The Role of Universities in Regional Development and Cluster Formation

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Introduction

As the economies of the industrial countries rapidly become more knowledge-based, universities are seen as holding the key to regional economic development and cluster formation. The OECD defines the knowledge-based economy as one in which the production, use, and distribution of knowledge and information are critical to the process of economic growth (OECD 1996). Not surprisingly, the role of the university is central to the emerging knowledge-based economy. Indeed a recent survey in *The Economist* suggests the conception of the knowledge-based economy "portray(s) the university not just as a creator of knowledge, a trainer of young minds and a transmitter of culture, but also as a major agent of economic growth: the knowledge factory, as it were, at the centre of the knowledge economy" (David 1997, 4).

Closely related to this is the idea that universities can also jump start the emergence of dynamic regional clusters of firms and thus act as crucial contributors to regional economic development. The well documented cases of a few highly successful examples, particularly the central role attributed to Stanford University in the growth of Silicon Valley (Gibbons 2000), or MIT in the development of Route 128, have contributed to the widely held view that universities can act as 'engines of innovation' generating new ideas to spur the creation of commercial products and indirectly, as the spark for regional industrial clusters. This overly mechanistic view of the process by which basic scientific research is transformed into economically valuable products places an unacceptable burden on the role that universities are expected to play. At the same time, this widely accepted piece of conventional wisdom fails to explain the equally significant number of cases where leading research institutions, such as Carnegie Mellon (Florida 1999)or Johns Hopkins (Feldman and Desrochers 2003)have clearly failed to generate the same kind of spinoffs and regional benefits as occurred in Silicon Valley. Clearly these counter factual cases suggest the need for a more nuanced and contextualized understanding of the actual role that universities play in regional economic development and cluster formation.

The shift to a more knowledge-based economy embodies a number of changes in both the production and application of new scientific knowledge that have critical implications for the processes of knowledge transfer and regional economic development. One of the most significant of these changes involves the relation between the codified and tacit dimensions of knowledge. The dramatic expansion of the higher education sector and the increased funding for research that has, in part, fueled its growth has generated substantial increases in scientific and research output which largely takes the form of codified knowledge, transmitted relatively easily between researchers through published scientific papers and formal presentations. But as the stock of scientific knowledge grows and becomes more widely accessible through electronic and other means, the relative economic value of that knowledge is diminished by its sheer abundance. Often access to the key elements of the knowledge base depends upon the second or tacit dimension. Following the work of Michael Polanyi (1962), tacit knowledge refers to knowledge or insights, which individuals acquire in the course of their scientific work that is ill-defined or uncodified and that they themselves cannot articulate fully. It is highly subjective and often varies from person to person. Furthermore, individuals or groups working together for the same firm or organization often develop a common base of tacit knowledge in the course of their research and production activities (Nelson and Winter 1982, 76-82; Dosi 1988, 1126). The tacit dimension of knowledge is particularly significant for regions and communities, for it is the kind of knowledge that tends to be locally embedded. In a knowledge-based economy, spatial proximity is thus a critical factor for accessing this kind of knowledge and exploiting its commercial potential.

The second change concerns the centrality of learning for the innovative process. Lundvall, among others, argues that the knowledge frontier is moving so rapidly that access to, or control over, knowledge assets affords merely a fleeting competitive advantage. It may be more appropriate to describe the emerging paradigm as that of a ‘learning economy’, rather than a ‘knowledge-based’ one. Recent work indicates that innovation is a *social process* triggered by consumers (or users) who engage in a mutually beneficial dialogue and interaction with producers. In this way, users and producers actively *learn* from each other, by 'learning-through-interacting' (Lundvall 1992). It involves a capacity for localized learning within firms, between firms, and between firms and the supporting institutions. Learning in this sense refers to the building of new competencies and the acquisition of new skills, not just gaining access to information or codified scientific knowledge. In tandem with this development, forms of knowledge that cannot be codified and transmitted electronically (tacit knowledge) increase in value, along with the ability to acquire and assess both codified and tacit forms of knowledge, in other words, the capacity for learning (Maskell and Malmberg 1999). The regional level is important for this form of learning because firms within a local region often share a common culture that facilitates learning among them and it is supported by a common set of regional institutions.

The Role of Universities in the Knowledge-Based Economy

Despite the growing consensus that the industrial economies are becoming more 'knowledge-based', there remains considerable controversy over the role that universities should be expected to play. Consistent with the view of universities as 'knowledge factories' for the new economy, many policy-makers view universities as largely untapped reservoirs of potentially commercializable knowledge waiting to be taken up by firms and applied. They hope that once this knowledge is harnessed, it will fuel innovation within the firm, thereby increasing the firm's productivity, stimulate the emergence of regional industrial clusters and indirectly, contribute to national economic growth. Yet the task of transferring knowledge from universities to industries has proven far more complex than this perspective assumes.

In reality, universities fulfill at least two essential roles in the knowledge-based economy – the performance of research and the training of highly qualified personnel. They thus act both as a primary source of 'knowledge workers', as well as the key factor of production – knowledge itself. However, a number of changes in other elements of the innovation system have placed new demands and stress on the way in which the university performs these roles. The 'social contract' for science, forged in the aftermath of World War II, saw society willing to fund massive investments in basic research in the expectation of long-term economic benefits, while leaving the principal research institutions, the universities, autonomous in the conduct of that research. The social contract for science in postwar society implied a high degree of autonomy for the realm of science, vigorously reinforced by the 'boundary work' of the scientific community itself; it afforded 'expert' status to the role of scientists in the exercise of judgment about most matters relating to the conduct of scientific investigations and the application of the resulting knowledge; and it privileged the role of the universities and other public research organizations as the principal site for the conduct of scientific research, although these arrangements exhibited considerable variation across national innovation systems (Martin 2003).

Underlying this view of the social contract for science was the 'linear model' of innovation that supported the development of postwar science policy in the US. The model defined the relationship between basic research and more applied forms of technology development as a linear one, involving the progression through a sequence of steps leading eventually to product development – the final stage involving the systematic adoption of research findings into useful materials, devices, systems, methods and processes. The entire sequence was referred to as the process of technology transfer in an early report of the National Science Foundation. In the idealized linear model, the innovation process commences with basic research conducted without any thought of potential application that leads to discoveries. These discoveries, in turn, open up the possibility of potential applications that are pursued, usually by firms, through applied research, development, design, production and marketing. The latter stages in this sequence lead to the successful commercialization of the resulting products and processes (Brooks 1996, 21; Stokes 1997, 10-11).

But the essential elements of the social contract for science have been subject to increasing strain in the past two decades as the linear model of innovation has been open to question. These developments are a consequence of major shifts in the relationship between the university and other constituent parts of the national innovation system. The shift results from the modification of the lines demarcating the university from other institutions in society, reflecting the massification and democratization of the post-secondary education system; a questioning of the role of universities and their individual disciplines as the sole, or even primary source, of scientific expertise; the growing internationalization of scientific communities facilitated by the adoption of information and communication technologies; a greater involvement of industry with university research; an increase in interdisciplinary research and a shift in the emphasis of government funding from basic to more applied research; and finally, a greater expectation that university-based research lead directly to commercializable results (Wolfe 2003).

Increased demands on universities to support the innovation process are partly a consequence of changes in the nature of innovation patterns in the business sector that have limited the ability of private firms to support basic research. Under competitive pressure to introduce new products, processes and services more quickly, many large corporations have restructured their R&D operations to link research programs more tightly with product development processes. Broader-based inquiries into fundamental science have consequently been scaled back in many firms. At the same time, the globalization of R&D and more widespread sharing of knowledge among researchers and business in different countries do not appear to have diminished the importance of a strong domestic knowledge base, or the role of universities/government in helping create it.

The universities have come under increasing pressure in recent years to expand their traditionally dominant role in the conduct of basic research and to supplement with more applied research activities, frequently based on university-industry partnerships. The changes impacting on the university system are characterized by three trends: 1) the linking of government funding for academic research and economic policy; 2) the development of more long term relationships between firms and academic researchers; and 3) the increasing direct participation of universities in commercializing research (Etkowitz and Webster 1998). Universities are now expected to generate more applied knowledge of greater relevance to industry, to diffuse knowledge, and provide technical support to industry. This shift reflects the change in the nature of business R&D described above, but it is also the result of a parallel expectation on the part of government that their investments in basic research should produce a higher economic return. It is reinforced by the political expectation that research funding be tied to broader public policy objectives about promoting national innovative capacity, greater competitiveness and, increasingly, local and regional economic development.

While the shift in policy perspective was partly stimulated by a questioning of the assumptions underlying the linear model, it has yet to be replaced with a more complex and realistic appreciation of the way in which knowledge flows between universities and industry. Conventional approaches to the issue of knowledge flows frequently treat knowledge itself as a universally available commodity, virtually as a free public good, and knowledge transfer as a commercial and legal transaction between clearly defined agents. This view simplifies the complex nature of scientific knowledge and the linkages and processes that facilitate knowledge flows across institutional boundaries and enable firms to absorb and employ that knowledge. Evidence from a growing number of sources, including studies of the economics of innovation and studies of regional innovation systems, suggest that successful knowledge transfer depends on the type of knowledge involved, and how it is employed. While linkages between universities and industry have proliferated in the past decade and a half, our understanding of the process by which knowledge is transferred from one to the other has not kept pace. As Fumio Kodama and Lewis Branscomb argue,

> . . . disappointment awaits those who expect quick results from university-based high-technology strategies for industrial renewal. First-rank research universities can and most often do make a large and positive contribution to economic performance, regionally and nationally. But to understand the effects we should not focus on the style and content of the transactions with firms but rather look at the university as a pivotal part of a network of people and institutions who possess high skills, imagination, the incentive to take risks, the ability to form other networks to accomplish their dreams (1999, 16).

The Relationship between Research and Innovation

The preceding discussing suggests that the relationship between publicly funded research and the innovation process is far more complex than that assumed by many recent public policy discussions of the role of the university in the commercialization of scientific research. A more accurate understanding of this role requires a sophisticated framework for analysing the character of the institutional and interpersonal linkages between universities and firms and how those linkages contribute to knowledge transfers between the two. An alternative approach to assessing the economic benefits that flow from knowledge transfer focuses on the properties of knowledge not easily captured by the informational view associated with early work on the economics of basic research and the linear model. Keith Pavitt stresses that scientific and technological knowledge often remains tacit, i.e. person embodied in the knowledge, skills and practices of the researcher (Pavitt 1991). Other scholars in the tradition of evolutionary economics describe knowledge as dynamic, often unarticulated, and claim that firms must invest substantial resources to capture and employ it. This view shifts attention from the applicability of knowledge to the processes that enable a firm to successfully absorb and apply that knowledge.

Pavitt argues that inherent in the traditional rationale for public support of basic research is the danger of confusing the notion of science as a public good (i.e., codified, published, easily reproducible) with science as a free good (i.e., costless to apply as technology). He builds on Nathan Rosenberg's claim that to assimilate and benefit from external research, firms have to develop a considerable capacity for research themselves (Rosenberg 1990). Pavitt maintains that knowledge transfers are mainly person-embodied and that policies that attempt to direct basic research towards specific goals or targets ignore the considerable indirect benefits across a broad range of scientific fields that result from training and unplanned discoveries. This introduces the notion of knowledge as the capacity to acquire and apply research results, rather than as an end in itself. In this perspective, knowledge is the ability to put information to productive use. It provides the basis for understanding new ideas and discoveries and places them in a context that enables more rapid application. The development of such internalized or 'personal knowledge' (Polanyi 1962) requires an extensive learning process. It is based on skills accumulated through experience and expertise. It also emphasizes the learning properties of individuals and organizations. Of crucial importance are the role of skills, the networks of researchers, and the development of new capabilities on the part of actors and institutions in the innovation system.

Analyzing this process from the perspective of the firm, Cohen and Levinthal (1990) argue that the process of knowledge transfer from universities and research institutes is strongly conditioned by the capabilities of firms. Firms need to build an internal knowledge base and research capacity to effectively capture and deploy knowledge acquired from external sources. The ability to exploit external knowledge is a critical component of a firm's innovative capabilities. The ability to evaluate and utilize outside knowledge is largely a function of the level of prior, related knowledge within the firm. This prior knowledge includes basic skills or even a shared language, but may also include knowledge of the most recent scientific or technological developments in a given field. These abilities collectively constitute a firm's 'absorptive capacity'. The overlap between the firm's knowledge base and external research allows the firm to recognize potentially useful outside knowledge and use it to reconfigure and augment its existing knowledge base. Research shows that firms which conduct their own R&D are better able to use externally available information. This implies that absorptive capacity may be created as a by-product of the firm's own R&D investment. A key implication of this argument is that firms require a strong contingent of highly qualified research scientists and engineers as a prerequisite to the ability to absorb and assess scientific results, most frequently recruited from institutions of higher education. The members of this scientific and engineering labour force brings with them not only the knowledge base and research skills acquired in their university training, but often, more importantly, a network of academic contacts acquired during their university training. This underlines Pavitt's point that the most important source of knowledge transfer is person embodied.

Knowledge Transfer from Universities

One of the difficulties with understanding the nature of the relationship between university-performed basic research and firm-based innovation is that it avoids the question of how firms in different industry sectors deploy scientific knowledge in the innovation process. One study that cast some light on this question was the Yale survey conducted by Richard Nelson and several colleagues in the early 1980s. It queried 650 R&D managers in US firms, representing 130 lines of business. It distinguished between two roles that science plays in supporting innovation: one as an expanding pool of theory and problem-solving techniques deployed in industrial R&D, but not necessarily new science; the other as a direct source of new technological possibilities pointing the way towards new solutions to old problems. Overall, university-based research in a field was reported by the R&D managers as much less important to recent technical advance in industry than was the overall body of scientific knowledge in the field. In most fields, academic research does not provide pilot inventions, but the broad understandings and techniques that industry can later employ for a variety of different purposes. Industrial R&D managers also reported that they value the scientific background and training of their R&D staff more highly than the current research activities of university-based researchers (Klevorick, Levin, Nelson, et al. 1995). Nelson expands on the reason why research activity with a direct impact on industrial innovation is limited in research organizations that specialize in the conduct of R&D, such as university research laboratories,

> To do effective industrial R&D generally requires knowledge about the technology of an industry that is not taught in school. It also often requires a certain amount of close and not preprogrammable interaction between the lab and client firm or firms, and complementary work and investment on their part. . . . Thus effective lab

> work requires not only industry-specific, but firm specific, knowledge and sensitivity of the lab to the needs of its client firm (Nelson 1996, 62).

The findings of the original Yale survey are broadly supported by a more recent survey of industrial R&D managers conducted at Carnegie Mellon University in 1994 (CMS). The results of the Carnegie Mellon Survey (CMS) reinforce the notion that industrial firms draw upon feedback from their own customers and manufacturing operations as the primary source of ideas for new product and process innovations. Public research is significant in addressing previously identified needs or problems, rather than suggesting new lines of innovative activities, with the exception of a select few industries, such as pharmaceuticals, that draw directly upon the public research base. However a significant proportion, almost a third, of industrial R&D projects do make use of public research findings and the authors of the study argue that knowledge from public research findings beyond this stated level is transmitted to industrial researchers through a wide range of supplementary channels, such as consulting and informal communications. This insight is supported by an additional finding that the most important mechanisms for communicating research results from public research institutes to industry are the traditional ones of publication and conferences, strongly complemented by informal exchanges and private consulting arrangements between firms and researchers (Cohen, Nelson, and Walsh 2003, 139-41).

The findings of the Carnegie Mellon Survey reinforce the perspective that a key aspect of the process of knowledge transfer from universities and research institutes is through personal connections and that the knowledge being transferred is thus ‘tacit’ and ‘embodied’. To deploy university-generated knowledge in a commercial setting, firms need to capture both its tacit, as well as its more explicit, or codified, component. Another study by Wendy Faulkner and Jacqueline Senker employed a somewhat different research methodology designed to analyse this dimension of knowledge transfer in greater detail. This study explored the relationship from the perspective of the innovating organization, focusing on its knowledge requirements and trying to develop a better understanding of the knowledge flows from academia to industry. The researchers conducted interviews with a number of managers in firms across three science-related industries, biotechnology, engineering ceramics, and parallel computing. They probed for links between the firms and universities and the types of knowledge flowing to the firms. They also attempted to determine the degree of formality of these links and the relative importance of tacit versus codified knowledge. While the findings differ slightly by industry, they conclude that partnering with universities contributes most to firm innovation through an exchange of tacit knowledge and that the channels for communicating this knowledge are often informal. Such informal linkages are both a precursor and a successor to formal linkages and many useful exchanges of research materials or access to equipment take place through non-contractual barter arrangements. The flexibility inherent in such arrangements promotes the goodwill between partners that supports more formal linkages (Senker 1995).

Proximity and Spillovers in Knowledge Transfer

The preceding analysis emphasizes the fact that knowledge transfer between universities and their partners are highly personalized and, as a consequence, often highly localized. This underscores the significance of geographical proximity for the process of knowledge transfer. Proximity to the source of the research is important in influencing the success with which knowledge generated in the research laboratory is transferred to firms for commercial exploitation, or process innovations are adopted and diffused across developers and users. A growing body of empirical research reinforces the finding that the linkages and benefits that flow from public investments in basic research are localized in this manner. The most frequently cited explanation for this proximity effect is the need to gain access to tacit knowledge, or at least knowledge that is not yet codified. Conversely, the role of proximity declines when useful knowledge is readily available in more codified forms that can easily be transmitted and accessed across broad distances. Proximity may also be more important for the transfer of relatively new research results in science-based fields, where personal access to those conducting the research is critical for the effective transfer of its insights (Feldman 2000; Adams 2001; Arundel and Geuna 2001).

One prominent line of research has investigated the geographic spillovers from government funding of scientific research to other types of activities, such as industrial R&D. Access to the US patent office data base enabled researchers to assemble large volumes of patent data with geographic precision. These data provide a rich geographic time series which has been further broken down into patent families, patents that reference or cite each other and are used to indicate the flows of knowledge from one intervention to another. Using patents as a proxy for innovative output, Jaffe related the incidence of patents assigned to various corporations in different states with industrial R&D and university research. He found an important indirect or induced effect. There is also an association between industrial R&D and university research at the state level (Jaffe 1989). In a subsequent study, Acs et al (1991). replaced the number of patents with the number of announcements of new or improved products found in newspapers and trade journals. Their analysis indicated that spillovers from university research to industrial innovation were greater than Jaffe described.
Using the same data as Acs, Feldman and Florida's model showed that the process of innovation is highly dependent on the underlying technological infrastructure of an area, consisting of both university and industrial R&D, agglomerations of related firms and business services. Furthermore, these innovative capabilities tend to be highly specialized in regional concentrations of distributed across the US. "In the modern economy, locational advantage in the capacity to innovate is ever more dependent on the agglomerations of specialized skills, knowledge, institutions, and resources that make up the underlying technological infrastructure" (Feldman and Florida 1994, 226).

Jaffe et al (1993). also used patent citations to analyze the spillover effects of academic research. The results indicated that knowledge flows from universities to firms are highly localized at the regional or state level. They found evidence that patents cite other patents originating in the same city more frequently. Citations are five to ten times as likely to come from the same city as the control patents. This research highlights some of the factors that condition localization. Citations are more likely to be localized in the first year following the patent. This effect fades with time: citations show fewer geographic effects as knowledge diffuses. In a slightly different approach, Audretsch and Feldman (1996) used innovation citations that represent the market introduction of new commercial products. These data consist of new product announcements compiled from technology, engineering, and trade journals. They found a direct relationship between the propensity for industries to concentrate geographically and the knowledge intensity of the industries' activity. They also used survey data to discern the disciplines that form a common science base that contribute to cross-industry increasing returns. This work found that industries relying on the same science base also tend to cluster geographically.

Knowledge Transfer and Cluster Formation

The proximity effect of knowledge transfer provides a strong clue as to why universities are increasingly seen as an essential element to the process of regional economic development and for stimulating the formation of clusters, especially in knowledge-intensive industries, such as information and communications technology or biotechnology. But a critical issue that has been less well explored in the literature involves both the degree to, and the way in, which the proximity effect of university research on innovativeness contributes to the process of cluster formation. This is a point that has more frequently been assumed in much of the literature, rather than studied systematically. A critical issue involves the question of which of the university's central roles in the knowledge-based economy – the performance of scientific research and the training of highly qualified personnel – exert the dominant influence on the process of regional economic development and cluster formation.

Clusters are defined as "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter 1998, 199). They can include concentrations of interconnected companies, service providers, suppliers of specialized inputs to the production process, customers, manufacturers of related products and governmental and other institutions, such as national laboratories, universities, vocational training institutions, trade associations and collaborative research institutes.

The mutually beneficial activities of the firms in a cluster generate a number of cluster assets that can be viewed as quasi-public goods. The general level of knowledge and information built up in the cluster can act as such a good, if the level of trust is sufficient to generate an easy and mutual exchange of both tacit and codified knowledge. Similarly, the mobility of personnel between firms in a cluster can constitute a similar source of knowledge flows. Even more important, the strength of the cluster can provide an important stimulus to public investment in specialized infrastructure, such as communication networks, joint training and research institutions, specialized testing facilities and the expansion of public laboratories or post-secondary educational institutions. As the depth and value of such investments increase, so do the economic benefits flowing to firms located in the cluster. Thus the strength of the cluster and its supporting infrastructure of quasi-public goods and public institutions create a mutually reinforcing positive feedback loop (Porter 1998, 218-19).

Clusters have an additional effect on improving the capacity of member firms to innovate and thus enhance their potential for productivity growth. Membership within the cluster affords firms a clearer view of current and prospective technology trends, allowing them to identify more rapidly new market opportunities for product or process enhancements through better information about buyer needs. On the supply side of the equation, cluster participation provides the firm with early information about new technology trends, component and machinery capabilities, allowing them to perceive opportunities for improving or enhancing their own products or firm capabilities. Even more important than these valuable sources of information, membership in the cluster allows firms to act quickly by providing them with the ready source of supply that they need to bring new products or services to the market. These advantages are strongly reinforced by the competitive pressure that comes with location in the cluster. The presence of multiple rivals in the cluster, competing to take advantage of similar market opportunities and supply capabilities, pushes firms to excel at the innovative process. However, these internal competitive pressures are strongly reinforced by the potential for cooperation. Competition and cooperation are both present within the cluster because they work on different dimensions and between different economic actors (Porter 1998, 220-23; Best 1990).

A number of recent studies have also identified the finding and retaining of talent as a critical factor influencing the development of clusters and the growth of dynamic urban economies. Locations with large talent pools reduce the costs of search and recruitment of talent – they are also attractive to individuals who are relocating because they provide some guarantee of successive job opportunities. In Richard Florida's interviews, numerous executives confirmed that they will "go where the highly skilled people are". Highly educated, talented labour flows to those places that have a 'buzz' about them – the places where the most interesting work in the field is currently being done. One way to track this is through the inflow of so-called 'star scientists', or by tracking the in-migration of tomorrow's potential stars (post-docs). Another approach, employed by Florida and colleagues (Florida 2002; Gertler, Florida, Gates, et al. 2002) utilizes a more broadly defined measure of 'talent', and documents its strong geographical attraction to the presence of other creative people and activities locally. In-bound talented labour represents knowledge in its embodied form flowing into the region. Such flows act to reinforce and accentuate the knowledge assets already assembled in a region.

Knowledge and Learning in Clusters

Much of the literature on the economic benefits of clusters stresses the fact that the key advantages are derived from the agglomeration economies afforded by the cluster. These agglomeration economies arise primarily from the ready access afforded to firms by colocating with key suppliers. Porter stresses that the location of a firm within a cluster contributes to enhanced productivity by providing it with superior or lower cost access to specialized inputs, including components, machinery, business services and personnel, as opposed to the alternative, which may involve vertical integration or obtaining the needed inputs from more remote locations. Sourcing the required inputs from within the cluster reduces the need to maintain costly inventory and the consequent delays that can arise with shipments from distant locations. It also facilitates communication with the key suppliers in the sense that repeated interactions with the supply firms in the value chain creates the kind of trust conditions and the potential for conducting repeated transactions on the basis of tacit, as well as more codified, forms of knowledge. Clusters also offer distinct advantages to firms in terms of the availability of specialized and experienced personnel. The cluster itself can act as a magnet drawing skilled labour to it or conversely the location of specialized training and educational institutions in the region provides a steady supply of highly qualified labour to the firms in the cluster (Porter 1998).

While not diminishing the importance of these agglomeration economies, a more recent stream of analysis suggests that the underlying dimension which confers competitive advantages on the firms located in the cluster is ready access to a common knowledge base. The central argument in this literature is that the joint production and transmission of new knowledge occurs most effectively among economic actors located close to each other. Proximity to critical sources of knowledge, whether they are found in public or private research institutions or grounded in the core competencies of lead or anchor firms, facilitates the process of acquiring new technical knowledge, especially when the relevant knowledge is located at the research frontier, as in the field of biotechnology research, or involves a largely tacit dimension. Knowledge of this nature is transmitted most effectively through interpersonal contacts and interfirm mobility of skilled workers. From this perspective, "a key feature of successful high-technology clusters is related to the high level of embeddedness of local firms in a very thick network of knowledge sharing, which is supported by close social interactions and by institutions building trust and encouraging informal relations among actors” (Breschi and Malerba 2001, 819). This argument is strongly supported by the empirical findings of the literature on the impact of proximity on knowledge flows, discussed above.

Building on this stream of the literature, Peter Maskell has proposed that we require a knowledge-based theory of the cluster, but extends this approach to both high-technology and conventional clusters. He suggests the primary reason for the emergence of clusters is the enhanced knowledge creation that occurs along two complementary dimensions: the cluster affords firms benefits along a horizontal dimension through the reduced costs of coordinating dispersed sources of knowledge and overcoming the problems of asymmetrical access to information for different firms; as well as facilitating the actual flow of knowledge between firms along the vertical dimension. The horizontal dimension of the cluster consists of those firms that produce similar goods and compete with one another. The advantages of proximity arise from continuous monitoring and comparing of what rival firms are doing, which acts as a spur to innovation as firms race to keep up with, or get ahead of, their rivals. The vertical dimension of the cluster consists of those firms that are complementary and interlinked through a network of supplier, service and customer relations. Once a specialized cluster develops, firms within it increase demand for specialized services and supplies Further, once the cluster has emerged, it acts as a magnet drawing in additional firms whose activities require access to the existing knowledge base or complement it in some significant respect (Maskell 2001, 937).

A knowledge-based theory of the cluster necessitates an awareness of the fact that knowledge flows present in a cluster frequently involve a combination of both local and global sources. Bathalt, Malmberg and Maskell maintain that successful clusters are effective at building and managing a variety of channels for accessing relevant knowledge from around the globe. However, the skills required when dealing with the local environment are substantially different than the ones needed to generate the inflow and make the best use of codified knowledge produced elsewhere and these differences must be managed by the cluster. They maintain that an accurate model of the knowledge-based cluster must account for both dimensions of these knowledge flows (Bathalt, Malmberg, and Maskell 2002). They refer to these two kinds of knowledge flows as *local buzz* and *global pipelines* respectively. According to Storper and Venables buzz arises from the fact of physical co-presence. It incorporates both the broad general conditions that exist when it is possible to glean knowledge from intentional face-to-face contacts, as well as the more diffuse forms of knowledge acquisition that arise from chance or accidental meetings and the mere fact of being in the same location. Buzz is the force that facilitates the circulation of information in a local economy or community and it is also the mechanism that supports the functioning of networks in the community (Storper and Venables 2003, 32). Pipelines refer to channels of communication used in distant interaction, between clusters and external sources of knowledge. Important knowledge flows are generated through network pipelines. The effectiveness of these pipelines depends on quality of trust that exists between the firms in the different nodes involved. The advantages of global pipelines derive from the integration firms located in multiple selection environments, each of which is open to different technical potentialities. Access by firms to these global pipelines can feed local interpretations and the usage of knowledge that developed elsewhere into a cluster. Firms need to access to both local buzz and the knowledge acquired through international pipelines. The ability of firms to access such global pipelines and to identify both the location of external knowledge and its potential value depends very much on the internal organization of the firm, in other words, its ‘absorptive capacity’. The same can be said of local and regional clusters (Bathalt, et al. 2002).

Path Dependency and the Creation of Clusters

According to a number of observers, clusters are seeded by a variety of methods; however, their growth can only be facilitated by building upon existing resources. There is considerable disagreement over whether they can be built just anywhere from scratch. The key assets that determine the viability of a cluster are firm-based. Of particular importance is the emergence of an anchor firm for the cluster. Whole clusters can develop out of the formation of one or two critical firms that then feed the growth of numerous smaller ones. Examples of the role played by this kind of anchor firm can be found in the case of MCI and AOL in Washington, DC, or Nortel in Ottawa, or NovAtel in the case of the Calgary wireless cluster. In other instances, the presence of major anchor firms in a local cluster can act as a magnet, attracting both allies and rivals to locate in the region to monitor the activities of the dominant firm. This is the case with San Diego, where Nokia, Ericsson and Motorola have all located their CDMA wireless research efforts to benefit from Qualcomm's leadership in the field or in Ottawa, where Cisco and Alcatel both acquired local firms to benefit from the optical and telecommunications expertise in the region. This process can require decades to take root, a point not well recognized by many of the localities currently engaged in developing cluster strategies. And while universities and public research institutes can play a supporting role in the development of the cluster, as was the case with the NRC's laboratories and the Communications Research Centre in attracting the Bell Northern Research Laboratories to Ottawa, or UC San Diego as home to the research that led indirectly to the founding of Qualcomm, the role is far less direct or instrumental than is often presumed. Other analysts emphasize the role that highly skilled labour, or a unique mix of skill assets, often produced by the post-secondary educational institutions, play in seeding the growth of a cluster. However, this process also requires a long time to take root.

The presence, or absence, of key institutional elements in a local or regional economy may affect both their innovative capacity and their potential to serve as nodes for cluster development. Other studies underscore the importance of local governments and economic development agencies adopting sustained development strategies and key role played by civic entrepreneurs in those strategies. Similarly, the ability, or inability, of the local or regional economy to develop the underlying conditions of trust and social capital that contribute to the presence of a learning economy may inhibit its capacity to sustain the growth of dynamic clusters. A critical question that remains unexplored through most of this literature is how the conditions that influence the trajectory of growth for specific regional or local economy can be altered by direct intervention.

Many clusters enjoy the knowledge assets and research infrastructure that are necessary for the development of an innovation-based development strategy, but they differ dramatically in their capacity to mobilize these assets in the pursuit of such a strategy. Similarly, experience suggests that local communities can formulate strategies to alter their economic trajectory and improve their chances of economic development. The successful initiation of this kind of process depends upon the ability to collaborate across boundaries – both geographic and social. Even in established clusters, the mere concentration of a large number of firms is not sufficient to transform a particular locale into a vibrant and dynamic regional economy. It also requires the presence of an 'economic community' – strong, responsive relationships between the economy and community that afford both companies and the community a sustained advantage. These relationships are mediated by key people and organizations that bring the economic, social and civic interests in the community together to collaborate (Henton, Melville, and Walesh 1997). Henton and his colleagues argue that social capital is a critical ingredient in the success of the most dynamic clusters and regional economies. Social capital *can* be created and the basis for doing so is the establishment of collaborative networks between various elements of the business and civic communities, including the university research institutions.

> The presence of *collaborative institutions and organizations*, such as cluster organizations, professional networks, research-industry consortia and entrepreneurial support networks, greatly facilitates this environment. These alliances, networks and other relationship-building mechanisms create connections and linkages vital to economic development in a technology-driven world. . . . many regions fortunate enough to have university research assets underuse these knowledge economy resources, precisely because relationships have not been

> established to connect the university and local industry. . . . Relationships matter (Montana, Reamer, Henton, et al. 2001, 10).

Successful clusters are built on local institutions of collaboration, which are formal, and informal organizations that facilitate the exchange of information and technology, and foster cooperation and coordination. They create social capital and improve competitiveness within clusters by creating relationships and establishing trust, facilitating the organization of collective action, developing collective institutions that benefit the members of the cluster, identifying common strengths or mutual needs and contributing to the development of a common economic agenda. Collaborative organizations and institutions embody values and attitudes that are intrinsic to the region. This element of the regional culture is an important, but overlooked, component in the design of cluster development strategies. The essential criterion for success is finding the appropriate mechanisms to engage key members of the community in a sustained effort to advance its opportunities. The recruitment of a committed, creative and collaborative leadership is the most essential element for the success of a strategic planning process in regional economic development. These collaborative leaders share certain characteristics: they can see the opportunities opened by the emergence of the knowledge-based economy; they exhibit an entrepreneurial personality, in both a business and a 'civic' sense; they are willing to cross functional, political and geographic boundaries in pursuit of their strategic goals and they are committed to, and comfortable working in teams (Montana, et al. 2001, 31-35). Universities can, and have played, a critical role as sources of this dynamic, farsighted community leadership and in building collaborative institutions at the local level.

Universities as Knowledge Poles for Cluster Development

As we saw at the outset, the mere presence of leading research universities in a community is not sufficient to stimulate the formation of a dynamic and innovative cluster, or sustain the process of regional economic development. However, their presence can play a vital role in contributing to cluster development. That role should not be viewed simply as a source of scientific ideas for generating new technology to transfer to private firms, or as a source of new firm formation as research scientists spin findings out of their laboratories into new startups. While successful research universities perform these functions, overall they play a more fundamental role as providers and attractors of talent to the local and regional economy and as a source of civic leadership for the local community.

At the same time, communities located around the research institution cannot simply rely upon the presence of a leading research university as the ‘engine of innovation’ that will drive economic growth in their region. They must display both the capacity to absorb and utilize the knowledge and the skilled labour produced by the institution – in other words, a ‘regional absorptive capacity’ (Mallet 2002, 605) – and the social cohesion to build an economic community around their research infrastructure. Ultimately, the most valuable contribution that universities make to this process is as providers of high skilled labour, or talent. If knowledge is rapidly becoming the central factor of production in the emerging economy, the ability to absorb and use that knowledge, or to learn is the most essential skill or process. Learning processes are eminently person embodied in the form of talent. “Universities . . . are a crucial piece of the infrastructure of the knowledge economy, providing mechanisms for generating and harnessing talent” (Florida 1999, 72)

This means that the role of public policy in seeding cluster development, particularly as it applies to the research intensive universities is critical. The impact of public sector interventions on cluster development can be positive, negative or inadvertent in character. On balance, however, the public interventions which have the most effect in seeding the growth of clusters are those that strengthen the research infrastructure of region or locality and contribute to the expansion of its talent base of skilled knowledge workers. These points were strongly emphasized in a recent report prepared for the Ontario government,

> Basic university research advances fundamental understanding and provides a substantial rate of economic return through the preparation of a highly skilled workforce, contributing to the foundation of many new technologies, attracting long-term foreign (and domestic) investment, supporting new company development

and entrepreneurial companies and participating in global networks. Government funding is the primary support for virtually all investment in truly frontier university research (Munroe-Blum 1999, 14).

Recent research on the growth and development of three major information and communications technology (ICT) clusters in Ontario – Ottawa, Toronto and Waterloo – documents the important contribution made by the research infrastructure in all three communities, both public research laboratories and post-secondary educational institutions (Wolfe 2002). However, the findings underline the fact that direct seeding of the cluster by postsecondary institutions is the exception, rather than the rule. The case studies of the three clusters suggest that the presence of universities and research institutes act primarily as attractors of inward investments by leading anchor firms interested in tapping into the knowledge base of the local community, or its *local buzz*, and as providers of the talent pool that firms in the cluster draw upon, rather than as direct initiators of cluster development. In this respect, universities also act as part of the network linking actors in the local cluster to the *global pipelines* that are also essential to the knowledge flows in the cluster. Successful research universities also attract leading scientists further reinforcing their linkages to external knowledge flows through the extensive network of contacts they bring to their new location.

Several examples from the case studies serve to illustrate this point. Among the three cases, the one which most clearly represents a central role for the university is Waterloo. All accounts of the origins of this cluster link its roots to the farsighted vision of a key group of business leaders to create a new university in the region in the late 1950s in a period when the provincial government (with financial support from the federal government) was expanding the post-secondary education system. Even more influential were subsequent decisions to focus the core strengths of the university in the sciences and engineering and to establish what has become one of the most successful co-op education programs in North America. The founders of many of the firms that populate this cluster are graduates of the university and many started their companies with core technologies developed while they were at the university. Even the most internationally successful of these firms maintain their primary research base in the Waterloo area because of their ability to draw upon a highly trained group of science and engineering graduates from the university.

An illustration of the inadvertent role that public policy can sometimes play is provided in the case of the telecommunications cluster in Ottawa which originated partly with the judicial decision in the US to force the Western Electric Company to divest itself of its subsidiary, the Northern Electrical Manufacturing Company (now Nortel) in the late 1950s. Cut off from its sources of innovation and research, Northern Electric searched for a location to establish its own facility. It eventually bought a substantial tract of land on the outskirts of Ottawa to be the home of Bell Northern Research, largely because it viewed the presence of the National Research Council laboratories and the Communications Research Centre in the nation's capital as a substantial draw for the highly skilled research scientists and engineers it expected to populate its research facility. Many of the leading entrepreneurs in the Ottawa telecommunications and photonics cluster began their careers as researchers for BNR or another subsidiary, Microsystems International. Although the research universities played a secondary role the official genealogy of Ottawa high tech companies credits Carleton University with contributing substantial to the development of firms in the community.

> The Ottawa story emphasizes the critical importance in cluster development of deeply rooted R&D strength. It also clearly underscores the fact that access to technology demands the presence of world-class scientific research institutions. Only through the combined impact of public and private sector research activity could Ottawa have spawned its own homegrown high-tech industry (Mallet 2002, 6).

In a series of interviews conducted for the case studies, universities were identified as a source of strength for the sector, both in terms of their ability to provide a steady stream of highly skilled personnel, a prime driver of sector growth in Ontario, as well as a strong base of research with close links to industry.[1] Industry representatives feel that specific programs

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[1] The following discussion draws upon a number of confidential interviews with business, education and industry association leaders conducted as part of a study of ICT clusters in Ontario (Wolfe 2002).

such as the coop programs at Waterloo and others have been effective at moving students into industry settings. In addition to providing a strong talent base for firms located in the clusters to draw upon, the university research infrastructure is important for the clusters in two additional respects – one as a key source of new ideas for domestic companies, both in terms of spin-offs and knowledge transfer; and second, as a factor contributing to the reputation of the key clusters, in Ottawa, the Greater Toronto Area and in Waterloo, thus helping to attract large foreign firms to invest in the province. The case of Cisco (both with respect to the Ottawa cluster and more recently Waterloo) is widely cited as the most significant inward investment to the regional clusters, but Alcatel, Lucent and other leading IT were also mentioned. Most recently IBM, with one of its Centres for Advanced Studies located in its software laboratories in Markham, just north of Toronto, has expanded its presence in the Ottawa cluster as well. Through the acquisition of two local software companies – Tarian Software and Rational Software Corporation – it tripled the size of its Ottawa laboratories to 300 people. This expansion was furthered with the opening of a new Centre for Advanced Studies in the Ottawa laboratories to give graduate students from Carleton and the University of Ottawa experience in working with experienced software engineers in the development of new programs for database management (Pilieci 2003). The growing presence of these large multinational players is seen as evidence that the Ontario clusters have emerged as a major player on the international scene due, in part, to the growing reputation of their research infrastructure.

Many companies are expanding their investments in the university research base; through direct funding of basic research, affiliation with federal and provincial Centres of Excellence or partnering on more applied research initiatives. Companies cite the positive benefits that have flowed from recent federal and provincial increases in university funding through programs such as the Centres of Excellence, the Canada Foundation for Innovation or the Ontario Research and Development Challenge Fund. The two largest players in the sector, Bell Canada and Nortel Networks have both launched major research initiatives in the past several years, principally at the University of Toronto and the University of Waterloo. In 2000, Nortel was funding $15 million of research at 11 Ontario universities and had invested an additional $18 million to create two dedicated institutes, the Nortel Institute of Optical Electronics at U. of T. and the Software Institute at the University of Waterloo. For its part, Bell Canada invested $35 million over three years in its Bell University Laboratories program at the Universities of Toronto and Waterloo. Although the level of Nortel research funding has declined in the recession, its strong links to the research base remain intact. Representatives of the business and industry association sectors cite the strong entrepreneurial culture at the University of Waterloo and the encouragement that faculty receive to develop and exploit their innovations as a critical factor in the growth of the ICT cluster in Canada's Technology Triangle. They agree emphatically on the driving role that the university's research base has played in the recent growth and expansion of the ICT cluster in their region. The region is currently reaping the benefits of investments in the post-secondary research and education base made in the late 1950s and 1960s.

While the Waterloo case suggests that farsighted investments in post-secondary education and the research infrastructure can seed cluster development, more often universities are followers, rather than leaders, in cluster formation – as they respond to the demands of local firms for an expanding talent pool by increasing their own teaching and research activities in areas of technical competence critical for the growth of those firms. One of the key factors cited repeatedly as crucial for the current and future well being of the ICT sector in Ontario is a continuing supply of highly skilled personnel. A number of new federal and provincial initiatives address this issue directly. Foremost is Ontario's Access to Opportunities Program with $150 million in new funding over three years, designed to increase the number of students enrolled in computer science and related engineering programs by 17,000 students a year. Virtually all the province's universities and colleges submitted proposals under this program and the Council of Ontario Universities noted that the universities exceeded the initial target, resulting in the creation of 23,000 new places. While employment in the sector fell from 2000 to 2002, the decline was largely limited to the manufacturing sector as employment in the services sector continued to grow. Over the longer period from 1997 to 2001, employment in the ICT sector increased by 32 per cent, suggesting that demand remains strong for the graduates from these programs.

Conclusion

The strength and vitality of universities remains essential for growth in the knowledge–based economy. Universities perform vital functions both as generators of new knowledge through their leading-edge research activities and as trainers of highly qualified labour. As most research universities will attest, the two functions are integrally linked and when they are most effective, they contribute strongly to regional economic growth and development. As such, they provide the essential infrastructure from which clusters can develop. But it is important to be clear about the precise role they play. Strong research intensive universities feed the growth of clusters by expanding the local knowledge base and providing a steady stream of talent to feed supports the growth of firms in the cluster. They also serve as magnets for investments by leading or anchor firms, drawing them into the cluster to gain more effective access to the knowledge base and *local buzz*. In some instances, successful research efforts can expand the cluster by spinning off research results into new products and firms, but it is a mistake to view this as their primary purpose. But it is dangerous to assume that the economic returns to this investment be judged solely on the success with which research findings are transformed into commercial products. Recent policy initiatives which aim to elevate the commercialization of technology to equal status with research and teaching as mandates of the university fundamentally miss this point. Universities must also be a vital part of the local 'economic community' by building the region's social capital and taking a leadership role in activities designed to enhance the region's absorptive capacity. Continued public support for both the teaching and research mandates of the university are essential if they are to succeed in these roles and contribute to the growth of their local and regional economies.

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