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LOCATION OF INNOVATIVE ACTIVITY**

David B Audretsch

**INDUSTRIAL ORGANIZATION AND
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ABSTRACT

Agglomeration and the Location of Innovative Activity*

Only a few years ago the conventional wisdom predicted that globalization would render 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 the international comparative advantage. The comparative advantage of the high-cost countries of North America 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.

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NON-TECHNICAL SUMMARY

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 eight years has come as a shock. Unemployment and stagnant growth are the twin economic problems confronting Europe. The traditional comparative advantage in mature, technologically moderate industries such as metalworking, machine tools and automobile production had provided an engine for growth, high employment and economic stability throughout Western Europe for most of the Post War economic period. This 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 from not just the emerging economies in Southeast 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.

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% in Silicon Valley between 1992-6, even though the mean income is 50% greater than in the rest of the country.

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. Only a few years ago the conventional wisdom predicted that globalization would render 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 the international comparative advantage.

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 America 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 United States, 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 is emerging which focuses on enabling the creation and commercialization of knowledge. Examples of such policies include encouraging R&D, venture capital and new-firm startups.

The second fundamental shift involves the locus of such enabling policies, which are increasingly at the state, regional or even local level. The downsizing of federal agencies charged with the regulation of business in the United Kingdom and the United States 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 of the jurisdiction of the traditional regulatory agencies. Such policies constitute the new

Industrial Policy Approach, which are targeted towards the creation of agglomeration-based economic activity, which is compatible with high wages in a global economy.

1. 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. Only a few years ago the conventional wisdom predicted that globalisation would render 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 the international comparative advantage.

The second section of this paper explains how globalisation and the telecommunications revolution have triggered a shift in the comparative advantage of the leading developed countries towards an 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 than 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 localisation. 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, the implications for public policy are explained in the last 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.

2. Innovation and Comparative Advantage

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 eight years has come as a shock. Unemployment and stagnant growth are the twin economic problems confronting Europe. Over 11 percent of the work force in the European Union was unemployed in 1997, ranging from 6.1 percent in the United Kingdom and 6.2 percent in the Netherlands, to 11.1 percent in Germany, 12.6 percent in France, and over 20 percent in Spain.¹

The traditional comparative advantage in mature, technologically moderate industries such as metalworking, machine tools and automobile production had provided an engine for growth, high employment and economic stability throughout Western Europe for most of the Post-War economic period. This traditional comparative advantage

¹ OECD, *Employment Outlook*, 1997.

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 globalisation, or the advent of competition from not just the emerging economies in Southeast 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 economic force shaping society in the first half of the next century."

Much of the policy debate responding to the twin forces of the telecommunications revolution and increased globalisation 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. Globalisation 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 percent in Silicon Valley between 1992 and 1996, even though the mean income is 50 percent greater than in the rest of the country.²

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

² "The Valley of Money's Delights." *The Economist*, 29 March, 1997, special section, p. 1.

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 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 40,000-80,000 per year. By contrast, in 1995 there were over 120,000 patent applications. Similarly, Berman, Bound and Machin (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.

3. 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, formalised 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 than 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.³ 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. This 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 either tenuous and 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

³ Arrow (1962) pointed out this is one of the reasons for inherent market failure.

corporations, but a series of studies (Acs and Audretsch, 1990) has clearly documented that small firms account for a disproportional share of new product innovations given their low R&D expenditures.

4. 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 organisational structure of the firm developing the knowledge and appropriate roughly the expected value of that knowledge, he has no reason to leave the firm. On the other hand, if he places a greater value on his ideas than do the decision-making bureaucracy of the incumbent firm, he may choose to start a new firm to appropriate the value of his knowledge. In the metaphor provided by Albert O. Hirschman (1970), if voice proves to be ineffective within incumbent organisations, and loyalty is sufficiently weak, a knowledge worker may resort to exit the firm or university where the knowledge was created in order to form a new company. In this spillover channel the knowledge production function is actually reversed. The knowledge is exogenous and embodied in a worker. The firm is created endogenously in the worker's effort to appropriate the value of his knowledge through innovative activity.

5. 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*,⁴ 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 localisation 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 recognised. 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 Hippel (1994) demonstrates that high context, uncertain knowledge, or what he terms as 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 some 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, Kallal, Scheinkman and Shleifer (1992, p. 1126) have observed, “intellectual breakthroughs must cross hallways and streets more easily than oceans and continents.”

⁴ “The Death of Distance.” *The Economist*, 30 September, 1995.

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 sixty 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. . . U.S. 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 centers 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

6. 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 (Jaffe, Trajtenberg and Henderson, 1993) 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

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 of Moran, Stahl & Boyer of New York City.

⁷ “The Best Cities for Knowledge Workers.” *Fortune*, 15 November, 1993, p. 44.

production function to include an explicit specification for both the spatial and product dimensions:

$$I_{st} = IRD_{st}^{\beta_1} * (UR_{st})^{\beta_2} * [UR_{st} * (GC_{st})^{\beta_3}] * \varepsilon_{st} \quad (1)$$

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, Audretsch and Feldman (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 $\beta_1 \geq 0, \beta_2 \geq 0, \beta_3 \geq 0$ 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, Trajtenberg and Henderson (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, Darby and Armstrong (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 Appendix, which links knowledge inputs to innovative output. Since Krugman (1991, p. 57) has emphasised, "States aren't really the right geographical units," the relevant geographic unit of observation is at the city level in the Appendix. 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 who have graduated from a four-year college (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 Jose (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 Jose. When patent rates, or the number of patents per one hundred thousand residents, are compared in the second column, San Jose emerges as the most innovative city in the United States. San Jose, 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, Audretsch and Feldman (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

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

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 the industry 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 spatially cluster is shaped by the stage of the industry life cycle. On the one hand, new economic knowledge embodied in skilled workers tends to raise the

propensity for innovative activity to spatially cluster 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 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 spatially cluster 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 Raton, Florida, way outside of the mainframe agglomeration, in the Northeast Corridor. Thus, there is at least some evidence suggesting that spatial agglomerations, just as other organisational units of economic activity are vulnerable to technological lock-in, with the result being in certain circumstances that new ideas need new space.

7. Penetrating the Black Box of Geographic Space

While a new literature has emerged identifying the important 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 organised 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 (1994) argues that a culture of greater interdependence and exchange among individuals in the Silicon Valley region has contributed to a superior innovative performance than is found around Boston's Route 128, where firms and individuals tend to be more isolated and less interdependent.

In studying the networks located in California's Silicon Valley, Saxenian (1990, pp. 96-97) emphasises 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 organisations, and a myriad of specialised 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 startups (or vice versa) and even to market research or consulting firms, and from consulting firms back into startups. And they continue to meet at trade shows, industry conferences, and the scores of seminars, talks, and social activities organised by local business organisations 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 decentralised and fluid environment also promotes the diffusion of intangible technological capabilities and understandings."⁹

Such observations suggest a limitation inherent to the general knowledge production function approach described in the previous section. While economists tend to

⁹ Saxenian (1990, pp. 97-98) 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."

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 specialisation and the degree of monopoly versus local competition.

One view, which Glaeser, Kallal, Scheinkman and Shleifer (1992) attribute to the *Marshall-Arrow-Romer externality*, suggests that an increased concentration of a particular industry within a specific geographic region facilitates knowledge spillovers across firms. This model formalises 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 minimised. 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 others research.” Jacobs (1969) argues that the most important source 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 emphasises that the variety of industries within a geographic region promotes knowledge externalities and ultimately innovative activity and economic growth.¹⁰

The extent of regional specialisation 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 maximises 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.¹¹ It should be emphasised that by local competition Jacobs does not mean competition within product markets as has

¹⁰ For an extension of this see Vernon (1994) and Vernon et al. (1995).

traditionally been envisioned within the industrial organisation 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 specialising 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 specialisation versus diversity debate measured economic performance in terms of employment growth. Glaeser, Kallal, Sheinkman and Schleifer (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 specialisation, diversity and local competition play in influencing industry growth rates. The authors find evidence that contradicts the Marshall-Arrow-Romer model but is consistent with the theories of Jacobs. However, their study provided no direct evidence as to whether diversity is more important than specialisation in generating innovative activity.

Feldman and Audretsch (forthcoming) identify the extent to which the organisation 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

¹¹ Porter (1990) provides examples of Italian ceramics and gold jewelry as industries in which numerous

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 specialisation. In addition, their results indicate that the degree of local competition for new ideas within a city is more conducive to innovative activity than is local monopoly. Perhaps the most important conclusions from these two studies, however, is that more than simply an endowment of knowledge inputs is required to generate innovative activity. The underlying economic and institutional structure matters, as do the microeconomic linkages across agents and firms.

8. Conclusions

Globalisation 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 America 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 globalisation is that even as the relevant geographic market

firms are located within a bounded geographic region and compete intensively for new ideas

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 U.S., 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 privatisation along with the decreased emphasis of competition policy throughout the OECD. Instead, a new policy approach is emerging which focuses on enabling the creation and commercialisation of knowledge. Examples of such policies include encouraging R&D, venture capital and new-firm startups.

The second fundamental shift involves the locus of such enabling policies, which are increasingly at the state, regional or even local level. The downsizing 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, privatisation 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 of 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, precompetitive 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 underway. 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 U.S. Steel" for a very different contemporary version, "How can we grow the next Silicon Valley?"

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Table 1: Patent Activity of Major U.S. Cities

City	Number of Patents	Patents/Population	Number of Research Centers	Education Level
Albany	3086	350.33	115	23.60
Atlanta	2776	86.80	205	26.10
Austin	2121	231.01	174	30.70
Baltimore	2400	98.14	225	23.10
Birmingham	223	25.81	72	19.70
Boston	9013	179.05	650	28.80
Buffalo	1498	124.98	23	18.80
Charlotte	953	77.13	25	19.60
Chicago	11793	154.92	516	24.50
Cincinnati	2353	149.73	141	19.90
Cleveland	3871	174.21	118	18.50
Columbus	1524	108.12	170	23.30
Dallas	4557	159.65	126	26.90
Dayton	1958	202.55	98	19.10
Denver	2097	121.34	302	29.10
Detroit	8652	200.46	361	17.70
Ft Lauderdale	1395	105.58	108	18.80
Ft Worth	1174	80.45	49	22.40
Grand Rapids	1301	132.78	26	17.80
Greensboro	1147	105.10	44	17.50
Hartford	1925	165.45	62	26.00
Honolulu	250	28.63	115	24.60
Houston	5765	163.00	199	25.00
Indianapolis	1818	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	9598	104.99	515	22.30
Louisville	639	65.74	53	17.20
Memphis	473	45.19	85	18.70
Miami	1011	50.07	108	18.80
Milwaukee	2685	182.80	106	21.30
Minneapolis	7513	282.42	235	26.90
Nashville	417	40.18	117	21.40
New Orleans	647	49.69	73	19.30
New York	7482	43.92	788	25.40
Norfolk	689	45.74	67	19.80
Oakland	4445	205.66	283	29.90
Oklahoma	526	52.90	83	21.60
Orlando	957	71.56	33	20.40

Table 1: Patent Activity of Major U.S. Cities (contin.)

City	Number of Patents	Patents/Population	Number of Research Centers	Education Level
Philadelphia	8565	171.95	469	22.60
Phoenix	3334	140.11	121	21.40
Pittsburgh	4367	182.22	220	18.70
Portland	1842	112.49	72	23.30
Raleigh-Durham	1745	188.55	248	31.70
Richmond	940	103.80	41	23.80
Rochester	7034	647.89	77	22.90
Sacramento	886	60.76	97	22.70
St. Louis	2473	97.57	136	17.70
Salt Lake City	1398	122.29	109	22.90
San Antonio	517	37.20	56	19.30
San Diego	4590	173.00	195	25.30
San Francisco	4233	259.04	345	34.90
San Jose	10138	665.14	91	32.60
Scranton	256	39.83	22	13.60
Seattle	3424	157.67	153	29.50
Tampa	1285	59.84	42	17.30
Tulsa	858	116.19	81	20.30
West Palm Beach	1460	157.73	25	22.10