EVERYWHERE? THE GEOGRAPHY OF KNOWLEDGE[1]

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Abstract. This paper is reviews what we know about the spatial manifestations of knowledge. The knowledge production function addresses the easily measured portion of knowledge produced. Research on learning, particularly interactive and collective learning, in firms and in innovation systems, promises to unveil the human and organizational processes by which knowledge is created, stored, and transmitted to others. Our understanding of innovation and technological change depends on how well we tackle knowledge and its geography.

1. INTRODUCTION

A paper on the geography of knowledge presupposes that knowledge is not uniformly but, rather, unevenly distributed across the landscape. Knowledge – and innovative activity – are geographically clustered, and the "tendency toward spatial concentration has become more marked over time, not less" (Asheim and Gertler, 2005, p. 291). Moreover, producing knowledge is different from the production of other goods and services. Knowledge can be shared freely – akin to the "viral" spread of digital files – but it also is very individualized and difficult to transmit to others. Some knowledge is embodied in machinery, capital equipment, and complex systems. Other knowledge must be learned through experience, observation, research, or apprenticeship. This suggests, then, that there are several different types of knowledge, with distinct attributes.

Not long ago, the economics of knowledge had an ill-defined, "black box" character. Foray (2004) describes the "comfortable world" of standard models, in which only some agents and institutions (such as research and development (R&D) laboratories) and sectors ("knowledge industries") were specialized in the production of knowledge. The output of this production, modeled by the knowledge production function (Griliches, 1979; Pakes and Griliches, 1984) is invention, typically represented by patents. See Audretsch (2003) and Feldman (1999) for summaries of the conventional approach.

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Foray (2004) summarizes three properties of knowledge as an economic good: first, knowledge is *nonexcludable* and therefore difficult to control or to prevent others from using it; second, knowledge is *nonrival* – that is, others can use it, even simultaneously, and therefore it is inexhaustible (i.e. transmitting knowledge is a positive-sum game); and third, knowledge is *cumulative,* although old knowledge does become obsolete as best practice advances (Schumann, 2003).

This paper focuses on how knowledge is produced and how it is shared, exchanged and spread from place to place. The production of knowledge as an economic output is now standardized and this is the topic of Section 2. Knowledge exchange and learning, on the other hand, are much more complex, as Section 3 will show. The same is true of knowledge flows and spillovers (Section 4). Section 5 sketches some elements of a research agenda, followed by some conclusions.

2. KNOWLEDGE PRODUCTION: PATENTS AND OTHER OUTPUTS

Despite a flurry of research on patents and patent citations as observable knowledge flows, patents represent only a small fraction of knowledge. Instead, “knowledge is largely unobservable” and “most phenomena relating to knowledge are largely unmeasurable” (Foray, 2004, p. 9). Even within the standard model, the logic flows toward process or productivity improvements – of the production of existing goods and services – rather than toward product innovations, which are qualitatively new and different (Lundvall and Christensen, 2004).

Indeed, the knowledge production function ignores the fact that knowledge production is different from the production of goods in several ways. First, it entails greater uncertainty. Indeed, uncertainty is inherent in the entire process of technological change. Second, knowledge is embodied not only in capital goods, as commonly modeled, but also in people, a phenomenon addressed to some degree, but inadequately, by the concept of human capital. Third, knowledge also is embodied in organizations, taking the form of organizational routines (Howitt, 1997). Within firms, the resultant knowledge is greater than the sum of the individual knowledge possessed by the firm’s employees (Nahapiet and Ghoshal, 1998). Endogenous growth theory, as developed by Romer (1986, 1990) and Grossman and Helpman (1991, 1994) has not captured these phenomena adequately (Howitt, 1997).

Griliches (1990) justifies the use of patents by their high correlation with R&D, with the result that "in the absence of detailed R&D data, the much more plentiful patent data can be used instead as an indicator of both, inventive input and output. … Nothing else even comes close in the quantity of available data, accessibility, and the potential industrial, organizational, and technological detail" (p. 1702). Consequently, a flood of research has exploited the large, accessible data sets on patents and patent citations, despite cautions such as by Hall and Ziedonis (2001), who find a paradox: the number of patents has grown, but their quality has declined. Moreover, much research ignores substantial intersectoral and international differences in the propensity to patent, the uses of patents, and the prevalence of spillovers (Cohen et al., 2002; Foray, 2004).

Knowledge "spills over" from the R&D activity of a firm or university to others that have not invested in that R&D. Empirical research using this approach has confirmed that university research spills over to private industry, but with distance decay. The work of Jaffe (1989), Jaffe and Trajtenberg (1996), Acs et al. (1997) all support the "localization of spillovers" within a range of 50 miles from the metropolitan area of origin rather than their uniform spread from the source. The higher propensity of universities to patent inventions has reduced the spillovers from research (Stephan, 1996), perhaps due to the lower quality of more recent patents (Mowery and Ziedonis, 2002).

Despite the availability of data, patents and citations to patents do not capture all spillovers. The big set of missing beneficiaries of R&D – in this case, its consumers – are in the service sector, in which firms do relatively little R&D (Scherer, 1982).[2] A more important gap is that patents represent only *codified* knowledge, and not *tacit* knowledge – a distinction of major significance since the publication of Nonaka and Takeuchi's (1995) *The Knowledge-Creating Company*. The most invisible knowledge is tacit knowledge, which is central to innovation as a learning process. Codified knowledge includes scientific publications and citations to them, and the digital version of the citation indices has spawned an industry of *scientometrics* to study them. The geography of scientific publication itself is very concentrated in large cities, as one would expect, but also at the locations of major research universities located in remote areas

[2] See Cortada (2004, 2006) for details on how computers have changed the work of user industries, such as retailing, financial services, and entertainment, as well as manufacturing, and Cortada (2007) on uses by the public sector.

(Matthiessen et al., 2002, 2006). Codification does not simply make tacit knowledge available to others; codification refines knowledge and transforms it to a higher form (Lundvall, 2006).

Even corporate R&D no longer is confined to firms' R&D labs; it takes place within dispersed networks of sources, both internal to the firm but also increasingly from outside it. Global production networks (GPNs) and global innovation networks embody widespread connections among sources of knowledge (Ernst, 2002, 2009; Ernst and Kim, 2002). The "new ecology of R&D" or "open innovation" model suggests that the R&D-based knowledge production function is less and less an accurate reflection of empirical reality (Chesbrough, 2003; Coombs and Georghiou, 2002).[3] Therefore, there is more to knowledge than merely R&D, whether "open" or otherwise. Singh (2008), for example, suggests that achieving net positive spillovers seems to require informal mechanisms that promote knowledge integration and learning across locations and specific application of a firm's knowledge and capabilities or what Teece (1986) calls its "complementary assets" and "core competences.".

Preeminent among the non-firm sources of knowledge are universities and public research labs. While the innovation process has become less a linear model and more a series of interactive feedback loops (Myers and Rosenbloom, 1996), universities have become more centrally involved in the innovation process. They now patent researchers' findings from funded research and profit directly from those inventions (since the Bayh-Dole Act of 1980). Universities also form both formal and informal ties with companies, to mutual advantage but an advantage that predominantly benefits large firms (Cooke et al., 2007). However, there is evidence that the constraining effects of physical distance have weakened, at least between innovators and collaborators (Johnson *et al*., 2006).

"Learning by doing" and "learning by using" were early ways of capturing these kinds of learning that take place outside of formal R&D. We now recognize that user-producer interaction is a key mechanism for how outside knowledge and technologies are obtained, understood, and incorporated. The list of types of learning has expanded greatly over the years, now encompassing learning by operating, training, hiring, searching, trying, interacting, selling, borrowing, and failing (Malecki, 1997, p. 59). The implication of this view of knowledge is that

[3] Antonelli (2008) believes that technological externalities do not apply to acquisition of external knowledge. Dedicated interaction and specific resources are required if knowledge that spills over is to be exploited and absorbed. External knowledge has a cost and should not be treated as free. The relevant externalities, then, are pecuniary externalities, as distinct from technological externalities.

the traditional view, originating with Arrow (1962) and its emphasis on appropriability, is inadequate, as Cohendet and Meyer-Krahmer (2001) have pointed out.

The idea that knowledge spillovers can occur from unplanned interactions, combined with the high density of people within cities, has led to models of urban growth based on agglomeration economies (Glaeser et al. 1992; Glaeser, 2008; Fujita and Thisse, 2002). However, in these models, agglomeration serves only as a vehicle for proximity which, in turn, inspires interaction. The process of *interactive learning* is absent, despite recognition of its importance (Lundvall and Johnson, 1994). Knowledge also can be gained through know-how trading (Carter, 1989), and much is in the realm of *untraded interdependencies* (Storper, 1997). Just as not all firms do R&D, and not all knowledge is patented, regions vary in their level of untraded interdependencies for a variety of reasons. The oft-cited comparison of Boston and Silicon Valley by Saxenian (1994) illustrates the differences between two innovative regions. In some regions, the level of interaction (formal and especially informal) is high, generating regional competence (Lawson, 1999).

In universities, interactive learning and flows of tacit knowledge need to take place in order for new scientific fields to be developed. Zucker et al. (2007) find that cumulative advantage, indicated by the level of federal funding, has a large and robust impact on both publication and patenting in nanotechnology. However, nanotechnology also depends on channels through which new learning and collaboration may be achieved.

3. FROM KNOWLEDGE TO KNOWLEDGE SYSTEMS

Outside the world of the standard economic model, research on knowledge has not been limited to the knowledge production function. It has grown from evolutionary or neo-Scumpeterian economic thinking. That means that an emphasis is placed on learning, institutions, and the disruption of equilibrium (Boschma and Frenken, 2006; Freeman, 1994; Hodgson, 1988; Nelson, 1995, 1998; Quéré, 2008). A great deal of the critical process of learning-by-interacting is user-producer interaction, which involves the exchange of knowledge that is complex, imperfect, and changes rapidly – key features of many creative activities (Lundvall, 1988; Gertler, 1995; Storper and Venables, 2004).

The rich body of research on national and regional innovation systems goes some way toward understanding the implications of institutional variation on the production of knowledge and innovation (Cooke et al., 2004; Lundvall, 1992; Nelson, 1993; Tödtling and Trippl, 2005). In particular, "well-functioning" innovation systems do not exist in all regions (Chaminade and Vang; Lawson, 1999). Examples include *knowledge economies*, or "localized and regionalized, clustered, collective learning systems" (Cooke, 2002, p. 187). Other regions, by contrast, are "innovation-averse" (Rodriguez-Pose, 1999). Generally, the literature on national and regional innovation systems, however, still fails to capture the flows among regions (Oinas and Malecki, 2002).

A simple view of knowledge is that it is accumulated information and prior knowledge, providing skills and insights that can be used in future contexts. Table 1 presents a synthesis view of where knowledge is within what people accumulate: knowledge is more than data and information, but it is less than competence, expertise and, certainly, wisdom.

This view of accumulation is what leads many economists to equate knowledge with human capital and to measure both by means of educational attainment, with the common result that "One of the most persistent predictors of urban growth over the last century is the skill level of a city" (Glaeser, 2005, p. 143).[4] However, Zucker and Darby's (1996) work suggests that the presence of universities and of an educated population might be good in a general sense, but for specific technologies, the presence of research universities – a small fraction of the total – and, most importantly, of star scientists at a few of those universities determines the geographic pattern of technology start-ups. The paper returns later to the issue of entrepreneurship as a channel for knowledge transfer.

Moreover, educational attainment does not measure ongoing learning – especially collective learning – which includes many types and responds to institutional variation. Occupations and types of work, which vary to some degree with educational attainment, can be used to define "creative" jobs, including "symbolic analysts" (Florida, 2002; Reich, 1991). Levy and Murnane (2004) and Johnson et al. (2005) show that jobs vary not only in the cognitive knowledge they require, but also in the degree to which they involve complex communication with other people.

[4] If knowledge can be proxied by educational attainment (e.g. bachelor's degree), this "dumbs down" knowledge to the level of the weakest college education. By contrast, ISI citation data (e.g. Adams and Griliches, 1996) encompass only a small subset of publications. A counterpart to the ISI standard would be to consider only Ivy League bachelor's degrees as knowledge.

Innovation is one major outcome of knowledge production; competence is the other (Lundvall, 2004). Firms gain competence through their R&D, through which they accumulate related knowledge as well accomplish specific technological objectives (Cohen and Levinthal, 1994). Absorptive capacity – a richer concept than competence – is the second "face" of R&D. "While R&D obviously generates innovations, it also develops a firm's ability to identify, assimilate, and exploit knowledge from the environment – what we call a firm's 'learning' or 'absorptive' capacity" (Cohen and Levinthal, 1989, p. 569; 1990). As Cohendet and Meyer-Krahmer (2001, p. 1575) note,

> Appropriation is not the only incentive for knowledge production. Firms do have other incentives than the direct exploitation of the monopoly rent, the sale of licenses or the advantage in negotiations offered by patents. The willingness to maintain the firm on the technological frontier, the search for reputation, the objective of signalling, the need to build an absorptive capacity, entrance to networks, and more generally the endeavours of agents in building competencies, are amongst the main other incentives for the firms to invest in R&D.

Antonelli (1999, p. 245) suggests that knowledge is the result of a complex process of the creation of new knowledge building upon not only formal R&D activities, but also on the mix of competences acquired by means of learning processes, the socialization of experience, and the recombination of available information. Technological knowledge, as generated and used by firms, draws upon four different forms of knowledge: tacit and codified, and internal and external (to each firm). The learning processes that generate new knowledge require efforts such as those described by Nonaka and Takeuchi (1995) and Nonaka and Toyama (2002): internalization, externalization, socialization and combination. Learning involves adding new knowledge (learning), maintaining that knowledge (remembering), and losing knowledge that is no longer needed (forgetting).[5] These stocks and flows of knowledge all involve interactions among producers (old and new) and users (existing and potential) (Lundvall and Johnson, 1994).

The *geography* of innovative activity and the innovation process itself manifest "the centrality of 'sticky,' context-laden tacit knowledge and the growing importance of social interaction" in flows of knowledge between entities (Asheim and Gertler, 2005, 293). Giuliani and Bell (2005), for instance, show that knowledge is not diffused evenly "in the air," but flows

[5] How many who once knew how to compute on a slide rule can now remember the process?

primarily within a core group of firms that are characterized by their advanced absorptive capacities. A smaller group of firms act as *technological gatekeepers* – that contribute actively to the acquisition, creation and diffusion of knowledge.

The concepts of "buzz" and "pipelines" captures much of how knowledge actually flows (Bathelt et al., 2004). "Buzz" is the local flow within urban areas, and is among the advantages of agglomeration (Storper and Venables, 2004). The standard view now uses this rationale to explain agglomeration.[6] The role of pipelines or channels to external knowledge, however, is acknowledged to be very important. In small as well as large cities, universities act as pipelines connecting the locality to global knowledge in a variety of scientific fields (Benneworth and Hospers, 2007).

Tacit knowledge difficult to transfer over long distances, it is even more localized between partners who share basic commonalities, such as language, conventions, "codes" of communication (such as jargon), and trust based on prior knowledge of one another (Asheim and Gertler, 2005). Within firms, where many of these commonalities are present within the corporate culture and norms, knowledge transfer remains difficult and a continuing challenge as knowledge sourcing becomes geographically more diverse (Malecki, in press). Tacit knowledge does not flow automatically, and companies go to enormous lengths to facilitate knowledge transfer between those who have it and those who don't. If tacit knowledge cannot be codified and can only be observed through its application and acquired through practice, its transfer between people is slow, costly, and uncertain (Grant, 1996, p. 111). This is because, as Gertler (2003) argues, tacit knowledge is created within specific institutional contexts that are far from uniform (see also Henry and Pinch, 2006). This is why knowledge becomes "territorially sticky" and why there are "multiple geographies of tacit knowledge" that operate within and between firms. Examples include both "knowledge transfer" in the form of best practice and "the social production of new knowledge" (Faulconbridge, 2006).

Even within firms, knowledge travels within epistemic communities of like-minded and like-trained specialists (Brown and Duguid, 2000; Amin and Cohendet, 2004). Active membership and participation in epistemic communities (and communities of practice) reduces uncertainties and the degree of complexity when making decisions regarding technological shifts

[6] Buzz is not the same as face-to-face, as Asheim et al. (2007) stress. McCann (2007) sketches a model of innovation based on face-to-face interaction.

(Bathelt, 2007). Although the concept of spillovers suggests that anyone may benefit, this is not quite the case. In addition to marked variation in *absorptive capacity*, society is not homogeneous. Lissoni (2001) finds that knowledge does not flow freely, but travels among the epistemic community of mechanical engineers of individual machine producers, and a few suppliers' and customers' technicians. He finds no relationship with distance, and that local messages may be highly codified. He identifies the important role of "test customers" and "lead users," as suggested by von Hippel (2006). Notably, public labs and universities are almost totally absent from the epistemic communities.

Part if the reason why epistemic communities form is that knowledge is dissimilar; knowledge bases come in three types: analytical, synthetic, and symbolic (Asheim and Coenen, 2005; Asheim et al., 2007). Scientists work mainly with analytical knowledge, engineers with synthetic knowledge, and artists with symbolic knowledge. However, even within a field such as medicine, distinct patterns characterize knowledge and innovation. Ramlogan et al. (2007) show that different patterns of collaboration and experimentation contribute to knowledge of different diseases.

Except for patents and copyrights where knowledge owners are protected by legally established property rights, knowledge is generally not appropriable by means of market transactions (Grant, 1996). The lack of clear property rights creates ambiguity over the ownership of knowledge. Most codified knowledge (and all tacit knowledge) is stored within individuals, but much of this knowledge is created within firms and is firm-specific. In this view, the essence of the firm is its ability to create, transfer, integrate, and exploit knowledge assets. Indeed, tacit knowledge and the degree to which it can be transferred determine the boundaries of the firm and may well be overwhelm transaction costs considerations (Teece, 1998).

Although knowledge is an outcome of research, there are other forms of knowledge. Bhidé (2008) stresses levels of know-how: from high-level general principles to mid-level technologies to ground-level management know-how. All are needed for the commercialization of new products and services. This continuum, or multidimensional space, of knowledge, then, includes both *component knowledge* and complex *architectural knowledge*. Component knowledge, largely technical and typically patented, can be codified, offshored, and ubiquitous (Maskell, 2001; Maskell and Malmberg, 1999, 2007).

Architectural knowledge relates to the organization of an entire system as well as the structures and routines for organizing knowledge (Pinch *et al*. 2003). Most architectural knowledge is tacit, systemic, and embedded in an organization, and occasionally between organizations, closely related to the synthesis of capabilities known as *systems integration* (Hobday et al., 2005). The higher the degree of knowledge integration between member firms, and the higher the global scope of competition of member firms, the higher the economic performance of industrial clusters (Morosini, 2004).

In summary, the technology (represented by patents) is the easy part to change. In order to create products and services that customers are willing to pay for, a number of "soft" innovative capabilities are needed – and, better yet, if they are "integrated solutions" (Ernst, 2009). As Foray (2004) emphasizes, knowledge management goes beyond R&D to coordinate learning internal to global organizations, and to scan, obtain and coordinate knowledge from external sources.

4. FLOWS AND SPILLOVERS

Building upon the idea that firms learn is the *competence theory of the firm*, which differs markedly from both neoclassical economics and transaction-cost economics. In this view, "firms as seen essentially as repositories of competence" which is "a typically idiosyncratic knowledge capital that allows its holders to perform activities – in particular, to solve problems – in certain ways, and typically do this more efficiently than others" (Foss, 1996, p. 1). This perspective – actually a distinct theory of the firm – has grown from several roots: Nelson and Winter's (1982) evolutionary theory of the firm, and a series of contributions to the "resource-based view" (Teece et al, 1997) and the "knowledge-based view" of the firm (Grant, 1996). The origins of the competence perspective are reviewed masterfully by Knudsen (1996); a review focused more on the economics literature is found in Carlsson and Eliasson (1994).

In the competence perspective, the firm is essentially a repository of skill, experience and knowledge, rather than merely a set of responses to information or transaction costs (Hodgson, 1998; Langlois and Robertson, 1995). These capabilities of a firm comprise "the ability to identify, expand, and exploit the business opportunities" that arise (Carlsson and Eliasson, 1994, p. 694). Furthermore, "what is involved with managerial and entrepreneurial skills is not mere information or knowledge but sophisticated but essentially idiosyncratic judgements and conjectures in the context of uncertainty . . . This is a key difference between contractual and competence-based theories of the firm" (Hodgson, 1998, p. 183).

The consequences of the complex knowledge processes outlined above on the geography of knowledge are several. Regions or nations can accumulate knowledge and capabilities at a meso-level (Foss 1996). Large firms respond to, as well as generate, clusters of knowledge. Even if they are "flagships," they are dependent on external knowledge (Cooke et al., 2007; Ernst 2002; 2009).

All new is not necessarily better than old, but there is a best-practice method or process and the state-of-the-art is constantly changing and moving forward. Because the state-of-the-art keeps moving forward, companies must be aware of global best practice. It is critical to master, adapt, and improve on the imported knowledge and equipment. A large body of research suggests that this is not a straightforward task, and that it requires a purposeful and open knowledge system for generating new knowledge as well as one that is active and cooperative (Bell and Albu, 1999).

Some industries, such as the cultural industries, are "chart businesses," which must produce products and markets for novelty. These businesses live or die by the volume and success of their output being valued as "best" in the marketplace for a limited period (Jeffcutt and Pratt, 2002). Schoales (2006) identifies several other services as constantly innovative, with short product life cycles. The study of creative industries (Caves, 2000) illustrates how firms' objectives vary, resulting in infinite variety of products. However, Jeffcut and Pratt (2002) suggest that there is not a single ideal organizational form of such firms, but rather different forms that emerge as "local solutions" at different times, and for different technologies and industries. The heterogeneity of knowledge, then, results in the heterogeneity of firms. Even Pavitt's (1984) useful typology has limitations (Archibugi, 2001).

There are other explanations for the observed spillovers. Tappeiner et al. (2008) find that, in Europe, the high degree of spatial autocorrelation exhibited by patent applications can be explained by the spatial location of the input factors in the knowledge production function. However, those inputs are not all that is involved in knowledge creation: "the spatial concentration of social capital is as important as the concentration of R&D and human capital in explaining observed autocorrelation of innovation" (p. 869).

This is in large part a result of the importance of informal contacts. Dahl and Pedersen (2004) demonstrate that informal contacts are an important channel for the exchange of even quite valuable information. Similarly, McCann and Simonen (2005) find very little support for the argument that cooperation with universities, research institutes, or consultants plays any role in promoting innovation. In their Finnish data, once they control for labor mobility, the evidence for direct university-industry knowledge spillovers is very limited.

Spillovers everywhere? Not yet

A global view of the geography of knowledge can conclude simply that "the world is spiky" (Florida, 2005), reinforcing the stylized fact that that knowledge is concentrated. Cross-country differences in knowledge and the role of knowledge in economic growth have prompted analysis of the role of *catch-up* (Fagerberg, 2005).

Castellacci and Archibugi (2008) demonstrate that there are two major factors that explain most of the variance in the distribution of knowledge among 131 countries. The first factor is a broad measure of technological infrastructures and human skills which together define a country's absorptive capacity. The second factor is a measure of the creation and diffusion of codified knowledge. Both factors contribute to determine the innovative capability of nations, which distribute into three clusters, corresponding to innovation, imitation, and stagnation, which have been relatively stable over time. Less fully understood and still absent from formal models are the flows over distance, such as from one city to another. These flows take place over *channels*, or diffuse transmission across space, or through *pipelines*, which are restrictive, usually as a result of appropriated knowledge (Owen-Smith and Powell, 2004).

Firms and industries vary greatly in their technological regimes and knowledge characteristics (St. John and Pouder, 2006; Iammarino and McCann, 2006). Firms in the biotechnology and information technology sectors exhibit dramatically different reliance on local and distant sources of knowledge (Cooke et al., 2007). Importantly, biotech and its support networks are not as clustered as those in semiconductors and telecommunications, and they operate more as an archipelago of knowledge nodes (Kenney and Patton, 2005; Moodysson, 2008). Connection to one or two of these pools of knowledge may not be sufficient.

Over time, mainly through (im)mobility of workers, firms in a local cluster tend to develop a cluster-specific, inter-firm stock of knowledge that is distinct from that anywhere else in the industry. Henry and Pinch (2006) call this a *cluster-level architectural knowledge system*. A great deal of this practical knowledge is locally rooted, itself enabling creativity (Scott, 2006). Knowledge flows across cluster boundaries are minimal, leading to the creation of 'spatial knowledge monopolies' (Cooke, 2005). These reflect a combination of both local networks of local industrial knowledge and networks (or pipelines) to global knowledge. Clusters in large urban areas possess the ideal of agglomeration beneficial for exchange of tacit knowledge and connectivity within global networks which facilitates exchange of codified knowledge (Capello, 1999). For innovating firms, local agglomeration economies are particularly important because city size provides the kinds of assets required by such firms (Simmie, 2006). Matthiessen et al. (2006) show that the production of knowledge is relatively concentrated in large agglomerations, but that there is surprising variation in the rankings for science production in various disciplines.

In the *knowledge spillover theory of entrepreneurship* proposed by Acs et al. (2009) and Audretsch et al. (2006), knowledge created endogenously results in knowledge spillovers, which allow entrepreneurs to identify and exploit opportunities. In this model, entrepreneurs are among the few agents who "penetrate the knowledge filter" created by patented knowledge. In other words, entrepreneurs are key agents. A new firm is created endogenously via entrepreneurship, which is the recognition of an opportunity and its pursuit by an agent (or team of agents) to appropriate the value of that knowledge. Spillovers, as measured by start-up firms, are very localized – within 500 meters – according to a study of Canadian biotechnology firms (Aharonson et al., 2007).

5. A RESEARCH AGENDA

There is no shortage of suggestions about what we don't know about knowledge. For example, Paul Krugman has said that "developing solid models of knowledge spillovers is of urgent necessity" (Fujita and Krugman, 2004, p. 160). As such models are developed, it is critical to maintain the distinctions among knowledge bases. The science-based or analytical knowledge base measured by patents is only one model; other, less codified types of knowledge lead to innovation (Bhidé, 2008; Foray, 2004).[7]

[7] Game theory approaches to knowledge, such as that by Samuelson (2004), also do not seem to grasp the construction of knowledge within rich accounts (Amin and Cohendet, 2004).

To get beyond the study of patents and patent citations, the easily measured tip of the iceberg of knowledge production, will require recognition of the importance of the process of interactive learning. To some degree, this is possible in Europe, where several generations of the *Community Innovation Survey* provide a rich data set not available in the USA. See, for example, Arundel et al. (2006), Simmie (2003), and Tether (2002). There is evidence that knowledge production in the US and in Europe is governed by different territorial dynamics or geographical processes (Crescenzi et al., 2007). Breschi and Lissoni (2001, p. 270-271) suggest: "More research efforts should be placed on finding out how knowledge is transmitted, among whom, at what distance, and on the basis of which codebooks" and more needs to be known about the labor market, firm networks, and "the 'real' impact of research facilities and local universities on firms' innovative activities."

Migration is among the labor market issues that is poorly understood. We know little about how international migration shapes the emerging geography of knowledge. Many nations try to attract the same pool of highly skilled talent, thus relying on international flows to fill existing or future gaps in supply (Box and Basri, 2008). Saxenian (2006) suggests that education in the US has enabled Asians to learn not only technical knowledge but important cultural knowledge related to venture capital and entrepreneurship.

Another long-standing topic for research is the effect of information and communication technologies to reduce, as one would expect, the spatial and proximity effects of agglomeration. What might be happening instead of substitution, of course, is complementarity (Gaspar and Glaeser, 1998; Song et al., 2007). Electronic communication must be complemented with periodic co-location for the transmission of complex and tacit knowledge (De Meyer, 1993). But we do not know much more (Maznevski and Chudoba, 2000).

For what demand is knowledge produced? As Howells (2002) points out, no research has addressed the demand for knowledge; perhaps formal schooling would be the sole exception. Tacit knowledge has no actual market demand. In general, "compared with goods and other services, information and knowledge cannot be so readily 'bought as required' we do not know the value of information until after it is purchased" (Hodgson, 1998, p. 183). One category of demand on which too little is presently known is innovation under conditions of "scarcity" (Srinivas and Sutz, 2008). Demand at the "bottom of the pyramid" has led to "frugal engineering" and innovation for poor people rather than only for rich people (Kumar, 2008;

Prahalad and Hammond, 2002). This concern had been far more prevalent a few decades ago (Stewart, 1978).

Finally, another form of intellectual property right, the trademark, has been too little studied and not fully acknowledged by economists (Mendonça et al., 2004; Ramello and Silva, 2006). Apple Inc., for example, has devoted great effort to obtaining trademarks rather than merely patents for its iPod and iPhone. Unlike the more common utility and design patents, which exist to cover functions and the ornamental look and feel of products and expire after a set number of years, trademarks can remain in force potentially forever (Orozco and Conley, 2008).

6. CONCLUSION

This review of the geography of knowledge confirms that knowledge is acquired, transmitted, and transformed in many different ways. The standard model of knowledge production and spillovers, involving R&D effort that results in patents, which cite prior patents, holds most strongly at broader levels of aggregation, and "becomes less compelling is at the disaggregated microeconomic level of the enterprise, establishment, or even line of business" (Audretsch, 2003, p. 168). The standard model deals well with scientific advances, but less well with user needs and capabilities, and with problems raised by integration in complex technological systems (Foray, 2004).

The geography of tacit knowledge and learning has become more complex and more local as the world has "shrunk" thanks to new technologies. How knowledge is created and spread and how innovation occurs remain vexing issues for research. Will newcomer firms from outside the core countries succeed in the coming decades? The geography of innovation remains a central issue for researchers attempting to understand economic change.

REFERENCES

Acs, Zoltan J., Pontus Braunerhjelm, David B. Audretsch and Bo Carlsson. 2009. "The Knowledge Spillover Theory of Entrepreneurship," *Small Business Economics*, 32(1), 15-30.

Adams, James and Zvi Griliches. 1996. "Measuring Science: An Exploration," *Proceedings of the National Academy of Sciences*, 93(23), 12664-12670.

Aharonson, Barak S., Joel A.C. Baum and Maryann P. Feldman. 2007. "Desperately Seeking Spillovers? Increasing Returns, Industrial Organization and the Location of New Entrants in Geographic and Technological Space," *Industrial and Corporate Change*, 16(1), 89-130.

Amin, Ash and Patrick Cohendet. 2004. *Architectures of Knowledge: Firms, Capabilities, and Communities*, Oxford: Oxford University Press.

Anselin, Luc, Attila Varga and Zoltan Acs. 1997. "Local Geographic Spillovers between University Research and High Technology Innovations," *Journal of Urban Economics*, 42(3), 422-448.

Antonelli, Cristiano. 1999. "The Evolution of the Industrial Organisation of the Production of Knowledge," *Cambridge Journal of Economics*, 23(2), 243–260.

Antonelli, Cristiano. 2008. "Pecuniary Knowledge Externalities: The Convergence of Directed Technological Change and the Emergence of Innovation Systems," *Industrial and Corporate Change*, 17, 1049–1070.

Archibugi, Daniele. 2001. "Pavitt's Taxonomy Sixteen Years On: A Review Article," *Economics of Innovation and New Technology*, 10(5), 415-425.

Arrow, Kenneth J., 1962. "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity*. Princeton University Press, Princeton, pp. 609–625.

Arundel, Anthony, Edward Lorenz, Bengt-Åke Lundvall and Antoine Valeyre. 2006. "How Europe's Economies Learn: A Comparison of Work Organization and Innovation Mode for the EU-15," *Industrial and Corporate Change*, 16(6), 1175-1210.

Asheim, Bjørn T. and Lars Coenen. 2005. "Knowledge Bases and Regional Innovation Systems: Comparing Nordic clusters," *Research Policy*, 34(8), 1173-1190.

Asheim, Bjørn T., Lars Coenen and Jan Vang. 2007. "Face-to-Face, Buzz, and Knowledge Bases: Sociospatial Implications for Learning, Innovation, and Innovation Policy," *Environment and Planning C: Government and Policy*, 25(5), 655-670.

Asheim, Bjørn T. and Meric S. Gertler. 2005. "The Geography of Innovation: Regional Innovation Systems," in J. Fagerberg, D.C. Mowery and R.R. Nelson (eds.), *The Oxford Handbook of Innovation*, Oxford: Oxford University Press, pp. 291-317.

Audretsch, David B. 2003. "Innovation and Spatial Externalities," *International Regional Science Review*, 26(2), 167-174.

Audretsch, David B., Max C. Keilbach and Erik E. Lehmann. 2006. *Entrepreneurship and Economic Growth*, Oxford: Oxford University Press.

Bathelt, Harald. 2007. "Buzz-and-Pipeline Dynamics: Towards a Knowledge-Based Multiplier Model of Clusters," *Geography Compass*, 1(7), 1282-1298.

Bell, Martin and Michael Albu. 1999. "Knowledge Systems and Technological Dynamism in Industrial Clusters in Developing Countries," *World Development*, 27(9), 1715-1734.

Benneworth, Paul and Gert-Jan Hospers. 2007. "The New Economic Geography of Old Industrial Regions: Universities as Global–Local Pipelines," *Environment and Planning C: Government and Policy*, 25, 779-802.

Bhidé, Amar. 2008. *The Venturesome Economy: How Innovation Sustains Prosperity in a More Connected World*, Princeton, NJ: Princeton University Press.

Boschma, Ron A. and Koen Frenken. 2006. "Why is economic geography not an evolutionary science? Towards an evolutionary economic geography," *Journal of Economic Geography*, 6(3), 273-302.

Box, Sarah and Ester Basri. 2008. *The Global Competition for Talent: Mobility of the Highly Skilled*, Paris: OECD.

Breschi, Stefano and Francesco Lissoni. 2001. "Localised Knowledge Spillovers vs. Innovative Milieux: Knowledge 'Tacitness' Reconsidered," *Papers in Regional Science*, 80(3), 255–273.

Brown, John Seely and Paul Duguid. 2000. *The Social Life of Information*, Boston, Harvard Business School Press.

Capello, Roberta. 1999. "Spatial Transfer of Knowledge in High Technology Milieux: Learning versus Collective Learning Processes," *Regional Studies*, 33, 353-365.

Carlsson, Bo and Gunnar Eliasson. 1994. "The Nature and Importance of Economic Competence," *Industrial and Corporate Change*, 3(3), 687-711.

Carter, Anne P. 1989. "Knowhow Trading as Economic Exchange," *Research Policy* 18(3), 155-164.

Castellacci, Fulvio and Daniele Archibugi. 2008. "The Technology Clubs: The Distribution of Knowledge across Nations," *Research Policy*, 37(10), 1659–1673.

Caves, Richard E. 2000. *Creative Industries: Contracts between Art and Commerce*, Cambridge, MA: Harvard University Press.

Chesbrough, Henry W. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Cohen, Wesley M. and Daniel A. Levinthal. 1989. "Innovation and Learning: The Two Faces of R&D," *The Economic Journal*, 99, 569–596.

Cohen, Wesley M. and Daniel A. Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, 35(1), 128–152.

Cohen, Wesley M. and Daniel A. Levinthal. 1994. "Fortune Favors the Prepared Firm," *Management Science*, 40(2): 227-251.

Cohen, Wesley M., Akira Goto, Akiya Nagata, Richard R. Nelson and John P. Walsh. 2002. "R&D Spillovers, Patents and the incentives to innovate in Japan and the United States," *Research Policy*, 31(8-9), 1349-1367.

Cohendet, Patrick and Frieder Meyer-Krahmer. 2001. "The Theoretical and Policy Implications of Knowledge Codification," *Research Policy*, 30(9), 1563–1591.

Cooke, Philip. 2002. *Knowledge Economies: Clusters, Learning and Cooperative Advantage*, London: Routledge.

Cooke, Philip. 2005. "Regionally Asymmetric Knowledge Capabilities and Open Innovation: Exploring 'Globalisation 2'—A New Model of Industry Organization," *Research Policy*, 34(8), 1128–1149.

Cooke, Philip, Martin Heidenreich and Hans-Joachim Braczyk, eds. 2004. *Regional Innovation Systems: The Role of Governance in a Globalised World* (2nd edition), London: Routledge.

Cooke, Philip, Carla De Laurentis, Franz Tödtling and Michaela Trippl. 2007. *Regional Knowledge Economies: Markets, Clusters and Innovation*, Cheltenham: Edward Elgar.

Coombs, Rod and Luke Georghiou. 2003. "A New 'Industrial Ecology'," *Science*, 296 (19 April), 471.

Cortada, James W. 2004. *The Digital Hand: How Computers Changed the Work of American Manufacturing, Transportation, and Retail Industries*, Oxford: Oxford University Press.

Cortada, James W. 2006. *The Digital Hand*, Volume II*: How Computers Changed the Work of American Financial, Telecommunications, Media, and Entertainment Industries*, Oxford: Oxford University Press.

Cortada, James W. 2007. *The Digital Hand*, Volume III: *How Computers Changed the Work of American Public Sector Industries*, Oxford: Oxford University Press.

Crescenzi, Riccardo, Andres Rodriguez-Pose and Michael Storper. 2007. "The Territorial Dynamics of Innovation: A Europe–United States Comparative Analysis," *Journal of Economic Geography*, 7(6), 673-709.

Dahl, Michael S. and Christian Ø.R. Pedersen. 2004. "Knowledge flows through informal contacts in industrial clusters: myth or reality?" *Research Policy*, 33(10), 1673–1686.

De Meyer, Arnoud. 1993. "Management of an International Network of Industrial R&D Laboratories," *R&D Management*, 23(2), 109-120.

Ernst, Dieter. 2002. "Global Production Networks and the Changing Geography of Innovation Systems. Implications for Developing Countries," *Economics of Innovation and New Technology*, 11(6), 497-523.

Ernst, Dieter. 2009. A New Geography of Knowledge? Asia's Role in Global Innovation Networks, Honolulu: East-West Center.

Ernst, Dieter and Linsu Kim. 2002. “Global Production Networks, Knowledge Diffusion, and Local Capability Formation,” *Research Policy*, 31 (8-9), 1417-1429.

Fagerberg, Jan. 2006. “Knowledge in Space: What Hope for the Poor Parts of the Globe?” in B. Kahin and D. Foray (eds.), *Advancing Knowledge and the Knowledge Economy*, Cambridge, MA: MIT Press, pp. 217-234.

Feldman, Maryann P. 1999. “The New Economics of Innovation, Spillovers and Agglomeration: A Review of Empirical Studies,” *Economics of Innovation and New Technology*, 8(1-2), 5-25.

Florida, Richard. 2002. *The Rise of the Creative Class …. and how it’s transforming work, leisure, community, & everyday life*, New York: Basic Books.

Florida, Richard. 2005. “The World Is Spiky,” *The Atlantic Monthly*, October, 48-51.

Foray, Dominique. 2004. *The Economics of Knowledge*, Cambridge, MA: MIT Press.

Foss, Nicholas J. 1996. “Higher-Order Industrial Capabilities and Competitive Advantage,” *Journal of Industry Studies*, 3(1), 1–20.

Freeman, Chris. 1994. “The Economics of Technical Change,” *Cambridge Journal of Economics*, 18(5), 463-514.

Fujita, Masahisa and Paul Krugman. 2004. “The New Economic Geography: Past, Present and the Future,” *Papers in Regional Science*, 83(1), 139–164.

Fujita, Masahisa and Jacques-François Thisse. 2002. *Economics of Agglomeration: Cities: Industrial Location, and Regional Growth*, Cambridge: Cambridge University Press.

Gaspar, Jess and Edward L. Glaeser. 1998. “Information Technology and the Future of Cities”, *Journal of Urban Economics*, 43(1): 136-156.

Gertler, Meric S. 1995. “ ‘Being There’: Proximity, Organization, and Culture in the Development and Adoption of Advanced Manufacturing Technologies,” *Economic Geography*, 71(1), 1-26.

Gertler, Meric S. 2003. “Tacit Knowledge and the Economic Geography of Context, or The undefinable tacitness of being (there),” *Journal of Economic Geography*, 3(1), 75–99.

Giuliani, Elisa and Martin Bell. 2005. “The Micro-Determinants of Meso-Level Learning and Innovation: Evidence from a Chilean Wine Cluster,” *Research Policy*, 34(1), 47-68.

Glaeser, Edward L. 2000. “The Future of Urban Research: Nonmarket Interactions,” *Brookings-Wharton Papers on Urban Affairs*, 101–138.

Glaeser, Edward L. 2005. “Reinventing Boston: 1630-2003,” *Journal of Economic Geography*, 5(2), 119-153.

Glaeser, Edward L. 2008. *Cities, Agglomeration and Spatial Equilibrium*, Oxford: Oxford University Press.

Glaeser, Edward L., Hedi D. Kallal, José A. Scheinkman and Andrei Shleifer. 1992. “Growth in Cities,” *Journal of Political Economy*, 100(6), 1126-1152.

Grant, Richard M. 1996.

Griliches, Zvi. 1979. “Issues in Assessing the Contribution of Research and Development to Productivity Growth,” *Bell Journal of Economics*, 10(1), 92-116.

Griliches, Zvi. 1990. “Patent Statistics as Economic Indicators: A Survey,” *Journal of Economic Literature*, 28(4), 1661-1707.

Grossman, Gene M. and Elhanan Helpman. 1991. *Innovation and Growth in the Global Economy*, Cambridge, MA: MIT Press.

Grossman, Gene M. and Elhanan Helpman. 1994. “Endogenous Innovation in the Theory of Growth,” *Journal of Economic Perspectives*, 8(1), 23-44.

Hall, Bronwyn H. and Rosemary H. Ziedonis. 2001. “The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995,” *Rand Journal of Economics*, 32 (1), 101-128.

Henry, Nick and Steven Pinch. 2006. “Knowledge and Clusters,” in C. Pitelis, R. Sugden and J.R. Wilson (eds), *Clusters and Globalisation: The Development of Urban and Regional Economies*, Cheltenham: Edward Elgar, pp. 114-132.

Hobday, Michael., Andrew Davies and Andrea Prencipe. 2005. “Systems Integration: A Core Capability of the Modern Corporation,” *Industrial and Corporate Change*, 14(6), 1109-1143.

Hodgson, Geoffrey M. 1998. “Competence and Contract in the Theory of the Firm,” *Journal of Economic Behavior and Organization*, 35(2): 179-201.

Howells, Jeremy. 2002. "Tacit Knowledge, Innovation and Economic Geography," *Urban Studies*, 39(5-6), 871-884.
Howitt, Peter. 1997. "On Some Problems in Measuring Knowledge-Based Growth," in P. Howitt (ed.), *The Implications of Knowledge-Based Growth for Micro-Economic Policies*, Calgary: University of Calgary Press, pp. 9-29.
Iammarino, Simona and Philip McCann. 2006. "The Structure and Evolution of Industrial Clusters: Transactions, Technology and Knowledge Spillovers," *Research Policy*, 35(7), 1018-1036.
Jeffcutt, Paul and Andrew C. Pratt. 2002. "Managing Creativity in the Cultural Industries," *Creativity and Innovation Management*, 11(4), 225-233.
Jaffe, Adam B. 1989. "Real Effects of Academic Research," *American Economic Review*, 79(5), 957-970.
Jaffe, Adam B. and Manuel Trajtenberg. 1996. "Flows of Knowledge from Universities and Federal Laboratories: Modeling the Flow of Patent Citations over Time and across Institutional and Geographic Boundaries," *Proceedings of the National Academy of Sciences*, 93(23), 12671-12677.
Johnson, Daniel K.N., Nalyn Siripong and Amy S. Brown. 2006. "The Demise of Distance? The Declining Role of Physical Proximity for Knowledge Transmission," *Growth and Change*, 37(1), 19-33.
Johnson, Bradford C., James M. Manyika and Lareina A. Yee. 2005. "The Next Revolution in Interactions," *McKinsey Quarterly*, issue 4: 21–33.
Kenney, Martin and Donald Patton. 2005. "Entrepreneurial Geographies: Support Networks in Three High-Technology Industries," *Economic Geography*, 81(2), 201-228.
Knudsen, Christian. 1996. "The Competence Perspective: A Historical View," in N.J. Foss and C. Knudsen (eds.) *Towards a Competence Theory of the Firm*, London: Routledge, pp. 13-37.
Kumar, Nagesh. 2008. "Internationalization of Indian Enterprises: Patterns, Strategies, Ownership Advantages, and Implications," *Asian Economic Policy Review*, 3(2), 242-261.
Langlois, Richard N. and Paul L. Robertson. 1995. *Firms, Markets and Economic Change: A Dynamic Theory of Business Institutions*, London: Routledge.
Levy, Frank and Richard J. Murnane. 2004. *The New Division of Labor: How Computers Are Creating the Next Job Market*, Princeton, NJ: Princeton University Press.
Lissoni, Francesco. 2001. "Knowledge Codification and the Geography of Innovation: The Case of the Brescia Mechanical Cluster," *Research Policy*, 30(9), 1479–1500.
Lundvall, Bengt-Åke. 1988. "Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation," in G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete (eds.), *Technical Change and Economic Theory*, London: Pinter, 349-369.
Lundvall, Bengt-Åke, ed. 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.
Lundvall, Bengt-Åke. 2004. "The Economics of Knowledge and Learning," in J.L. Christensen and B.-Å. Lundvall (eds.), *Product Innovation, Interactive Learning and Economic Performance* (*Research on Technological Innovation and Management Policy*, volume 8), Amsterdam: Elsevier, 21-42.
Lundvall, Bengt-Åke. 2006. *One knowledge base or many knowledge pools?* DRUID Working paper no. 2006-8. Copenhagen: Danish Research Unit for Industrial Dynamics (DRUID).
Lundvall, Bengt-Åke and Jesper Lindgaard Christensen. 2004. "Introduction: Product Innovation – On Why and How It Matters for Firms and the Economy," in J.L. Christensen and B.-Å. Lundvall (eds.), *Product Innovation, Interactive Learning and Economic Performance* (*Research on Technological Innovation and Management Policy*, volume 8), Amsterdam: Elsevier, 1-18.
Lundvall, Bengt-Åke and Björn Johnson. 1994. "The Learning Economy," *Journal of Industry Studies*, 1(2), 23-42.
Malecki, Edward J. 1997. *Technology and Economic Development*, second edition, London, Addison Wesley Longman.
Malecki, Edward J. *in press*. "Global Knowledge and Creativity: New Challenges for Firms, Workers and Regions," *Regional Studies*.
Malecki, Edward J. and Bruno Moriset. 2008. *The Digital Economy: Business Organization, Production Processes and Regional Developments*, London: Routledge.
Maskell, Peter. 2001. "Towards a Knowledge-based Theory of the Geographical Cluster," *Industrial and Corporate Change*, 10(4), 921–943.

Maskell, Peter and Anders Malmberg. 1999. “Localised Learning and Industrial Competitiveness,” *Cambridge Journal of Economics*, 23(2), 167–185.
Maskell, Peter and Anders Malmberg. 2007. “Myopia, knowledge development and cluster evolution,” *Journal of Economic Geography*, 7(5), 603–618.
Matthiessen, Christian Wichmann, Annette Winkel Schwarz and Søren Find. 2002. “The Top-level Global Research System, 1997-99: Centres, Networks and Nodality. An Analysis Based on Bibliometric Indicators,” *Urban Studies*, 39(6), 903-927.
Matthiessen, Christian Wichmann, Annette Winkel Schwarz and Søren Find. 2006. “World Cities of Knowledge: Research Strength, Networks and Nodality,” *Journal of Knowledge Management*, 10(5), 14-25.
Maznevski, Martha L. and Katherine M. Chudoba. 2000. “Bridging space over time: global virtual team dynamics and effectiveness,” *Organization Science*, 11, 473-492.
McCann, Philip. 2007. “Sketching Out a Model of Innovation, Face-to-face Interaction and Economic Geography,” *Spatial Economic Analysis*, 2(2), 117-134.
McCann, Philip and Jaakko Simonen. 2005. “Innovation, Knowledge Spillovers and Local Labour Markets,” *Papers in Regional Science*, 84(3), 465–485.
Mendonça, Sandro, Tiago Santos Pereira and Manuel Mira Godinho. 2004. “Trademarks as an Indicator of Innovation and Industrial Change,” *Research Policy*, 33(9), 1385-1404.
Moodysson, J. 2008. “Principles and Practices of Knowledge Creation: On the Organization of ‘Buzz’ and ‘Pipelines’ in Life Science Communities,” *Economic Geography*, 84(4), 449-469.
Morosini, Piero. 2004. “Industrial Clusters, Knowledge Integration and Performance,” *World Development*, 32(2), 305-326.
Mowery David C. and Arvids A. Ziedonis. 2002. “Academic Patent Quality and Quantity Before and After the Bayh-Dole Act in the United States,” *Research Policy*, 31(3), 399-418.
Myers, Mark B. and Richard S. Rosenbloom. 1996. “Rethinking the Role of Industrial Research,” in R.S. Rosenbloom and W.J. Spencer, eds. *Engines of Innovation*, Cambridge, MA: Harvard University Press, 209-228.
Nelson, Richard R., ed. 1993. *National Innovation Systems*, Oxford: Oxford University Press.
Nelson, Richard R. 1995. “Recent Evolutionary Theorizing About Economic Change,” *Journal of Economic Literature*, 33(1), 48-90.
Nelson, Richard R. 1998. “The Agenda for Growth Theory: A Different Point of View,” *Cambridge Journal of Economics*, 22(4), 497-520.
Nelson, Richard R. and Sidney G. Winter. 1982. *An Evolutionary Theory of Economic Change*, Cambridge, MA: Belknap Press.
Nonaka, Ikujiro and Hirotaka Takeuchi. 1995. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford: Oxford University Press.
Nonaka, Ikujiro and Ryoko Toyama. 2002. “A Firm as a Dialectical Being: Towards a Dynamic Theory of a Firm,” *Industrial and Corporate Change*, 11(5), 995–1109.
Oinas, Päivi and Edward J. Malecki. 2002. “The Evolution of Technologies in Time and Space: From National and Regional to Spatial Innovation Systems,” *International Regional Science Review*, 25(1), 102-131.
Orozco, David and James Conley. 2008. “Innovation: Shape of Things to Come,” *The Wall Street Journal*, May 12, R6.
Owen-Smith, Jason and Walter W. Powell. 2004. “Knowledge Networks as Channels and Conduits: The Effects of Spillovers in the Boston Biotechnology Community,” *Organization Science*, 15(1), 5-21.
Pakes, Ariel and Zvi Griliches. 1984. “Patents and R&D at the Firm Level: A Frist Look,” in Z. Griliches (ed.), *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, 55-72.
Pavitt, Keith. 1984. “Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory,” *Research Policy*, 13(6), 343-373.
Pinch, Steven, Nick Henry, Mark Jenkins and Stephen Tallman. 2003. “From ‘Industrial Districts’ to ‘Knowledge Clusters’: A Model of Knowledge Dissemination and Competitive Advantage in Industrial Agglomeration,” *Journal of Economic Geography*, 3(4), 373–388.
Prahalad, C.K. and Allen Hammond. 2002. “Serving the Poor, Profitably,” *Harvard Business Review*, 80(9), 48-57.

Quéré, Michel. 2008. "Knowledge and Innovation: Promoting a System Approach of Innovation Processes," *Economic of Innovation and New Technology*, 17(1&2), 137-152.

Ramello, Giovanni B. and Francesco Silva. 2006. "Appropriating Signs and Meaning: The Elusive Economics of Trademark," *Industrial and Corporate Change*, 15(6), 937-963.

Ramlogan, Ronnie, Andrea Mina, Gindo Tampubolon and J. Stanley Metcalfe. 2007. "Networks of Knowledge: The Distributed Nature of Medical Innovation," *Scientometrics*, 70(2), 459-489.

Reich, Robert B. 1991. *The Work of Nations*, New York: Alfred A. Knopf.

Romer, Paul M. 1986. "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 94(5), 1002-1037.

Romer, Paul M. 1990. "Endogenous Technological Change," *Journal of Political Economy*, 98(5, supplement), S71-S102.

Samuelson, Larry. 2004. "Modeling Knowledge in Economic Analysis," *Journal of Economic Literature*, 42(2), 367-403.

Saxenian, AnnaLee. 1994. *Regional Advantage*, Cambridge, MA: Harvard University Press.

Saxenian, AnnaLee. 2006. *The New Argonauts*, Cambridge, MA: Harvard University Press.

Scherer, F.M. 1982. "Inter-industry Technology Flows in the United States," *Research Policy*, 11(4), 227-245.

Schumann, Jochen. 2003. "Human Capital, Knowledge and Knowledge Sharing: A View from the History of Economic Thoughts," in E. Helmstädter (ed.), *The Economics of Knowledge Sharing: A New Institutional Approach*, Cheltenham: Edward Elgar, pp. 121-128.

Scott, Allen J. 2006. "Entrepreneurship, Innovation and Industrial Development: Geography and the Creative Field Revisited," *Small Business Economics*, 26(1), 1-24.

Simmie, James. 2003. "Innovation and Urban Regions as National and International Nodes for the Transfer and Sharing of Knowledge," *Regional Studies*, 37(6&7), 607-620.

Simmie, James. 2006. "Do Clusters or Innovation Systems Drive Competitiveness?" in B. Asheim, P. Cooke and R. Martin, eds. *Clusters and Regional Development: Critical Reflections and Explorations*, Lodon: Routledge.

Singh, Jasjit. 2008. "Distributed R&D, Cross-Regional Knowledge Integration and Quality of Innovative Output," *Research Policy*, 38(1), 77-96.

Song, Michael, Hans Berends, Hans van der Bij and Mathieu Weggeman. 2007. "The Effect of IT and Co-location on Knowledge Dissemination," *Journal of Product Innovation Management*, 24(1), 52-68.

Srinivas Smita and Judith Sutz. 2008. "Developing Countries and Innovation: Searching for a New Analytical Approach," *Technology in Society*, 30(2), 129-140.

St. John, Caron H. and Richard W. Pouder. 2006. "Technology Clusters versus Industry Clusters: Resources, Networks, and Regional Advantages," *Growth and Change*, 37(2), 141-171.

Stephan, Paula. 1996. "The Economics of Science," *Journal of Economic Literature*, 34(3), 1199-1235.

Stewart, Frances. 1978. *Technology and Underdevelopment*, second ed., London: Macmillan.

Storper, Michael. 1997. *The Regional World*, New York: Guilford.

Storper, Michael and Anthony J. Venables. 2004. "Buzz: Face-to-Face Contact and the Urban Economy," *Journal of Economic Geography*, 4(4), 351-370.

Tallman, Stephen, Mark Jenkins, Nick Henry, and Steven Pinch. 2004. "Knowledge, Clusters, and Competitive Advantage," *Academy of Management Review*, 29(2), 258–271.

Tappeiner, Gottfried., Christoph Hauser and Janette Walde. 2008. "Regional knowledge spillovers: Fact or artifact?" *Research Policy*, 37(5), 861–874.

Teece, David J. 1986. "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," *Research Policy*, 15(6), 285-305.

Teece, David J. 1998. "Capturing Value from Knowledge Assets: The New Economy, Markets for Know-How, and Intangible Assets," *California Management Review*, 40(3), 55-79.

Teece, David J., Gary Pisano and Amy Shuen. 1997. "Dynamic Capabilities and Strategic Management," *Strategic Management Journal*, 18(7), 509-533.

Tether, Bruce S. 2002. "Who Co-operates for Innovation, and Why: An Empirical Analysis," *Research Policy*, 31(6), 947-967.

Tödtling, Franz and Michaela Trippl. 2005. "One Size Fits All? Towards a Differentiated Regional Innovation Policy Approach," Research Policy, 34(8), 1203-1219.

von Hippel, Eric. 2006. *Democratizing Innovation*, Cambridge, MA: MIT Press.
Zucker, Lynne G. and Michael R. Darby. 1996. "Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the Biotechnology Industry," *Proceedings of the National Academy of Sciences*, 93(23), 12709-12716.
Zucker, Lynne G., Michael R. Darby, Jonathan Furner, Robert C. Liu and Hongyan Ma. 2007. "Minerva Unbound: Knowledge Stocks, Knowledge Flows and New Knowledge Production," *Research Policy*, 36(6), 850-863.

TABLE 1. From Data to Creativity: Concepts Related to Information and Knowledge

Concept	Characteristics
Creativity	Creativity presumes a capacity to order and reorder information with the aid of a knowledge system.
Expertise	Specialized, deep knowledge and understanding gained via experience. Expertise is personalized. An individual with expertise is able to create new knowledge is his or her area of expertise.
Competence	Embodied knowledge. There are at least three types: (1) instrument-oriented competence, (2) sector-specific competence, and (3) regional-specific competence.
Knowledge	Structurally ordered information. Includes reflection, synthesis, and context. Information laden with experience, truth, judgment, intuition and values. Concepts, ideas and patterns are subsets of knowledge. Often tacit, hard to transfer.
Information	Data endowed with relevance and purpose.
Data	Simple observations of states of the world; easily structured, easily captured on machines, easily transferred.

Source: Malecki and Moriset (2008, p. 29, Table 2.3).