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AGGLOMERATION AND THE LOCATION OF INNOVATIVE ACTIVITY

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A paradox has been the emergence of the importance of local proximity and geographic clusters precisely at a time when globalization seems to dominate economic activity. The purpose of this paper is to resolve this paradox by explaining why and how geography matters for innovative activity and ultimately for the international comparative advantage. Globalization and the telecommunications revolution have triggered a shift in the comparative advantage of the leading developed countries towards an increased importance of innovative activity. This shift in comparative advantage has increased the value of knowledge-based economic activity. Since knowledge is generated and transmitted more efficiently via local proximity, economic activity based on new knowledge has a high propensity to cluster within a geographic region. This has triggered a fundamental shift in public policy towards business, away from policies constraining the freedom of firms to contract and towards a new set of enabling policies, implemented at the regional and local levels.

I. INTRODUCTION

That innovative activity has become more important is not surprising. What was perhaps less anticipated is that much of the innovative activity is less associated with footloose multinational corporations and more associated with high-tech innovative regional clusters, such as Silicon Valley, Research Triangle, and Route 122 around Boston. Only a few years ago the conventional wisdom predicted that globalization would lead to the demise of the region as a meaningful unit of economic analysis. Yet the obsession of policy-makers around the globe to 'create the next Silicon Valley' reveals the increased importance of geographic proximity and regional agglomerations. The purpose of this article is to explain why and how geography matters for innovative activity and ultimately for international comparative advantage.

The second section of this paper explains how globalization and the telecommunications revolution have triggered a shift in the comparative advantage of the leading developed countries towards an

[1] I would like to thank the editors of this journal and two anonymous referees.

increased importance of innovative activity. The importance of new knowledge as an input in generating innovative activity is explained in the third section, along with why knowledge is fundamentally different from the more traditional factors of production. These differences account for the propensity for knowledge to spill over from the source creating it to the firm commercializing it, which is explained in the fourth section. However, as is pointed out in the fifth section, there are important reasons why knowledge stops spilling over as it moves across geographic space, bestowing important economic benefits to geographic proximity and localization. In the sixth section the gains from agglomerations are explained by linking knowledge spillovers to innovative activity. In the seventh section, the black box of geographic space is penetrated to link the structure of economic activity within an agglomeration to the innovative performance of that region. Finally, policy implications are discussed in the concluding section. In particular, the increased importance of innovation has triggered a fundamental shift in public policy towards business, away from policies constraining the freedom of firms to contract and towards a new set of enabling policies, implemented at the regional and local levels.

II. INNOVATION AND COMPARATIVE ADVANTAGE

The traditional comparative advantage in mature, technologically moderate industries, such as metalworking, machine tools, and car production had provided an engine for growth, high employment, and economic stability throughout Western Europe for most of the post-war economic period. When the Berlin Wall fell in 1989, many people expected even greater levels of economic well-being resulting from the dramatic reduction of the economic burden in the West that had been imposed by four decades of Cold War. Thus, the substantial unemployment and general economic stagnation during the subsequent 8 years has come as a shock. Unemployment and relatively low growth are the twin economic problems confronting Europe. Over 11 per cent of the work-force in the European Union (EU) was unemployed in 1997, ranging from 6.1 per cent in the United Kingdom and 6.2 per cent in The Netherlands, to 11.1 per cent in Germany, 12.6 per cent in France, and over 20 per cent in Spain.[2]

The traditional comparative advantage has been lost in the high-cost countries of Europe and North America in the last decade for two reasons. The first has to do with globalization, or the advent of competition not just from the emerging economies in South-east Asia but also from the transforming economies of Central and Eastern Europe. The second factor has been the computer and telecommunications revolution. The new communications technologies have triggered a virtual spatial revolution in terms of the geography of production. According to *The Economist*, ‘The death of distance as a determinant of the cost of communications will probably be the single most important economic force shaping society in the first half of the next century.’[3]

Much of the policy debate responding to the twin forces of the telecommunications revolution and increased globalization has revolved around a trade-off between maintaining higher wages but suffering greater unemployment, versus higher levels of employment but at the cost of lower wage rates. Globalization and the telecommunications revolution have rendered the comparative advantage in traditional moderate technology industries incompatible with high wage levels. At the same time, the emerging comparative advantage that is compatible with high wage levels is based on innovative activity. For example, employment has increased by 15 per cent in Silicon Valley between 1992 and 1996, even though the mean income is 50 per cent greater than in the rest of the country.[4]

The global demand for innovative products in knowledge-based industries is high and growing rapidly; yet the number of workers who can contribute to producing and commercializing new knowledge is limited to just a few areas in the world. Economic activity based on new knowledge generates higher wages and greater employment opportunities reflecting the exploding demand for new and improved products and services. There are many indicators reflecting the shift in the comparative

[2] OECD, *Employment Outlook* (1997).
[3] ‘The Death of Distance’, *The Economist* (30 September 1995).
[4] ‘The Valley of Money’s Delights’, *The Economist* (29 March 1997, special section, p. 1).

advantage of the high-wage countries towards an increased importance of innovative activity. For example, Kortum and Lerner (1997, p. 1) document an unprecedented jump in patenting in the United States, as evidenced by the explosion in applications for United States patents by American inventors since 1985. Throughout this century, patent applications fluctuated within a band between 40,000 and 80,000 per year. By contrast, in 1995 there were over 120,000 patent applications. Similarly, Berman *et al*. (1997) have shown that the demand for less skilled workers has decreased dramatically throughout the OECD, while at the same time the demand for skilled workers has exploded.

III. THE KNOWLEDGE PRODUCTION FUNCTION

The starting point for most theories of innovation is the firm. In such theories the firms are exogenous and their performance in generating technological change is endogenous (Arrow, 1962). For example, in the most prevalent model found in the literature of technological change, the model of the knowledge production function, formalized by Zvi Griliches (1979), firms exist exogenously and then engage in the pursuit of new economic knowledge as an input into the process of generating innovative activity. The most decisive input in the knowledge production function is new economic knowledge. Knowledge as an input in a production function is inherently different from the more traditional inputs of labour, capital, and land. While the economic value of the traditional inputs is relatively certain, knowledge is intrinsically uncertain and its potential value is asymmetric across economic agents. The most important, although not the only, source of new knowledge is considered to be research and development (R&D). Other key factors generating new economic knowledge include a high degree of human capital, a skilled labour-force, and a high presence of scientists and engineers.

There is considerable empirical evidence supporting the model of the knowledge production function. However, the empirical link between knowledge inputs and innovative output apparently becomes stronger as the unit of observation becomes increasingly aggregated. For example, at the unit of observation of countries, the relationship between R&D and patents is very strong. The most innovative countries, such as the United States, Japan, and Germany, also tend to undertake high investments in R&D. By contrast, little patent activity is associated with developing countries, which have very low R&D expenditures. Similarly, the link between R&D and innovative output, measured in terms of either patents or new product innovations, is also very strong when the unit of observation is the industry. The most innovative industries, such as computers, instruments, and pharmaceuticals, also tend to be the most R&D-intensive. Audretsch (1995) finds a simple correlation coefficient of 0.74 between R&D inputs and innovative output at the level of four-digit standard industrial classification (SIC) industries. However, when the knowledge production function is tested for the unit of observation of the firm, the link between knowledge inputs and innovative output becomes tenuous and only weakly positive in some studies, and even non-existent or negative in others. The model of the knowledge production function becomes particularly weak when small firms are included in the sample. This is not surprising, since formal R&D is concentrated among the largest corporations, but a series of studies (Acs and Audretsch, 1990) has clearly documented that small firms account for a disproportionate share of new product innovations, given their low R&D expenditures.

IV. KNOWLEDGE SPILLOVERS

The breakdown of the knowledge production function at the level of the firm raises the question: *Where do innovative firms with little or no R&D get the knowledge inputs?* This question becomes particularly relevant for small and new firms that undertake little R&D themselves, yet contribute considerable innovative activity in newly emerging industries such as biotechnology and computer software (Audretsch, 1995). One answer that has recently emerged in the economics literature is from other, third-party firms or research institutions, such as universities. Economic knowledge may spill over from the firm conducting the R&D or the research laboratory of a university (Baptista, 1997).

Why should knowledge spill over 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. Cohen and Levinthal (1989) suggest that firms develop the capacity to adapt new technology and ideas developed in other firms and are therefore able to appropriate some of the returns accruing to investments in new knowledge made externally.

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 or she has no reason to leave the firm. On the other hand, if he places a greater value on his ideas than does the decision-making bureaucracy of the incumbent firm, he may choose to start a new firm to appropriate the value of his knowledge. 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 exiting 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 or her knowledge through innovative activity.

V. THE IMPORTANCE OF LOCATION AND AGGLOMERATION

That knowledge spills over is barely disputed. In disputing the importance of knowledge externalities in explaining the geographic concentration of economic activity, Krugman (1991) and others do 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 compelling reason for a geographic boundary to limit the spatial extent of the spillover. According to this line of thinking, the concern is not that knowledge does not spill over, but that it should stop spilling over just because it hits a geographic border, such as a city limit, state line, or national boundary. As illustrated by the title page of *The Economist* proclaiming 'The Death of Distance' (30 September 1995), the claim that geographic location is important to the process linking knowledge spillovers to innovative activity in a world of e-mail, fax machines, and cyberspace may seem surprising and even paradoxical. The resolution to the paradox posed by the localization of knowledge spillovers in an era where the telecommunications revolution has drastically reduced the cost of communication lies in a distinction between knowledge and information. *Information*, such as the price of gold on the New York Stock Exchange, or the value of the yen in London, can be easily codified and has a singular meaning and interpretation. By contrast, *knowledge* is vague, difficult to codify, and often only serendipitously recognized. While the marginal cost of transmitting information across geographic space has been rendered invariant by the telecommunications revolution, the marginal cost of transmitting knowledge, and especially tacit knowledge, rises with distance.

Von Hipple (1994) demonstrates 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. Geographic proximity matters in transmitting knowledge, because as Kenneth Arrow (1962) pointed out over three decades ago, such 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. As Glaeser *et al*. (1992, p. 1126) have observed, 'intellectual breakthroughs must cross hallways and streets more easily than oceans and continents'.

The importance of local proximity for the transmission of knowledge spillovers has been observed in many different contexts. It has been pointed out that, 'business is a social activity, and you have to be where important work is taking place.'[5] A survey of nearly one thousand executives located in America's 60 largest metropolitan areas ranked Raleigh/Durham as the best city for knowledge workers and for innovative activity.[6] The reason is that

> A lot of brainy types who made their way to Raleigh/Durham were drawn by three top research universities. . . . US businesses, especially those whose success depends on staying at the top of new technologies and processes, increasingly want to be where hot new ideas are percolating. A presence in brain-power centres like Raleigh/Durham pays off in new products and new ways of doing business. Dozens of small biotechnology and software operations are starting up each year and growing like *kudzu* in the fertile climate.[7]

VI. THE SPATIAL LINK BETWEEN KNOWLEDGE AND INNOVATION

Not only did Krugman (1991, p. 53) doubt that knowledge spillovers are not geographically constrained, but he also argued that they were impossible to measure because 'knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked'. However, an emerging literature has overcome data constraints to measure the extent of knowledge spillovers and link them to the geography of innovative activity. Jaffe (1989), Feldman (1994), and Audretsch and Feldman (1996) modified the model of the knowledge production function to include an explicit specification for both the spatial and product dimensions:

$$I_{si} = IRD^{\beta_1} * (UR_{si})^{\beta_2} * \left[UR_{si} * (GC_{si})^{\beta_3}\right] * \varepsilon_{si} \quad (1)$$

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 between university and corporate research. The unit of observation for estimation is at the spatial level, s, a state, and industry level, i. Jaffe (1989) used the number of inventions registered with the United States patent office as a measure of innovative activity. By contrast, Audretsch and Feldman (1996) and Acs *et al*. (1992) developed a direct measure of innovative output consisting of new product introductions.

Estimation of equation (1) essentially shifts the model of the knowledge production function from the unit of observation of a firm to that of a geographic unit. The consistent empirical evidence that supports the notion knowledge spills over for third-party use from university research laboratories as well as industry R&D laboratories. This empirical evidence suggests that location and proximity clearly matter in exploiting knowledge spillovers. Not only have Jaffe *et al*. (1993) found that patent citations tend to occur more frequently within the state in which they were patented than outside of that state, but 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. Prevenzer (1997) and Zucker *et al*. (1994) show that in biotechnology, which is an industry based almost exclusively on new knowledge, the firms tend to cluster together in just a handful of locations. 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.

The spatial link between knowledge inputs and innovative output can be seen in the Data Appendix which links knowledge inputs to innovative output. Since Krugman (1991, p. 57) has emphasized, 'States aren't really the right geographical units', the relevant geographic unit of observation is at the city level. The measure of innovative output is the number of patents registered by firms located within the city between 1988 and 1992. The Appendix also shows the education level, measured as the share of the labour-force in 1992 accounted for by workers

[5] 'The Best Cities for Knowledge Workers', *Fortune* (15 November 1993, p. 44).
[6] The survey was carried out in 1993 by the management consulting firm, Moran, Stahl & Boyer, of New York City.
[7] 'The Best Cities for Knowledge Workers', *Fortune* (15 November 1993, p. 44).

who have graduated from a 4-year college course (BA or higher). In addition, the number of research centres located in that city as of 1992 is listed. While the high number of patents issued to firms located at the heart of Silicon Valley in San José (10,138) and Los Angeles (9,598) is not particularly surprising, what is perhaps more striking is that the greatest number of patents (11,793) was issued to firms located in Chicago. One explanation may be that Chicago accounts for a greater number of research centres than any other city, with the exceptions of New York and Boston. Of course, Chicago is also a much larger city than San José. When patent rates, or the number of patents per 100,000 residents, are compared in the second column, San José emerges as the most innovative city in the United States. San José, in fact, has the second highest educational attainment level, where almost one-third of its workforce has a university degree or the equivalent. In general, a close relationship can be seen between the availability of knowledge resources in a city and its innovative performance.[8]

There is reason to believe that knowledge spillovers are not homogeneous across firms. In estimating equation (1) for large and small enterprises separately, Acs *et al.* (1994) provide some insight into the puzzle posed by the recent wave of studies identifying vigorous innovative activity emanating from small firms in certain industries. How are these 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.

A conceptual problem arises with economies accruing to the knowledge transmission associated with agglomeration. Once a city, region, or state develops a viable cluster of production and innovative activity why should it ever lose the first-mover advantage? One answer, provided by Audretsch and Feldman (1996) is that the relative importance of local proximity and, therefore, agglomeration effects is shaped by the stage of the industry life cycle. A growing literature suggests that who innovates and how much innovative activity is undertaken is closely linked to the phase of the industry life cycle (Klepper, 1996). Audretsch and Feldman (1996) argue that an additional key aspect to the evolution of innovative activity over this life cycle is *where* that innovative activity takes place. The theory of knowledge spillovers, derived from the knowledge production function, suggests that the propensity for innovative activity to cluster spatially will be the greatest in industries where tacit knowledge plays an important role. As argued above, it is *tacit knowledge*, as opposed to *information*, which can only be transmitted informally, and typically demands direct and repeated contact. The role of tacit knowledge in generating innovative activity is presumably the greatest during the early stages of the industry life cycle, before product standards have been established and a dominant design has emerged. Audretsch and Feldman (1996) classify 210 industries into four different stages of the life cycle. The results provide considerable evidence suggesting that the propensity for innovative activity to cluster spatially is shaped by the stage of the cycle. On the one hand, new economic knowledge embodied in skilled workers tends to raise the propensity for innovative activity to cluster spatially throughout all phases of the industry life cycle. On the other hand, certain other sources of new economic knowledge, such as university research, tend to elevate the propensity for innovative activity to cluster during the introduction stage of the life cycle, but not during the growth stage, and then again during the stage of decline.

Perhaps most striking is the finding that greater geographic concentration of production actually

[8] The link between innovative output and knowledge inputs at the city level has been substantiated in an econometric model.

leads to more, and not less, dispersion of innovative activity. Apparently innovative activity is promoted by knowledge spillovers that occur within a distinct geographic region, particularly in the early stages of the industry life cycle, but, as the industry evolves towards maturity and decline, may be dispersed by additional increases in concentration of production that have been built up within that same region. The evidence suggests that what may serve as an agglomerating influence in triggering innovative activity to cluster spatially during the introduction and growth stages of the industry life cycle, may later result in a congestion effect, leading to greater dispersion in innovative activity. While the literature on economic geography has traditionally focused on factors such as rents, commuting time, and pollution as constituting congestion and dissipating agglomeration economies (Henderson, 1986), this type of congestion refers to lock-in with respect to new ideas. While there may have been agglomeration economies in automobiles in Detroit in the 1970 and computers in the Northeast Corridor in the 1980s, a type of intellectual lock-in made it difficult for Detroit to shift out of large-car production and for IBM and DEC to shift out of mainframe computers and into mini-computers. Perhaps it was this type of intellectual congestion that led to the emergence of the personal computer in California, about as far away from the geographic agglomeration of the mainframe computer as is feasible on the mainland of the United States. Even when IBM developed its own personal computer, the company located its fledgling PC facility in Boca Ratton, Florida, way outside of the mainframe agglomeration in the Northeast Corridor. Thus, there is at least some evidence suggesting that spatial agglomerations, just like other organizational units of economic activity, are vulnerable to technological lock-in, with the result being, in certain circumstances, that new ideas need new space.

VII. PENETRATING THE BLACK BOX OF GEOGRAPHIC SPACE

While a new literature has emerged identifying the important role that knowledge spillovers within a given geographic location play in stimulating innovative activity, there is little consensus as to how and why this occurs. 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? Political scientists and sociologists have long argued that the differences in the culture of a region may contribute to differences in innovative performance across regions, even holding knowledge inputs such as R&D and human capital constant. For example, Saxenian (1990) 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.

In studying the networks located in California's Silicon Valley, Saxenian (1990, pp. 96–7) emphasizes that it is the communication between individuals that facilitates the transmission of knowledge across agents, firms, and even industries, and not just a high endowment of human capital and knowledge in the region:

> It is not simply the concentration of skilled labour, suppliers and information that distinguish the region. A variety of regional institutions—including Stanford University, several trade associations and local business organizations, and a myriad of specialized consulting, market research, public relations and venture capital firms—provide technical, financial, and networking services which the region's enterprises often cannot afford individually. These networks defy sectoral barriers: individuals move easily from semiconductor to disk drive firms or from computer to network makers. They move from established firms to start-ups (or vice versa) and even to market research or consulting firms, and from consulting firms back into start-ups. And they continue to meet at trade shows, industry conferences, and the scores of seminars, talks, and social activities organized by local business organizations and trade associations. In these forums, relationships are easily formed and maintained, technical and market information is exchanged, business contacts are established, and new enterprises are conceived. . . . This decentralized and fluid environment also promotes the diffusion of intangible technological capabilities and understandings.'[9]

[9] Saxenian (1990, pp. 97–8) claims that even the language and vocabulary used by technical specialists can be specific to a region: 'a distinct language has evolved in the region and certain technical terms used by semiconductor production engineers in Silicon Valley would not even be understood by their counterparts in Boston's Route 128'.

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. This debate revolves around two key structural elements—the degree of diversity versus specialization and the degree of monopoly versus local competition.

One view, which Glaeser *et al*. (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) has defined knowledge spillovers as, 'working on similar things and hence benefiting much from each other's research'. Jacobs (1969) argues that the most important sources of knowledge spillovers are 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 yields 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.

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 conducive to knowledge externalities than is local monopoly.[10] 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 does 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.

The first important 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 in influencing industry growth rates. The authors find evidence that contradicts the

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

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 (forthcoming) 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. 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 conclusion 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.

VIII. CONCLUSIONS

Globalization combined with the telecommunications revolution has drastically reduced the cost of transporting not just material goods but also information across geographic space. High wages are increasingly incompatible with information-based economic activity, which can be easily transferred to a lower cost location. By contrast, the creation of new ideas based on tacit knowledge cannot easily be transferred across distance. Thus, the comparative advantage of the high-cost countries of North American and Western Europe is increasingly based on knowledge-driven innovative activity. The spillover of knowledge from the firm or university creating that knowledge to a third-party firm is essential to innovative activity. Such knowledge spillovers tend to be spatially restricted. Thus, an irony of globalization is that even as the relevant geographic market for most goods and services becomes increasingly global, the increased importance of innovative activity in the leading developed countries has triggered a resurgence in the importance of local regions as a key source of comparative advantage.

As the comparative advantage in Western Europe and North America has become increasingly based on new knowledge, public policy towards business has responded in two fundamental ways. The first has been to shift the policy focus away from the traditional triad of policy instruments essentially constraining the freedom of firms to contract—regulation, competition policy or antitrust in the USA, and public ownership of business. The policy approach of constraint was sensible as long as the major issue was how to restrain footloose multinational corporations in possession of considerable market power. This is reflected by the waves of deregulation and privatization along with the decreased emphasis of competition policy throughout the OECD. Instead, a new policy approach emerges which focuses on enabling the creation and commercialization of knowledge. Examples of such policies include encouraging R&D, venture capital and new-firm start-ups.

The second fundamental shift involves the locus of such enabling policies, which are increasingly at the state, regional, or even local level. The down-sizing of federal agencies charged with the regulation of business in the United States and Great Britain has been interpreted by many scholars as the eclipse of government intervention. But to interpret deregulation, privatization, and the increased irrelevance of competition policies as the end of government intervention in business ignores an important shift in the locus and target of public policy. The last decade has seen the emergence of a broad spectrum of enabling policy initiatives that fall outside the jurisdiction of the traditional regulatory agencies. Sternberg (1996) documents how the success of a number of different high-technology clusters spanning a number of developed countries is the direct result of enabling policies, such as the provision of venture capital or research support. For example, the Advanced Research Program in Texas has provided support for basic research and the strengthening of the infrastructure of the University of Texas, which has played a central role in developing a high-technology cluster around Austin (Feller, 1997). The Thomas Edison Centers in Ohio, the Advanced Technology Centers in New Jersey, and the Centers for Advanced Technology at Case Western Reserve University, Rutgers University, and the University of Rochester have supported generic, pre-competitive research. This support has generally provided diversified technology development involving a mix of activities encompassing a broad spectrum of industrial collaborators.

Such enabling policies, that are typically implemented at the local or regional level, are part of a silent policy revolution currently under way. The increased importance of innovative regional clusters as an engine of economic growth has led policy-makers to abandon the policy cry frequently heard two decades ago, 'Should we break up, regulate, or simply take over General Motors, IBM and US Steel?' for a very different contemporary version, 'How can we grow the next Silicon Valley?'

DATA APPENDIX: PATENT ACTIVITY OF MAJOR US CITIES

City	No. of patents	Patents/population	No. of research centres	Education level
Albany	3,086	350.33	115	23.60
Atlanta	2,776	86.80	205	26.10
Austin	2,121	231.01	174	30.70
Baltimore	2,400	98.14	225	23.10
Birmingham	223	25.81	72	19.70
Boston	9,013	179.05	650	28.80
Buffalo	1,498	124.98	23	18.80
Charlotte	953	77.13	25	19.60
Chicago	11,793	154.92	516	24.50
Cincinnati	2,353	149.73	141	19.90
Cleveland	3,871	174.21	118	18.50
Columbus	1,524	108.12	170	23.30
Dallas	4,557	159.65	126	26.90
Dayton	1,958	202.55	98	19.10
Denver	2,097	121.34	302	29.10
Detroit	8,652	200.46	361	17.70
Fort Lauderdale	1,395	105.58	108	18.80
Fort Worth	1,174	80.45	49	22.40
Grand Rapids	1,301	132.78	26	17.80
Greensboro	1,147	105.10	44	17.50
Hartford	1,925	165.45	62	26.00
Honolulu	250	28.63	115	24.60
Houston	5,765	163.00	199	25.00
Indianapolis	1,818	126.30	69	20.00
Jacksonville	323	33.59	20	18.60
Kansas City	883	53.92	140	23.20
Las Vegas	273	27.26	27	13.30
Los Angeles	9,598	104.99	515	22.30
Louisville	639	65.74	53	17.20
Memphis	473	45.19	85	18.70
Miami	1,011	50.07	108	18.80

City	No. of patents	Patents/population	No. of research centres	Education level
Milwaukee	2,685	182.80	106	21.30
Minneapolis	7,513	282.42	235	26.90
Nashville	417	40.18	117	21.40
New Orleans	647	49.69	73	19.30
New York	7,482	43.92	788	25.40
Norfolk	689	45.74	67	19.80
Oakland	4,445	205.66	283	29.90
Oklahoma	526	52.90	83	21.60
Orlando	957	71.56	33	20.40
Philadelphia	8,565	171.95	469	22.60
Phoenix	3,334	140.11	121	21.40
Pittsburgh	4,367	182.22	220	18.70
Portland	1,842	112.49	72	23.30
Raleigh-Durham	1,745	188.55	248	31.70
Richmond	940	103.80	41	23.80
Rochester	7,034	647.89	77	22.90
Sacramento	886	60.76	97	22.70
St Louis	2,473	97.57	136	17.70
Salt Lake City	1,398	122.29	109	22.90
San Antonio	517	37.20	56	19.30
San Diego	4,590	173.00	195	25.30
San Francisco	4,233	259.04	345	34.90
San José	10,138	665.14	91	32.60
Scranton	256	39.83	22	13.60
Seattle	3,424	157.67	153	29.50
Tampa	1,285	59.84	42	17.30
Tulsa	858	116.19	81	20.30
West Palm Beach	1,460	157.73	25	22.10

REFERENCES

Acs, Z., and Audretsch, D. (1990), *Innovation and Small Firms*, Cambridge, MA, MIT Press.

— — Feldman, M. (1992), 'Real Effects of Academic Research', *American Economic Review*, **82**(1), 363–70.

— — — (1994), 'R&D Spillovers and Recipient Firm Size', *Review of Economics and Statistics*, **100**(2), 336–40.

Arrow, K. (1962), 'Economic Welfare and the Allocation of Resources for Invention', in R. Nelson (ed.), *The Rate and Direction of Inventive Activity*, Princeton, NJ, Princeton University Press.

Audretsch, D. (1995), *Innovation and Industry Evolution*, Cambridge, MA, MIT Press.

— Feldman, M. (1996), 'R&D Spillovers and the Geography of Innovation and Production', *American Economic Review*, **86**(4), 253–73.

— Stephan, P. (1996), 'Company-Scientist Locational Links: The Case of Biotechnology', *American Economic Review*, **86**(4), 641–52.

Baptista, R. (1997), *An Empirical Study of Innovation, Entry and Diffusion in Industrial Clusters*, PhD dissertation, University of London (London Business School).

Berman, E., Bound, J., and Machin, S. (1997), 'Implications of Skill-Biased Technological Change: International Evidence', Working Paper No. 6166, National Bureau of Economic Research, Cambridge, MA.

Cohen, W., and Levinthal, D. (1989), 'Innovation and Learning: The Two Faces of R&D', *The Economic Journal*, **99**(3), 569–96.

Ellison, G., and Glaeser, E. (1997), 'Geographic Concentration in US Manufacturing Industries: A Dartboard Approach', *Journal of Political Economy*, (4), 889–927.
Feldman, M. (1994), 'Knowledge Complementarity and Innovation', *Small Business Economics*, **6**(3), 363–72.
— Audretsch, D. (forthcoming), 'Innovation in Cities: Science-Based Diversity, Specialization, and Localized Competition', special issue of the *European Economic Review*, edited by E. Helpman.
Feller, I. (1997), 'Federal and State Government Roles in Science and Technology', *Economic Development Quarterly*, **11**(4), 283–96.
Glaeser, E., Kallal, H., Scheinkman, J., and Shleifer, A. (1992), 'Growth of Cities', *Journal of Political Economy*, **100**, 1126–52.
Griliches, Z. (1979), 'Issues in Assessing the Contribution of R&D to Productivity Growth', *Bell Journal of Economics*, **10**, 92–116.
— (1992), 'The Search for R&D Spill-Overs', *Scandinavian Journal of Economics*, **94**, 29–47.
Henderson, V. (1986), 'Efficiency of Resource Usage and City Size', *Journal of Urban Economics*, **19**(1), 47–70.
Hirschman, A. O. (1970), *Exit, Voice, and Loyalty*, Cambridge, MA, Harvard University Press.
Jacobs, J. (1969), *The Economy of Cities*, New York, Random House.
Jaffe, A. (1989), 'Real Effects of Academic Research', *American Economic Review*, **79**, 957–70.
— Trajtenberg, M. L., and Henderson, R. (1993), 'Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations', *Quarterly Journal of Economics*, **63**, 577–98.
Klepper, S. (1996), 'Entry, Exit, Growth, and Innovation over the Product Life Cycle', *American Economic Review*, **86**(4), 562–83.
Kortum, S., and Lerner, J. (1997), 'Stronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?', Working Paper No. 6204, National Bureau of Economic Research, Cambridge, MA.
Krugman, P. (1991), *Geography and Trade*, Cambridge, MA, MIT Press.
Porter, M. (1990), *The Comparative Advantage of Nations*, New York, Free Press.
Prevenzer, M. (1997), 'The Dynamics of Industrial Clustering in Biotechnology', *Small Business Economics*, **9**(3), 255–71.
Saxenian, A. (1990), 'Regional Networks and the Resurgence of Silicon Valley', *California Management Review*, **33**, 89–111.
Sternberg, R. (1996), 'Technology Policies and the Growth of Regions', *Small Business Economics*, **8**(2), 75–86.
Venables, A. J. (1996), 'Localization of Industry and Trade Performance', *Oxford Review of Economic Policy*, **12**(3), 52–60.
Von Hipple, E. (1994), 'Sticky Information and the Locus of Problem Solving: Implications for Innovation', *Management Science*, **40**, 429–39.
Zucker, L., Darby, M., and Armstrong, J. (1994), 'Intellectual Capital and the Firm: The Technology of Geographically Localized Knowledge Spillovers', Working Paper No. 9496, National Bureau of Economic Research, Cambridge MA.