar in the industrial organization literature – the plant, or at least the firm – but rather at the level of a spatially distinguishable unit. In fact, it was assumed that the externalities across firms and even industries would generate increasing returns in production. In particular, Krugman (1991),

invoking Marshall (1920), focused on external increasing returns arising from spillovers from (1) a pooled labor market; (2) pecuniary externalities enabling the provision of nontraded inputs to an industry in a greater variety and at lower cost; and (3) information or technological spillovers.

That knowledge spills over was barely disputed. Some thirty years earlier, Arrow (1962) identified externalities associated with knowledge due to its non-exclusive and non-rival use. However, what has been contested is the geographic range of knowledge spillovers: knowledge externalities are so important and forceful that there is no reason that knowledge should stop spilling over just because of borders, such as a city limit, state line, or national boundary. Krugman (1991), and others, did not question the existence or importance of such knowledge spillovers. In fact, they argue that such knowledge externalities are so important and forceful that there is no reason for a political boundary to limit the spatial extent of the spillover.

In applying the model of the knowledge production function to spatial units of observation, theories of why knowledge externalities are spatially bounded were needed. Thus, it took the development of localization theories explaining not only that knowledge spills over but also why those spillovers decay as they move across geographic space. An older but insightful literature addressed these concerns.

Jacobs (1969), writing about cities, suggests that *information*, such as the price of gold on the New York Stock Exchange, or the value of the Yen in London, has a familiar meaning and interpretation. By contrast, *knowledge* or what is sometimes referred to as *tacit knowledge*, is vague, difficult to codify and often only serendipitously recognized. While information is codified and can be formalized, written down, tacit knowledge, by definition, is non-codifiable and cannot be formalized and written down. Geographic proximity matters

³ Lucas (2001) , and Lucas and Rossi-Hansberg (2002) impose a spatial structure on production externalities in order to model the spatial structure of cities. The logic is that spatial gradients capture some of the externalities

in transmitting knowledge, because tacit knowledge is inherently non-rival in nature, and knowledge developed for any particular application can easily spill over and have economic value in very different applications. Manski (2000) considers that many of the interactions in R&D and human capital formation that are important to endogenous growth theory occur in non-market environments and are influenced by the expectations, preferences and constraints of related economic agents. Moreover, social interactions have economic value in transmitting knowledge and ideas. Von Hippel (1994) explains that high context, uncertain knowledge, or what he terms *sticky knowledge*, is best transmitted via face-to-face interaction and through frequent and repeated contact. An implication of the distinction between information and tacit knowledge is that the marginal cost of transmitting information across geographic space has been rendered invariant by the revolution in telecommunications while *the marginal cost of transmitting knowledge, especially tacit knowledge, is lowest with frequent social interaction, observation and communication*. After all, geographic proximity matters in transmitting knowledge, because as Glaeser, Kallal, Scheinkman and Shleifer (1992, p.1126) observe, “intellectual breakthroughs must cross hallways and streets more easily than oceans and continents.”

Feldman (1994a and 1994b) developed the theory that location mitigates the inherent uncertainty of innovative activity: *proximity enhances the ability of firms to exchange ideas and be cognizant of important incipient knowledge*, hence reducing uncertainty for firms that work in new fields. Innovation clusters spatially where knowledge externalities reduce the costs of scientific discovery and commercialization. In addition, Feldman (1994a) suggests that firms producing innovations tend to be located in areas where there are necessary resources: resources that have accumulated due to a region’s past success with innovation. In this way, firms and resources are endogenous.

associated with localized human capital accumulation.

Studies identifying the extent of knowledge spillovers are based on the model of the knowledge production function applied at spatial units of observation. In what is generally to be considered to be the first important study re-focusing the knowledge production function, Jaffe (1989) modified the traditional approach to estimate a model specified for both spatial and product dimensions:

$$I_{si} = \alpha IRD^{\beta_1} UR_{si}^{\beta_2} (UR_{si} GC_{si}^{\beta_3}) \varepsilon_{si} \quad (2)$$

where I is innovative output, IRD is private corporate expenditures on R&D, UR is the research expenditures undertaken at universities, and GC measures the geographic coincidence of university and corporate research. The unit of observation for estimation was at the spatial level, s , a state, and industry level, i . Estimation of equation (2) essentially shifted the knowledge production function from the unit of observation of a firm to that of a geographic unit. Implicitly contained within the knowledge production function model is the assumption that innovative activity should take place in those regions, s , where the direct knowledge-generating inputs are the greatest, and where knowledge spillovers are the most prevalent. Jaffe (1989) dealt with the measurement problem raised by Krugman (1991) by linking the patent activity within technologies located within states to knowledge inputs located within the same spatial jurisdiction.

Estimation of equation (1) essentially shifted the model of the knowledge production function from the unit of observation of a firm to that of a geographic unit. Jaffe (1989) found empirical evidence that $\beta_1 > 0, \beta_2 > 0, \beta_3 > 0$ supporting the notion knowledge spills over for third-party use from university research laboratories as well as industry R&D laboratories. Acs, Audretsch and Feldman (1992) confirmed that the knowledge production function represented by equation (2) held at a spatial unit of observation using a direct measure of innovative activity, new product introductions in the market. Feldman (1994b) extended the model to consider other knowledge inputs to the commercialization of new products. The

results confirmed that the knowledge production function was robust at the geographic level of analysis: the output of innovation is a function of the innovative inputs in that location.

Other studies concur that knowledge spillovers tend to be geographically bounded within the region where new economic knowledge was created (Agrawal 2002a and 2002b, Anselin, Acs and Varga 1997; Black forthcoming, Orlando 2000, Autant-Bernard 2001a and b). Scholars have continued to work in this tradition adding new measures of innovative output and refining the measures of innovative inputs and outputs. For example, Black (forthcoming) developed a measure of innovation based on awards made in the United States Small Business Innovation Research (SBIR) Program. In estimating a knowledge production function along the lines of equation (2) for a variety of geographic units and using different measure of innovative output, the results concur that the logic of the knowledge production function is robust across geography. Autant-Bernard (2001a, 2001b) and Orlando (2000) model the interplay between geographic and technological proximity for inter-firm spillovers. Their results suggest the importance of geographic proximity for spillovers is dependent on the propensity of similar industrial activity to agglomerate geographically.

Estimation of the knowledge production function has typically varied the spatial unit from relatively broad geographic units of observations, such as states, to much more focused geographic units of observations such as cities, counties or even zip codes. Most scholars concur that states are probably too broad to represent an appropriate geographic unit of observation. Some have tried to estimate the geographic extent of knowledge spillovers in miles using the concept of distance decay (Adams and Jaffe 2002; Adams 2002; Wallsten 2001). Others contend that geography is more a platform for organizing economic activity and that “as the crow flies” measures of distance do not capture complex social relationships (Feldman 2002; Branstetter 2002). The role of social relationships will be explicitly discussed when we examine the literature on industrial districts.

There are also good reasons to believe that knowledge spillovers are not homogeneous across firms. In estimating Equation (1) for large and small enterprises separately, Acs, Audretsch and Feldman (1994) provide some insight into the puzzle about how small, and frequently new, firms able to generate innovative output while undertaking generally negligible amounts of investment into knowledge generating inputs, such as R&D. The answer appears to be through exploiting knowledge created by expenditures on research in universities and on R&D in large corporations. Their findings suggest that the innovative output of all firms rises along with an increase in the amount of R&D inputs, both in private corporations as well as in university laboratories. However, R&D expenditures made by private companies play a particularly important role in providing knowledge inputs to the innovative activity of large firms, while expenditures on research made by universities serve as an especially key input for generating innovative activity in small enterprises. Apparently large firms are more adept at exploiting knowledge created in their own laboratories, while their smaller counterparts have a comparative advantage at exploiting spillovers from university laboratories.

Jaffe, Trajtenberg and Henderson (1993) and Jaffe and Trajtenberg (2002) analyze patent families -- patents that reference or cite each other and indicate the flows of knowledge from one invention to another.⁴ Specifically, they compare the probabilities of patents citing prior patents with inventors from the same city against a randomly drawn control sample of cited patents. Their results suggest that citations are significantly more localized than the control group. The same methodology has been applied by Almedia and Kogut (1997) to study patenting in the semiconductor industry. The basic results agree: patent citations are highly localized, indicating that location and proximity clearly matter in exploiting knowledge spillovers.

⁴ Griliches (1990) provides a survey of the uses and limitations of patent data.

Table 1: Innovative Activity in Cities			
Consolidated Metropolitan Statistical Area	Innovations	Population (thousands)	Innovations per 100,000 Population
San Francisco - Oakland	477	5368	8.886
Boston – Lawrence	345	3972	8.686
New York - Northern New Jersey	735	17539	4.191
Philadelphia - Wilmington	205	5681	3.609
Dallas - Fort Worth	88	2931	3.002
Hartford	30	1014	2.959
Los Angeles - Anaheim	333	11498	2.896
Buffalo – Niagara	35	1243	2.816
Cleveland – Akron	77	2834	2.717
Chicago – Gary	203	7937	2.558
Providence - Pawtucket	25	1083	2.308
Portland – Vancouver	25	1298	1.926
Cincinnati – Hamilton	30	1660	1.807
Seattle – Tacoma	37	2093	1.768
Pittsburgh	42	2423	1.733
Denver - Boulder	28	1618	1.731
Detroit - Ann Arbor	68	4753	1.431
Houston - Galveston	39	3101	1.258
Miami - Fort Lauderdale	13	2644	0.492
Source: Feldman and Audretsch (1999)			

⁵ The Gini coefficients are weighted by the relative share of economic activity located in each state. Computation of weighted Gini coefficients enables us to control for size differences across states. The Gini coefficients are based on the share of activity in a state and industry relative to the state share of the national activity for the industry. The locational Gini coefficients for production are based on industry value-added. We calculate the amount of value added in an industry and a state divided by national value-added for the industry. This ratio is normalized by the state share of total manufacturing value-added in order to account for the overall distribution of manufacturing activity. An industry which is not geographically concentrated more than is reflected by the overall distribution of manufacturing value-added would have a coefficient of 0. The closer the industry coefficient is to 1, the more geographically concentrated the industry would be. Cases in which data are suppressed are omitted from the analysis. The Gini Coefficients for innovation are based on counts of innovation in a state and industry are calculated in a similar way.

Audretsch and Feldman (1996) found that the propensity of innovative activity to cluster geographically tends to be greater in industries where new economic knowledge plays a more important role. This effect was found to hold even after holding the degree of production at that location constant. Audretsch and Feldman (1996), follow Krugman's (1991) example, and calculate Gini coefficients for the geographic concentration of innovative activity to test this relationship.⁶ The results indicate that a key determinant of the extent to which the location of production is geographically concentrated is the relative importance of new economic knowledge in the industry. Even after controlling for the geographic concentration of production, the results suggest a greater propensity for innovative activity to cluster spatially in industries in which industry R&D, university research and skilled labor are important inputs. In this work, skilled labor is included as a mechanism by which knowledge spillovers may be realized as workers move between jobs in an industry taking their accumulated skills and know-how with them.

Table 2: The Innovative Advantage of U.S. Cities (MSA and Count)			
Industry		N	Most Innovative MSA
3573	Electronic Computing Machinery	787	San Jose (166); Boston (48); Los Angeles (48); Anaheim (35)
3823	Process Control Instruments	464	Boston (45); Philadelphia (31); Chicago (26)
3662	Radio/TV Equipment	311	San Jose (58); Boston (25); New York (17); Los Angeles (14)
3674	Semiconductors	168	San Jose (53); Boston (10); Dallas (10); Los Angeles (10)
3825	Instruments to Measure Electricity	114	San Jose (22); Boston (20)
2834	Pharmaceuticals	116	Newark (27); Philadelphia (11); New York (10)

⁶ The Gini coefficients are weighted by the relative share of economic activity located in each state. Computation of weighted Gini coefficients enables us to control for size differences across states. The Gini coefficients are based on the share of activity in a state and industry relative to the state share of the national activity for the industry. The locational Gini coefficients for production are based on industry value-added. We calculate the amount of value added in an industry and a state divided by national value-added for the industry. This ratio is normalized by the state share of total manufacturing value-added in order to account for the overall distribution of manufacturing activity. An industry which is not geographically concentrated more than is reflected by the overall distribution of manufacturing value-added would have a coefficient of 0. The closer the industry coefficient is to 1, the more geographically concentrated the industry would be. Cases in which data are suppressed are omitted from the analysis. The Gini Coefficients for innovation are based on counts of innovation in a state and industry are calculated in a similar way.

3842	Surgical Appliances	101	Newark (20); Nassau-Suffolk (10); Bergen-Passaic (8); Philadelphia (6)
3494	Values and Pipe Fittings	81	Anaheim (6); Los Angeles (6); Cleveland (6); Cincinnati (5)
3679	Electronic Components	72	San Jose (19); Anaheim (7); Boston (6);
3561	Pumps and Pumping Equipment	68	Philadelphia (8); Aurora-Elgin (7)
3861	Photographic Equipment	57	Rochester (8); Minneapolis (7)
3579	Office Machines	54	New York (11); Philadelphia (7); Stamford (5)
3622	Industrial Controls	51	San Jose (7); Cleveland (4)
3841	Surgical and Medical Instruments	51	Nassau- Suffolk (10); Bergen-Passaic (8)

Source: Feldman and Audretsch (1999)

The spatial distribution of innovative output can be seen in Table 1. The measure of innovative output is new product innovations introduced to the U.S. market. The majority of new product innovations were located in cities indicating that innovation is an urban activity. Table 2 shows that the propensity for innovative activity to cluster spatially is even greater for specific industries, such as computers and process control instruments, pharmaceuticals, etc. Even more mundane types of industrial activities such as industrial pumps and pumping equipment demonstrate a tendency to concentrate in certain locations.

In sum, *the empirical evidence suggests that location and proximity clearly matter in exploiting knowledge spillovers.* The geographic estimation of the knowledge production function, however, is limited because there is no understanding of the way in which spillovers occur and are realized at the geographic level. The pre-existing pattern of technology related activities makes it difficult to separate spillovers from the correlation of variables at the geographic level. Economic activity may be co-located, but the pattern of causality is difficult to decipher.

4. Penetrating the Black Box of Geographic Space

The contribution of the new wave of studies described in the previous section was simply to shift the unit of observation away from firms to a geographic region. But does it make a difference how economic activity is organized within the black box of geographic

space? Geographers, political scientists and sociologists have long argued that the differences in the culture of a region and relationships between actors may contribute to differences in innovative performance across regions, even holding knowledge inputs such as R&D and human capital constant (see, Malecki 1997 for a review of the literature). For example, Saxenian (1994) argues that a culture of greater interdependence and exchange among individuals in the Silicon Valley region has contributed to a superior innovative performance than is found around Boston's Route 128, where firms and individuals tend to be more isolated and less interdependent.

Such observations suggest a limitation inherent to the general knowledge production function approach described in the previous section. While economists tend to avoid attributing differences in economic performance to cultural differences, there has been a series of theoretical arguments suggesting that differences in the underlying structure between regions may account for differences in rates of growth and technological change. In fact, a heated debate has emerged in the literature about the manner in which the underlying economic structure within a geographic unit of observation might shape economic performance (see Rosenthal and Strange in this volume). In this section we review the debate that revolves around two key structural elements – the degree of diversity versus specialization and the degree of monopoly versus local competition.

One view, which Glaeser, Kallal, Scheinkman and Shleifer (1992) attribute to the *Marshall-Arrow-Romer externality*, suggests that an increased concentration of a particular industry within a specific geographic region facilitates knowledge spillovers across firms. This model formalizes the insight that the concentration of an industry within a city promotes knowledge spillovers among firms and therefore facilitates innovative activity. To the degree that individuals in the population are identical and engaged in identical types of activities, the costs of communication and transactions are minimized. Lower costs of transaction in

communication result in a higher probability of knowledge spilling over across individuals within the population. An important assumption of the model is that knowledge externalities with respect to firms exist, but only for firms within the same industry. Thus, the relevant unit of observation is extended from the firm to the region in the tradition of the Marshall-Arrow-Romer model, but the spillovers are limited to occur solely within the relevant industry.

By contrast, restricting knowledge externalities to occur only within the same industry may ignore an important source of new economic knowledge – inter-industry knowledge spillovers. After all, Griliches (1992, p. 29) defined knowledge spillovers as, “working on similar things and hence benefiting much from each others research.” Jacobs (1969) argues that the most important source of knowledge spillovers is external to the industry in which the firm operates and that cities are the source of considerable innovation because the diversity of these knowledge sources is greatest in cities. According to Jacobs, it is the exchange of complementary knowledge across diverse firms and economic agents which yield a greater return on new economic knowledge. She develops a theory that emphasizes that the variety of industries within a geographic region promotes knowledge externalities and ultimately innovative activity and economic growth.⁷

The extent of regional specialization versus regional diversity in promoting knowledge spillovers is not the only dimension over which there has been a theoretical debate. A second controversy involves the degree of competition prevalent in the region, or the extent of local monopoly. The Marshall-Arrow-Romer model predicts that local monopoly is superior to local competition because it maximizes the ability of firms to appropriate the economic value accruing from their investments in new knowledge. By contrast, Jacobs (1969) and Porter (1990) argue the opposite – that competition is more

⁷ For an extension see Henderson (1994) , Henderson et al. (1995) and Rosenthal and Strange (2003).

conducive to knowledge externalities than is local monopoly.⁸ It should be emphasized that by local competition Jacobs does not mean competition within product markets as has traditionally been envisioned within the industrial organization literature. Rather, Jacobs is referring to the competition for the new ideas embodied in economic agents. Not only do an increased number of firms provide greater competition for new ideas, but in addition, greater competition across firms facilitates the entry of a new firm specializing in some particular new product niche. This is because the necessary complementary inputs and services are likely to be available from small specialist niche firms but not necessarily from large, vertically integrated producers.

A test of the specialization versus diversity debate measured economic performance in terms of employment growth. Glaeser et al. (1992) employ a data set on the growth of large industries in 170 cities between 1956 and 1987 in order to identify the relative importance of the degree of regional specialization, diversity and local competition play in influencing industry growth rates. The authors find evidence that contradicts the Marshall-Arrow-Romer model but is consistent with the theories of Jacobs. However, their study provided no direct evidence as to whether diversity is more important than specialization in generating innovative activity.

Feldman and Audretsch (1999) identify the extent to which the organization of economic activity is either concentrated, or alternatively consists of diverse but complementary economic activities, and how the underlying structure of economic activity influences innovative output. They link the innovative output of product categories within a specific city to the extent to which the economic activity of that city is concentrated in that industry, or conversely, diversified in terms of complementary industries sharing a common science base. Feldman and Audretsch (1999) identify the extent to which the organization of

⁸ Porter (1990) provides examples of Italian ceramics and gold jewelry as industries in which numerous firms are located within a bounded geographic region and compete intensively for new ideas.

economic activity is either concentrated, or alternatively consists of diverse but complementary economic activities, and how the underlying structure of economic activity influences innovative output. They link the innovative output of product categories within a specific city to the extent to which the economic activity of that city is concentrated in that industry, or conversely, diversified in terms of complementary industries sharing a common science base.

Table 3: Innovation in Science-Based Industry Clusters		
Cluster	Prominent Cities	Mean Industry Innovations per 100,000 workers
Agra-Business	Atlanta Dallas Chicago St. Louis	92.40 41.15 33.03 91.74
Chemical Engineering	Dallas Minneapolis San Francisco Wilmington	38.09 66.67 43.89 85.47
Office Machinery	Anaheim-Santa Ana Minneapolis Rochester Stanford	92.59 31.86 72.20 68.40
Industrial Machinery	Anaheim-Santa Ana Cincinnati Cleveland Passaic, NJ	54.95 66.01 141.51 90.90
High-Tech Computing	Boston Houston San Jose Minneapolis	73.89 62.08 44.88 181.74
Biomedical	Boston Cleveland Dallas New York	38.71 68.76 35.22 188.07

Source: Feldman and Audretsch (1999)

Table 3 shows the innovative activity of cities sharing a common science base. Their results indicate that diversity across complementary economic activities sharing a common science base is more conducive to innovation than is specialization. In addition, their results

indicate that the degree of local competition for new ideas within a city is more conducive to innovative activity than is local monopoly. Perhaps the most important conclusions from these two studies, however, is that more than simply an endowment of knowledge inputs is required to generate innovative activity. The underlying economic and institutional structure matters, as do the microeconomic linkages across agents and firms. These findings do not address the path that spillovers take or the mechanisms by which spillovers are realized. These have been examined by work reviewed in the following sections.

5. Spillover Mechanisms

Romer (1986), Lucas (1988 and 1993) and Grossman and Helpman (1991) established that knowledge spillovers are an important mechanism underlying endogenous growth. However, they shed little light on the actual mechanisms by which knowledge is transmitted across firms and individuals. By necessity, the knowledge production function focused on the quantifiable aspects of innovation. However, formal R&D data ignore the complex processes of technological accumulation whereby tacit knowledge is built up and accumulates meaning – complex transactions that involves local institutions, social convention and legal rights as well as economic interests (Feldman et al. 2002). Thus, *the literature on knowledge spillovers and the geography of innovation has begun to consider the mechanisms by which knowledge spills over and is put into economic use and the degree to which these process are geographically localized*. Understanding these issues are important because a policy implication commonly drawn from the new economic growth theory is that, as a result of convexities in knowledge and the resultant increasing returns, knowledge resources, such as R&D should be publicly supported. While this may be valid, it is also important to recognize that the mechanisms for spillover transmission may also play a key role and may also serve as a focus for public policy enhancing economic growth and development.

The concepts of localized knowledge spillovers and absorptive capacity – the ability of economic agents to recognize, assimilate and apply new scientific knowledge, are closely linked (Agrawal 2000a and 2000b). Cohen and Levinthal (1989 and 1990) suggest that firms that invest in R&D develop the capacity to adapt knowledge developed in other firms and are therefore able to appropriate some of the returns accruing to external investments in new knowledge. Cockburn and Henderson (1998) build on this concept to suggest that firms that are connected to the community of open science are able to increase their investment in R&D by absorbing knowledge spillovers. Firms are able to acquire and benefit from external knowledge by cultivating relationships with universities, participating in research consortia and partnering with academics that do related scientific work.

Edwin Mansfield was perhaps the earliest to point out that research laboratories of universities provide one source of innovation-generating knowledge that is available to private enterprises for commercial exploitation (Mansfield 1995, 1998). The empirical work reviewed previously supported that finding. For example, Jaffe (1989) and Acs, Audretsch, and Feldman (1992), Audretsch and Feldman (1996) and Feldman and Audretsch (1999) found that the knowledge created in university laboratories spills over to contribute to the generation of commercial innovations by private enterprises. Even after controlling for the location of industrial R&D, knowledge created at universities results in greater innovation. The ability of research universities to create benefits for their local economies has created a new mission for research universities and a developing literature examines the mechanism and the process of technology transfer from research universities (Mowery and Shane 2002).

A different literature has emphasized the impact of networks and social capital found within a geographic region. Relational networks exist at multiple levels of analysis because they can link together individuals, groups, firms, industries, geographic regions, and nation-states. In addition, they can tie members of any one of these categories to members of another

category. For example, Powell et al. (1996), Florida and Cohen (1999) and Feldman et. al. (2002) demonstrate the ways in which research universities provide a link that facilitates knowledge spillovers in the form of recruiting talent to the region, transferring technology through local linkages and interactions, placing students in industry, and providing a platform for firms, individuals and government agencies to interact. Similarly, Florida and Kenney (1988) examine the connections and special access to talent and resources that venture capital firms provide to link their new high technology startups clients. Gompers and Lerner (1999) have shown how geography affects the location of venture capital. In particular, they show that the geographic distribution of venture capital is highly spatially skewed with California, New York, and New England as the major location of venture capital funds. Furthermore, Sorenson and Stuart (2001) show that location matters in obtaining venture capital. By analyzing the determinants of venture capital investment in the United States between 1986 and 1998, they find that the likelihood of a venture capitalist investing in a given target declines with geographical distance between the venture capitalist and the company.

Malecki (1997) was perhaps the first to note *the importance of skilled labor as a mechanism for knowledge transfer in technology based industrial clusters*. It is also the case that for certain science based industries that the location and preferences of scientists influence the geographical location of innovation. Zucker, Darby and Brewer (1998) and Prevenzer (1997) show that in biotechnology, an industry based almost exclusively on new knowledge and cutting edge scientific discoveries, firms tend to cluster together in just a handful of locations and find that this is due to the location of star scientists – those individuals with high amounts of human capital who are able to appropriate their knowledge through start-up firms. This finding is supported by Audretsch and Stephan (1996) who examine the geographic relationships of scientists working with biotechnology firms. The importance of geographic proximity is clearly shaped by the role played by the scientist. The

scientist is more likely to be located in the same region as the firm when the relationship involves the transfer of new economic knowledge. However, when the scientist is providing a service to the company that does not involve knowledge transfer, local proximity becomes much less important.

6. Entrepreneurship as a Spillover Mechanism

The literature identifying mechanisms actually transmitting knowledge spillovers is sparse and remains underdeveloped. However, one important area where such transmission mechanisms have been identified is entrepreneurship. Entrepreneurship is concerned with the startup and growth of new enterprises.

Why should entrepreneurship serve as a mechanism for the spill over of knowledge from the source of origin? At least two major channels or mechanisms for knowledge spillovers have been identified in the literature. Both of these spillover mechanisms revolve around the issue of appropriability of new knowledge and absorptive capacity. This view of spillovers is consistent with the traditional model of the knowledge production function, where the firm exists exogenously and then undertakes (knowledge) investments to generate innovative output.

By contrast, Audretsch (1995) proposes shifting the unit of observation away from exogenously assumed firms to individuals, such as scientists, engineers or other knowledge workers – agents with endowments of new economic knowledge. When the lens is shifted away from the firm to the individual as the relevant unit of observation, the appropriability issue remains, but the question becomes, *How can economic agents with a given endowment of new knowledge best appropriate the returns from that knowledge?* If the scientist or engineer can pursue the new idea within the organizational structure of the firm developing the knowledge and appropriate roughly the expected value of that knowledge, he has no reason to leave the firm. On the other hand, if he places a greater value on his ideas than do

the decision-making bureaucracy of the incumbent firm, he may choose to start a new firm to appropriate the value of his knowledge. Small enterprises can compensate for their lack of R&D is through spillovers and spin-offs. Typically an employee from an established large corporation, often a scientist or engineer working in a research laboratory, will have an idea for an invention and ultimately for an innovation. Accompanying this potential innovation is an expected net return from the new product. The inventor would expect to be compensated for his/her potential innovation accordingly. If the company has a different, presumably lower, valuation of the potential innovation, it may decide either not to pursue its development, or that it merits a lower level of compensation than that expected by the employee.

In either case, the employee will weigh the alternative of starting his/her own firm. If the gap in the expected return accruing from the potential innovation between the inventor and the corporate decision maker is sufficiently large, and if the cost of starting a new firm is sufficiently low, the employee may decide to leave the large corporation and establish a new enterprise. Since the knowledge was generated in the established corporation, the new start-up is considered to be a spin-off from the existing firm. Such start-ups typically do not have direct access to a large R&D laboratory. Rather, these small firms succeed in exploiting the knowledge and experience accrued from the R&D laboratories with their previous employers.

In the metaphor provided by Albert O. Hirschman (1970), if voice proves to be ineffective within incumbent organizations, and loyalty is sufficiently weak, a knowledge worker may resort to exit the firm or university where the knowledge was created in order to form a new company. In this spillover channel the knowledge production function is actually reversed. The knowledge is exogenous and embodied in a worker. The firm is created endogenously in the worker's effort to appropriate the value of his knowledge through innovative activity.

One group of studies has focused on how location has influenced the entrepreneurial decision, or the decision to start a new firm. Within the economics literature, the prevalent theoretical framework has been the general model of income choice. The model of entrepreneurial choice dates back at least to Knight (1921), but was more recently extended and updated by Lucas (1978), Kihlstrom and Laffont (1979), Holmes and Schmidt (1990) and Jovanovic (1994). In its most basic rendition, individuals are confronted with a choice of earning their income either from wages earned through employment in an incumbent enterprise or else from profits accrued by starting a new firm. The essence of the entrepreneurial choice model is made by comparing the wage an individual expects to earn through employment, W^* , with the profits that are expected to accrue from a new-firm startup, P^* . Thus, the probability of starting a new firm, $Pr(s)$, can be represented as

$$Pr(s) = f(P^* - W^*) \quad (3)$$

The model of entrepreneurial choice has been extended by Kihlstrom and Laffont (1979) to incorporate aversion to risk, and by Lucas (1978) and Jovanovic (1994) to explain why firms of varying size exist, and has served as the basis for empirical studies of the decision to start a new firm by Evans and Leighton (1989a, 1989b and 1990).

Geographic location should influence the entrepreneurial decision by altering the expected return from entrepreneurial activity, P^* . The theory of knowledge spillovers suggests that P^* will tend to be greater in agglomerations and spatial clusters, since access to tacit knowledge is greater. Geography and spatial location also influences entrepreneurship. The important role that geographic clusters and networks play as a determinant of entrepreneurial activity was identified in Europe and only recently has been discovered within the North American context (Porter 1990 and 2000; Saxenien 1994). By contrast, there is a longer and richer tradition of research linking entrepreneurship to spatial clusters and networks in Europe. However, most of these studies have been in social science fields other

than economics. For example, Becattini (1990) and Brusco (1990) identified the key role that spatial clusters and networks play in promoting SMEs in Italy. With the development of recent theoretical models by Soubeyran and Thisse (1999) and Soubeyran and Weber (2002), it became clear and accepted that spatial agglomerations were also important in the North American context.

An important distinction between the European literature and the emerging literature in North America was the emphasis on high technology and knowledge spillovers in the North American context. By contrast, the European tradition focused much more on the role of networks and clusters in fostering the viability of SMEs in traditional industries, such as textiles, apparel and metalworking. For example, seminal studies by Becattini (1990) and Brusco (1990) argue that small and new firms enjoy a high degree of stability when supported by networks in Italy. A rich literature has provided a body of case studies, spanning the textile industries of northern Italy to the metal working firms of Baden Wuerttemberg (Piore and Sabel 1984), documenting the long-term viability and stability of small and new firms embedded in the so-called industrial districts of Europe. Pyke and Sengenberger (1990) argue that through the support of an industrial district, small firms in European spatial clusters have been able to compensate for what would otherwise be an inherent size disadvantage. According to Pyke and Sengenberger (1990), an industrial district is a geographically defined production system, involving a large number of enterprises engaging in production at a wide range of stages, and typically involved in the production of a well-defined but differentiated product. A particularly significant feature of Italian industrial districts is that almost all of the firms are small or even micro-enterprises. Examples of such industrial districts include Prato, Biella, Carpi and Castelfelfredo, which specialize in textile (coolants in Castelfelfredo); Vigevano, Montebellune and Montegrano

where shoes are manufactured (ski boots in Montebellune); Pesaro and Nogarà which manufacture wooden furniture; Sassuolo where ceramic tiles are produced.

Brusco (1990) emphasizes the cooperation among network firms within an industrial district. Such cooperation presumably reduces any size-inherent disadvantages and improves the viability of small firms operating within the network. According to Pyke and Sengenberger (1990, p. 2), "A characteristic of the industrial district is that it should be conceived as a social and economic whole. That is to say, there are close inter-relationships between the different social, political and economic spheres, and the functioning of one, say the economic, is shaped by functioning and organization of the others." Grabher (1993) similarly argues that the social structure underlying industrial networks contributes to the viability of small firms that would otherwise be vulnerable if they were operating in an isolated context.

Feldman (2001) and Feldman and Francis (2001) examine the formation of innovative clusters and argue that entrepreneurs are key agents. Based on an analysis of the development of an Internet and biotechnology cluster around Washington, D.C., Feldman (2001) provides evidence that clusters form not because resources are initially located in a particular region, but rather through the work of entrepreneurs. Entrepreneurship is a local phenomenon as most entrepreneurs were previously employed in the region. Moreover, entrepreneurs are endogenous and organize resources and institutions to support their firms. An industry agglomeration is simply a collection of localized firms with a common focus and there are gains to collective action. As their businesses begin to thrive, resources such as money, networks, experts, and related services develop in, and are attracted to, the region. With this infrastructure in place, more entrepreneurial ventures locate and thrive in the region, which ultimately may create a thriving cluster where none previously existed. Feldman and Francis (2001) develop a conceptual model to formalize the process of cluster

formation through entrepreneurship. Using simulations, Zhang (2002) demonstrates how a small number of successful entrepreneurs can generate a cluster.

A series of studies, spanning a broad spectrum of countries, has attempted to link entrepreneurial activity to characteristics specific to a geographic region, including measures of knowledge, such as R&D and human capital. Entrepreneurship activity has been typically measured as new-firm startups (rates), self-employment (rates), business ownership (rates), or a combination of startups and exits referred to as turbulence (rates). For example, the collection of European country studies included in the special issue of *Regional Studies* on “Regional Variations in New Firm Formation” (Reynolds, Storey and Westhead 1994), along with the survey by Storey (1991) suggest that the empirical evidence has been generally unambiguous with respect to the findings for population density (a positive impact on startup rates), population growth (positive impact on startup rates), skill and human capital levels of the labor force (positive impact), and mean establishment size (negative impact on startup rates). By contrast, the empirical evidence about the impact of unemployment on startup rates is considerably more ambiguous. But an unambiguous positive relationship has emerged between measures of human capital and entrepreneurial activity at the regional level.⁹

Audretsch and Fritsch (1994) examined the impact that location plays on entrepreneurial activity in (West) Germany. Using a data base derived from the social insurance statistics, which covers about 90 percent of employment, they identify the birth rates of new startups for each of 75 distinct economic regions. These regions are distinguished on the basis of planning regions, or *Raumordnungsregionen*. They find that, for the late 1980s, the birth rates of new firms are higher in regions experiencing low unemployment, which have a dense population, a high growth rate of population, a high share of skilled workers, and a strong presence of small businesses.

Similarly, Pfirrmann (1994) has found that the innovative activity of small- and medium-sized firms in West Germany is shaped by regional factors. He uses a database consisting of innovative small and medium-sized firms and finds that the innovative activity of small- and medium-sized enterprises tends to be greater in those regions where there is a strong presence of knowledge resources. However, his results also indicate that factors internal to the firm are more important for the innovation efforts of a small firm than is the regional environment.

If entrepreneurship serves as a mechanism for knowledge spillovers, it should not only be reflected by the model of entrepreneurial choice, or the decision to start a new firm. Rather, measures of entrepreneurial activity should also be positively linked to the growth performance of regions. The view of entrepreneurship is based on its role as an agent of change in a knowledge-based economy implies that a positive economic performance should be linked to entrepreneurial activity. This hypothesis has raised two challenges to researchers: (1) What is meant by economic performance and how can it be measured and operationalized? and (2) Over which units of analysis should such a positive relationship between entrepreneurship and economic performance be manifested? In fact, these two issues are not independent from each other. The answer to the second question, the appropriate unit of analysis, has influenced the first question, the performance criteria and measure.

The most prevalent measures of performance has been employment growth. The most common and almost exclusive measure of performance is growth, typically measured in terms of employment growth. These studies have tried to link various measures of entrepreneurial activity, most typically startup rates, to economic growth. Other measures sometimes used include the relative share of SMEs, and self-employment rates.

⁹ The positive relationship between entrepreneurship activity and economic growth could also be at least partially explained by the fact that a large number of entrepreneurs implies a greater number of firms and a

For example, Audretsch and Fritsch (1996) analyzed a database identifying new business startups and exits from the social insurance statistics in Germany to examine whether a greater degree of turbulence leads to greater economic growth, as suggested by Schumpeter in his 1911 treatise, *A Theory of Economic Development*. These social insurance statistics are collected for individuals. Each record in the database identifies the establishment at which an individual is employed. The startup of a new firm is recorded when a new establishment identification appears in the database, which generally indicates the birth of a new enterprise. While there is some evidence for the United States linking a greater degree of turbulence at the regional level to higher rates of growth for regions (Reynolds, 1999), Audretsch and Fritsch (1996) find that the opposite was true for Germany during the 1980s. In both the manufacturing and the service sectors, a high rate of turbulence in a region tends to lead to a lower and not a higher rate of growth. They attribute this negative relationship to the fact that the underlying components – the startup and death rates – are both negatively related to subsequent economic growth. Those areas with higher startup rates tend to experience lower growth rates in subsequent years. Most strikingly, the same is also true for the death rates. The German regions experiencing higher death rates also tend to experience lower growth rates in subsequent years. Similar evidence for Germany is found by Fritsch (1997).

Audretsch and Fritsch (1996) conjectured that one possible explanation for the disparity in results between the United States and Germany may lie in the role that innovative activity, and therefore the ability of new firms to ultimately displace the incumbent enterprises, plays in new-firm startups. It may be that innovative activity did not play the same role for the German *Mittelstand* as it does for SMEs in the United States. To the degree

stronger accumulation of physical capital.

that this was true, it may be hold that regional growth emanates from SMEs only when they serve as agents of change through innovative activity.

The empirical evidence suggested that the German model for growth provided a sharp contrast to that for the United States. While Reynolds (1999) had found that the degree of entrepreneurship was positively related to growth in the United States, a series of studies by Audretsch and Fritsch (1996) and Fritsch (1997) could not identify such a relationship for Germany. However, the results by Audretsch and Fritsch were based on data from the 1980s.

Divergent findings from the 1980s about the relationship between the degree of entrepreneurial activity and economic growth in the United States and Germany posed something of a puzzle. On the one hand, these different results suggested that the relationship between entrepreneurship and growth was fraught with ambiguities. No confirmation could be found for a general pattern across developed countries. On the other hand, it provided evidence for the existence of distinct and different national systems. The empirical evidence clearly suggested that there was more than one way to achieve growth, at least across different countries. *Convergence in growth rates seemed to be attainable by maintaining differences in underlying institutions and structures.*

However, in a more recent study, Audretsch and Fritsch (2002) find that different results emerge for the 1990s. Those regions with a higher startup rate exhibit higher growth rates. This would suggest that, in fact, Germany is changing over time, where the engine of growth is shifting towards entrepreneurship as a source of growth. The results of their 2002 paper suggest a somewhat different interpretation. Based on the empirical evidence that the source of growth in Germany has shifted away from the established incumbent firms during the 1980s to entrepreneurial firms in the 1990s, it would appear that a process of convergence is taking place between Germany and the United States, where entrepreneurship provides the

engine of growth in both countries. Despite remaining institutional differences, the relationship between entrepreneurship and growth is apparently converging in both countries.

The positive relationship between entrepreneurship and growth at the regional level is not limited to Germany in the 1990. For example, Foelster (2000) examines not just the employment impact within new and small firms but on the overall link between increases in self-employment and total employment in Sweden between 1976-1995. By using a Layard-Nickell framework, he provides a link between micro behavior and macroeconomic performance, and shows that increases in self-employment rates have had a positive impact on regional employment rates in Sweden.

Hart and Hanvey (1995) examine measures of new and small firms start-ups to employment generation in the late 1980s for three regions in the the United Kingdom. While they find that employment creation came largely from SMEs, they also identify that most of the job losses also came from SMEs.

Callejon and Segarra (1999) use a data set of Spanish manufacturing industries between 1980-1992 to link new-firm birth rates and death rates, which taken together constitute a measure of turbulence, to total factor productivity growth in industries and regions. They adopt a model based on a vintage capital framework in which new entrants embody the edge technologies available and exiting businesses represent marginal obsolete plants. Using a Hall type of production function, which controls for imperfect competition and the extent of scale economies, they find that both new-firm startup rates and exit rates contribute positively to the growth of total factor productivity in regions as well as industries.

The evidence linking entrepreneurship to growth at the regional level may actually be more convincing in the European context than in the North American context. Only a handful of studies have been undertaken for North America, while the evidence from Europe is considerably more robust and consistent.

In the U.S. a series of studies (Wilson 1996; Bates 1998) have attempted to identify whether the determinants of entrepreneurial activity differ for different immigrant and ethnic minority groups. In one of the most important studies, Saxenien (2001) documents that the decision to become an entrepreneur is shaped by immigrant group status. In particular, she provides evidence that the fastest-growing groups of immigrant engineers in Silicon Valley are from Mainland China and India. Chinese, in particular, are increasingly visible in the computer science and engineering departments on university campuses located in the Silicon Valley region. Saxenien (2001) suggests that these immigrant entrepreneurs provide a mechanism for a two-way flow of ideas and knowledge between Silicon Valley and their home regions in Asia.

7. Conclusions

Perhaps the greatest development in the literature on the economics of innovation and technological change in the last decade has been the insight that geography matters. A long tradition of analyzing the innovative process within the boundaries of the firm and devoid of spatial context has given way to the incorporation of spatial context in models of innovation and technological change.

Incorporating spatial relationships into the model of the knowledge production function has redeemed the view that knowledge inputs are linked to innovative output. While the boundaries of the firm still matter, so do the boundaries of spatial agglomerations. Geography has been found to provide a platform upon which new economic knowledge can be produced, harnessed and commercialized into innovations. Thus, *the model of the knowledge production has been found to hold better for spatial units of observation than for enterprises in isolation of spatial context.*

This is not to say that the research agenda of the geography of innovation and knowledge spillovers is in any way complete. Rather, a broad spectrum of research issues and questions remain open and virtually unexplored. One important but relatively uncharted area for future research involves the life cycle of spatial units, such as agglomerations, clusters and regions. Due to data constraints, most of the research reported in the chapter is based on cross-sectional analyses. *While research has determined that geographic space matters for innovation, it has yet to unravel how agglomerations are formed, where they come from, how they are either sustained and strengthened, or else deteriorate over time.* With the prevalence of new longitudinal panel data, we look forward to answers to these questions being provided by a new generation of scholars researching the spatial dimensions of innovative activity.

As this chapter concludes, scholars have confirmed that knowledge spills over and that such knowledge spillovers matter in the formation of clusters and agglomerations. But to move beyond this insight much work remains to be done. The concept of knowledge spillovers has been generally treated as being homogeneous. Yet, surely not all knowledge is the same. We look for a greater taxonomy identifying the rich heterogeneity involved in knowledge and the process by which it spills over. Just as the Eskimos have names for the many different types of snow, scholars must begin the arduous task of identifying and distinguishing among the many types of knowledge spillovers.

Similarly, the mechanisms transmitting knowledge spillovers remain relatively unexplored and unknown. How and why does knowledge spill over is more than an academic question. Firms would like to know how spillovers can be accessed and places – cities, states, regions and countries – would like to know how strategically invest in the development of absorptive capacity to enhance the spillover of knowledge. Thus, while the endogenous growth theory emphasizes the importance of investments in research and

development and human capital, a research agenda needs to be mapped out identifying the role that investments in spillover conduits can make in generating economic growth. It may be that a mapping of the process by which new knowledge is created, externalized and commercialized, hold the key to providing the microeconomic linkages to endogenous macroeconomic growth.

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