Knowledge, Learning and Social Capital in Ontario's ICT Clusters

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1.0 Introduction

Recent approaches to the study of innovation highlight that it is grounded in dense networks of geographically proximate firms engaged in related types of activity, often described as clusters. Ontario is home to three such clusters in the information and communications technology sector – in Ottawa, the Greater Toronto Area and Kitchener/Waterloo, Canada's Technology Triangle. This paper documents the current dimensions of these clusters and examines the role that the various factors contribute to their continuing growth and dynamism. The data is drawn from existing public sources and in depth interviews conducted with participants in the clusters. Several recent studies prescribe the elements essential to stimulate cluster formation and sustain their continued growth. While many of these studies emphasize the critical importance of economic factors and the role of a strong research infrastructure, a key factor that has spurred the growth of existing clusters is social rather than economic – the presence of strong, committed, community leadership. This has certainly been an important contributor to the success of the Ottawa and Waterloo ICT clusters and has been built around common goals of the public and private members for the development of the clusters and the maintenance of the local quality of life. Local economic authorities and policy-makers at regional levels of government are interested in the process by which clusters take hold and expand. This paper explores the dimensions of Ontario's three ICT clusters and the relative contribution that different factors have played in their development. It examines what we currently know about the process of cluster development based on these case studies and lays out a research agenda to further our collective efforts in the field.

2.0 Cluster Formation

The recent boom in information and communications technologies and the Internet phenomenon has contributed to a growing fascination with the emergence of dynamic, regional clusters in key locales across the North America. Michael Porter defines a cluster as "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (1998, 199). They include concentrations of interconnected companies, service providers, suppliers of specialized inputs to the production process, customers, manufacturers of

related products and finally governmental and other institutions, such as national laboratories, universities, vocational training institutions, trade associations and collaborative research institutes.

Numerous studies conducted in Canada and the US prescribe the key elements essential to the formation of a cluster and to sustain its growth. One such study completed in 1999 and 2000 by A.T. Kearney for *Joint Venture: Silicon Valley* prescribes a set of six such factors:

- strong, diverse and tech-savvy talent pool;
- 'pillar' companies in the core industries that comprise the cluster;
- risk-tolerant venture capital and angel investors;
- specialized support services such as IP law and accounting firms and headhunters;
- universities that supply talent as well as research results that can be transferred to commercial ventures;
- strong government programs that foster economic growth, develop the local workforce and address critical quality of life and economic issues.

The report notes that finding and retaining talent appears to be the primary challenge facing firms in the dynamic ICT-based clusters. This finding is strongly reinforced in a recent study released by Richard Florida of Carnegie Mellon University. The paper is based on both a qualitative and quantitative study of the geographic location of highly qualified personnel in the 50 largest metropolitan regions around the U.S. and the extent to which these concentrations of 'talent' are co-located with a number of other key variables including concentrations of high-technology industry. Not surprisingly, the top ranked locations in terms of talent, Washington, DC, Boston, San Francisco, Austin, Atlanta and Seattle, are strongly correlated with some of the most dynamic clusters of high technology firms in the US. The analysis of the data further suggests that talent is attracted to locations with strong cultural amenities and a respect for, or tolerance of, diversity (Florida, 2000). 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 Florida's interviews, numerous executives confirmed that they will "go where the highly skilled people are".

This analysis of the key factors that underlie the presence of clusters is also borne out in a related corpus of policy related work done in Canada and the US. Research undertaken for the National Research Council situates the process of industrial clustering within the systems of innovation approach (Nordicity Group Ltd 1996). Based on this analysis, the Planning and Assessment Branch of NRC has identified a set of eight factors that contribute to cluster development, including: the presence of local champions with greater vision than single firm success; the existence of a strong S&T knowledge infrastructure – which includes research universities, government laboratories, cooperative research centres; source of motivated learners and technology, knowledge and skills; the presence of at least one exporting firm, with some global reach; involvement by local networking facilitators who promote the growth of relationships within the cluster; involved, knowledgeable local sources of innovation financing; sustained, aligned development strategies by local institutions and governments; and a supportive business climate, and policy conditions favourable for innovators.

Michael Porter provides a compelling analysis of reason why co-location in clusters enhances firm-based competition. The first is by increasing the productivity of their constituent firms and industries. 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. Clusters also offer distinct advantages to firms in terms of the availability of specialized and experienced personnel. The cluster itself acts as a magnet drawing skilled labour to it. Conversely the location of specialized training and educational institutions within the cluster can provide a ready supply of new labour to the firms in the cluster. Clusters also enhance productivity by facilitating complementarities that exist between member firms. Membership in the cluster makes it easier for participants to source needed parts and components, thus enhancing the technological and productive capabilities of members firms.

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).

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 (Wolfe 2002). The 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.

Other regions eager to emulate the success of Silicon Valley must better understand the specific character of social capital and networked relations that underlie its success. Many regions enjoy the knowledge assets and research infrastructure necessary for cluster development, 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 cluster development. The successful initiation of this process depends upon the ability to collaborate across boundaries – both geographic and social.

The impact of one recent initiative, *Joint Venture: Silicon Valley,* on improving the quality of civic engagement in the Valley has led to the conclusion that even in established clusters, the 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). Based on this and similar experiences with community-based initiatives, Henton and his colleagues (Henton et al. 1997; Montana et al. 2001) 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.

> 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 et al. 2001, p. 10).

Successful clusters are built on local institutions of collaboration, which are formal, and information 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 foresight and regional economic development. These kinds of 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).

3.0 Overview of Ontario's ICT Clusters

Ontario has three major geographic concentrations of firms or clusters in the ICT sector – the Greater Toronto Area, Ottawa (formerly Ottawa-Carleton), and Canada's Technology Triangle (Kitchener, Waterloo, Cambridge and Guelph). Each of these clusters specializes in different segments of the sector and exhibit distinctive features, related to their origins and their trajectory of development. While the GTA is by far the largest of the three clusters, it is much less noticed and analyzed due to the broad diversity of the cluster and its lack of prominence within the overall GTA economy. The GTA is, of course, the heart of both Ontario's manufacturing sector and its burgeoning service economy. The ICT cluster in the GTA must compete with others that are equally as large, if not larger, for attention and 'air time'. For instance, the recently completed study of Toronto's clusters by ICF Consulting identified ten major clusters driving economic growth in the City of Toronto and the Census Metropolitan Area, of which the ICT cluster was only one. In terms of the 'growth share matrix' methodology developed by ICF (which measures the size and growth of employment in the cluster relative to those elsewhere in North America), the ICT cluster ranked fourth in terms of its rate of absolute job growth over the ten year period from 1988 to 1998 and fourth in terms of the location

quotient (which measures the degree of regional specialization in the cluster relative to the rest of Canada and the US) – behind Business and Professional Services, Tourism and Financial Services (ICF Consulting, 2000a: 34).

In contrast, the similar study of Ottawa identified four out of six leading clusters in the regional economy as ICT-related – telecommunications equipment, microelectronics, software and communications and photonics (life sciences and tourism being the remaining two). While the overall size and depth of the ICT cluster in the GTA is much greater, the relative scale and importance of the ICT clusters for the local economy explains why they attract much greater attention in Ottawa and Kitchener-Waterloo and why these clusters enjoy greater local prominence among community leaders and civic entrepreneurs.

Much of the cluster-specific data presented below is drawn from studies of the respective ICT clusters that were completed in 1999 and 2000. This might lead to the conclusion that the numbers should be considerably lower today in light of the severe impact of the recent recession on the ICT sector in general and telecommunications in particular. However, the most recent data from Statistics Canada suggest that both output and employment in the sector have held up relatively well through the recession, despite the well-publicized cutbacks and layoffs experienced by a number of the leading companies. Output in the ICT sector peaked in the third quarter of 2000 and fell throughout the following year. However, the overall decline masks a significant difference in the performance of the manufacturing and service sectors. During 2001, output in the ICT manufacturing sector decreased by 25.2% while output in the ICT services sector actually grew by 12.3% over the same period. However, when measured against the longer period since 1997, the ICT sector as a whole has experienced an annual growth rate of 14.1% compared to an annual growth rate of 3.5% for the economy as a whole. Total output for the ICT sector reached $58.1 billion in 2001. The ICT sector also remained the largest private sector performer of research and development in Canada, with total expenditures expected to reach $5.3 billion in 2001, almost half of this from the telecommunications

sector, and still accounting for 45.8% of total Canadian private sector R&D (Industry Canada 2002).

Studies by researchers at Statistics Canada present a more detailed analysis of the impact of this decline on employment in the sector, although due to the limitations of the labour force survey, the analysis focuses on the computer and telecommunications sector. This sector employed an average of 632,000 people in 2001, accounting for 4.2% of overall employment and 4.6% of hours worked. However, from its peak in March to the trough in October, employment in the sector fell by 61,000 jobs or 9%, with the greatest drop in communications equipment manufacturing. In the fourth quarter of 2001, total employment in the sector averaged 608,000, still down 5% from the level a year earlier. The Labour Force survey is also able to provide more specific data on the impact of this decline on specific communities. About two-thirds of all CT workers are concentrated in four communities nation-wide – Ottawa, Montreal, Toronto and Vancouver, each of which displays a significantly different employment profile, reflecting the differing concentration of firms and areas of technical specialization. Employment in the CT sector reached its peak of 69,000 in Ottawa in March, 2001, declined to 51,000 in September, but recovered to 57,200 in the fourth quarter of the year. The employment peak for this sector in Toronto was attained in July, 2001 at 204,000 and dropped to 169,000 at the end of the year, but was still only down 9.2% from the level of 186,000 at the end of 2000 (Bowlby and Langlois 2002). The overall implication of both the output and employment numbers suggests that although the decline in the sector occurred quite rapidly in mid-2001, the recovery was well underway by the end of the year and that current levels may be well on their way back towards the numbers reported below from the case studies for 1999 and 2000.

3.1 ICT Cluster in the Greater Toronto Area

According to the recent study conducted by Deloitte and Touche for the Greater Toronto Marketing Alliance and Smart Toronto, *Canada's Smart Community*, the GTA is home to approximately 3,100 firms across virtually every segment of the ICT sector, employing 155,000 people and generating $38 billion in revenues in 1999. The top ICT firms in the

region by employment include Bell Canada, IBM Canada, Rogers Communications, Nortel Networks, Celestica, Xerox Canada, Hewlett Packard Canada (now includes Compaq Canada), EDS Canada, Clearnet Communications and AT&T Canada.

Of the 3100 firms located in the region, approximately 500 are active R&D performers employing 15,000 people in research and development activities, making it one of the top five R&D performing centres in North America. This concentration of ICT firms and research activity has placed the GTA among the ranks of the world's key economic locations in terms of employment and revenue generation by its own technology and media industries according to another study by PricewaterhouseCoopers on the GTA's high tech industry. This study, along with the earlier one by Deloitte & Touche emphasize that the GTA is the principal Canadian focus for major foreign multinationals, including General Electric, Motorola, IBM and Xerox, many of whom conduct cutting-edge research in the GTA. The newly constructed IBM Software Solutions Laboratory in Markham is recognized as one of the company's key research facilities around the globe. The lab was identified as the recipient of a new investment of $125 million, supported in part by a grant from Technology Partnerships Canada. It employs 2,500 people and has a global software mandate in database management, application development, electronic commerce and e-business application tools (Domicity 2002). the Xerox Canada Research Centre, one of the anchor tenants in Sheridan Park located in Mississauga, is the home of one of Xerox' major research facilities and has received 600 patents since its inception.

The GTA's ICT cluster is comprised of eleven different sectors, including communications equipment, computer systems, semiconductors, professional services, software, end-user equipment, wireless services, content developers and wire line services. Of the eleven industry segments, the *computer systems* industry is by far the largest with 575 companies employing 28,300 people in 1999 (Deloitte & Touche 1999). The GTA cluster is the Canadian headquarters for several world-class companies, including IBM Canada, Hewlett-Packard Canada and Celestica. The presence of Compaq had catapulted it into the position of the largest supplier of both personal computers and business systems in Canada as a result of its acquisition of Tandem Computers and

Digital Equipment and the new merger with Hewlett-Packard will result in a further rationalization and consolidation of product lines. Celestica, following its acquisition by Onex and being spun off into a separate company, has expanded from its base of operations in the GTA to a total of twenty four facilities and is currently the third largest electronics manufacturing services company in the world. In its continuing expansion, it has negotiated deals to acquire manufacturing facilities from NEC in Brazil and the UK. All the other key players in the personal computer systems sub-sector, including Dell, HP and NEC, and in the high-end server market, including Fujitsu, Hitachi, Amdahl and Sun, are located in the Greater Toronto Area.

In the GTA, 52 wire line services companies employ 25,000 people. Sub-sectors within wire line services include facilities-based carriers, cable services and non-facilities based carriers. The GTA is the central 'hub' of Canadian communication networks, with all major Canadian and international carriers having their largest Canadian network points of presence here. Penetration rates for established and emerging services, such as telephone, cable, voice mail and Internet access are among the highest in the world. The GTA offers wire line services companies a large and sophisticated user base from which to launch leading edge services nationwide. Companies such as Bell Nexxia, AT&T Canada and Rogers Communications have their headquarters and significant operations in the Greater Toronto Area. The GTA is also home to many of the national Internet service providers in Canada. They have contributed to making it one of the most effectively wired regions in North America. It is also home to a growing number of innovative Internet-based companies who are developing new technologies to expand the functionality of the Internet.

The GTA is home to a very large IT professional services industry whose companies integrate technology into the business processes of established and emerging companies. In the region, 490 IT professional services companies employ 22,300 people. Sub-sectors include companies focused on IT consulting and IT outsourcing. Other non-IT professional services companies in the GTA focus on accounting, advertising/ communications, financial institutions, legal and management consulting. The GTA's

substantial economic structure provides an excellent market for both IT and non-IT professional services firms. Worldwide companies such as Deloitte & Touche and EDS have their Canadian headquarters and significant operations in the Greater Toronto Area. EDS Canada is the nation's second largest IT services provider, a status attained with the acquisition of MCI Systemhouse in April 1999.

In the GTA, 550 content developer/packagers employ 21,700 people. Sub-sectors within this sector include broadcasting, production, multimedia, and electronic information companies. The pace of change in the sector is accelerating. Consolidation is occurring at a rapid rate as traditional media players expand their presence into non-traditional (Internet, new media) channels exemplified by the acquisition of CTV by BCE and the subsequent merger of BCE's new media assets with the Globe and Mail's GlobeInteractive. The GTA has an international reputation as a new media centre of excellence, supported in part due to the presence of Sheridan College – and the resulting concentration of animation and graphics design companies.

In addition to Sheridan, the Bell Centre for Creative Communications housed at Centennial College also specializes in new media and recently received a substantial investment from the Province of Ontario and several private sector partners, including IBM Canada, SGI (Silicon Graphics Inc) Canada and Bell Canada. The GTA is one of the largest centres in North America for television and film production, as well as publishing and sound recording providing much of the technical infrastructure and core skills that are required to supply the growing new media sector. Recent studies of this sector in the GTA suggest that 400 content creation new media firms exist in the GTA, employing approximately 4,000 to 8,000 workers (Mills and Brail 2002).

Another key sector is software, where 410 companies employ 13,300 people. Sub-sectors include companies focused on personal software, enterprise software and industry specific software. The yearly Branham300 rankings profile the information-technology (IT) sector in Canada and rank the top 100 independent Canadian software developers

and the top 25 software and services multinationals in Canada. Of the top 100 firms in Canada, 38 are located in the GTA, accounting for $1.6B of the $3.4B in 1998 revenues generated by the top 100 firms. World class companies such as Microsoft Canada, Geac and Algorithmics have their headquarters and significant operations in the Greater Toronto Area. Smaller innovative firms, such as Janna Systems, have demonstrated their capacity to bring world leading technology to market in a relatively short-time frame and capture sufficient market share from their larger US competitors to become takeover targets. The recent buyout of Janna by Seibel Systems confirms this trend.

While less noticed than the Ottawa cluster, 245 telecommunications equipment companies employ 15,200 people in the GTA. Sub-sectors include companies concentrating on public networks, enterprise networks and components. Worldwide companies such as Nortel Networks, Motorola and Lucent have their Canadian headquarters and significant operations in the Greater Toronto Area. Nortel Networks, North America's 2nd largest communications equipment company, has its global headquarters in the GTA. Motorola Canada has global mandates for key access and wireless products. Lucent Canada operates research facilities that develop globally marketed enterprise network and wireless equipment.

Another industry segment where the GTA demonstrates considerable strength is in semiconductors with 70 semiconductors companies employing 4,400 people. Sub-sectors include companies focused on printed circuit boards (PCBs) and integrated circuits (ICs). Multinationals such as ATI Technologies, Genesis Microchip and Gennum have their corporate headquarters in the Greater Toronto Area. ATI is the world's largest supplier of 3D graphics and multimedia technology. Genesis Microchip designs ICs that perform the complex task of processing digital video and graphics for flat-panel displays and digital projection systems. Gennum designs and manufactures signal processing ICs for the hearing instrument industry, as well as, signal distribution and processing components for the video and broadcast television markets.

3.2 ICT Cluster in Ottawa

As noted above, the dynamic and rapidly expanding ICT cluster in the Ottawa area is dominated by three well-established segments or sub sectors – telecommunications equipment, microelectronics, and software – as well as an emerging photonics cluster. According to estimates by the Ottawa Economic Development Corporation, 1,100 firms currently comprise the high technology sector in Ottawa. The telecommunications segment is the oldest and most established in the region, owing its origins both to the local presence of the National Research Council's laboratories and the Communications Research Centre, as well as the fateful decision by Western Electric to sell its holdings in Northern Electric in 1956, following an unfavourable legal decision in a US antitrust case. In the same year, Computing Devices of Canada (the first of more than 100 high tech spin-offs from the NRC) decided to build a research facility in Bells Corners, followed two years later by Northern Electric's purchase of 75 acres of land from the National Capital Commission for its Bell Northern Research Laboratories. These key events paved the way for the emergence of a strong private sector research capacity in the future Kanata, now part of Ottawa.

What differentiates the Ottawa cluster from other comparable centres in North America is its strong concentration on R&D activities, operating as it does near the high end of the technology value chain. Ninety per cent of Canada's R&D in industrial telecommunications is conducted in the region, drawing upon the region's strong supply of engineers, software developers and other technical skills, as well as the presence of the key government laboratories mentioned above. Nortel alone accounts for almost 20% of all industrial R&D expenditures in Canada and hires one third of all Masters and Ph.D. graduates in electrical engineering and computer science from Canadian universities. A large share of this activity is concentrated in Ottawa. The government labs, often collaborating with local firms, have produced many key innovations in the field that have been successfully commercialized. In the geography of cluster location, the presence of such a strong local pool of talent is one of Ottawa's greatest cluster assets.

The region is home to most of Canada's leading telecommunications equipment manufacturers, Nortel Networks, the former Newbridge Networks (now part of Alcatel) and Mitel (recently broken up into Mitel (linked to March Networks) and Zarlink Semiconductor.

The strength of the cluster's key anchor firms, combined with its strong local pool of talent and its extremely high growth rate, are attracting the attention of multinational firms and venture capitalists from Canada and the US. Multinational firms like Cisco and Nokia view the Ottawa cluster as an attractive location because of its homegrown success. Both firms expanded their presence in the region in the late 1990s. In particular, the purchase by Cisco of Skystone Systems for $89 million in 1997 was widely seen as a defining moment in the growth and development of the region's cluster for the way it put Ottawa on the map for the US industry and the impact that it had on reshaping the region's own business culture and sense of entrepreneurship. Since that takeover, more that 20 Ottawa area high technology firms – including Extreme Packet Devices ($600 million), Innovative Fibres (($260 million) and Cadabra Design ($190 million) – have been sold to multinationals (*Ottawa Citizen*, Sept. 25, 2000).

The telecommunications equipment cluster is comprised of more than 100 firms employing roughly half of the area's high tech workforce and covering a wide range of activities from the assembly of basic telephone hand sets to highly sophisticated digital switches. This segment includes those firms engaged in or linked to the production of networking equipment, transmission systems, satellite/microwave equipment, and communication interface devices. The growth share matrix analysis conducted by ICF Consulting in its cluster study showed that over the ten years from 1988 to 1998, the Ottawa telecommunications cluster grew faster than any of its competitors in North America, and that it ranked third in employment concentration after the Raleigh-Durham and San Jose clusters (ICF Consulting, 2000b, 3-12).

The second key segment in the Ottawa region is microelectronics. It is a highly diversified segment that includes component design, some manufacturing capability, as

well computer hardware design and manufacturing and applications for defence and private industry. Over 75 % of employment in the semiconductor segment is in firms that have their headquarters in the region. One such firm, Cadence Design, has recently chosen to expand its operations in the region.

The vitality of the Ottawa area microelectronics cluster was bolstered by a federal initiative, the Microelectronics and Systems Development Program, launched in 1989 as a five year, $60 million undertaking to support the development of advanced microelectronics and information technology systems. According to one interviewee, four Ottawa area companies, whose sales at the time totaled $50-60 million a year, received funds to invest in R&D. Ten years later the companies, which include Tundra Semiconductor and Mosaid, have total sales of $490 million. The activities of the segment are strongly supported by two current national initiatives. The Strategic Microelectronics Consortium created in the late 1980s in response to a key federal government policy initiative and headquartered in Ottawa, is a national industry association whose mandate is the articulation of a national strategy for the segment. The Canadian Microelectronics Corporation is an organization that facilitates strategic alliances between the microelectronics industry and Canadian universities and educational institutions. The CMC, based in Kingston, works to promote cutting-edge research and contribute to the supply of well-trained graduates. Numerous firms specialize in 'fab-less' production – they do the designs in Ontario and ship them out to facilities in places like Taiwan or Singapore to have the devices built. Many view the absence of a fabrication facility as an advantage for the local cluster because it means that the local/regional economy is not tied down to a massive and vulnerable (to technological and market change) investment (on the order of $US 2-4 billion).

The third key segment is in software and communications services. The firms in this segment supply a range of packaged software, software and information technology services, as well as telecommunications services to domestic and international markets. Many of the software firms located in Ottawa are among the largest in Canada, including Corel which produces packaged business and graphics software for the PC market, and

Cognos, which specializes in business intelligence software. The region is also populated by hundreds of smaller software firms. There are close links between the software activities of this segment and firms in the telecommunications segment, such as Nortel Networks and Alcatel.

The other component of this segment is IT consulting firms which provide a wide array of services that include software engineering, information security, project support services, network design, computer communications network design and data processing. The more than 100 firms that comprise this part of the segment include major players such as EDS Systemhouse, originally an Ottawa-bred firm. The ICF Consulting Growth Share matrix analysis for this segment indicated that its employment concentration ranks fourth on the continent, although its rate of growth has been slower than some of the other leading software producing regions in North America (ICF Consulting, 2000b, 3-19).

The other segment worthy of note in Ottawa is the emerging photonics cluster which was spurred on by the explosive growth of its key anchor firm, JDS Uniphase, originally JDS Fitel in the late 1990s. This cluster specializes in the production of technologies related to the commercial application of light, including fibre optics, lasers, opto-electronics, images and optical processing of information. JDS Fitel, originally founded in 1981 by three engineers from Bell Northern's Research labs, who thought they could develop their commercial interest in opto-electronics outside of BNR, set the pace for the dynamic expansion of the sector. Through a series of fifteen mergers and acquisitions of key competitors in the US, principally Uniphase, E-Tek and SDL, JDS established itself as the North American 'gorilla' in the supply of fibre optic components to the major telecommunications equipment providers. However, given its overwhelming dependence on customers in the telecom sector, JDS was particularly hard hit by the downturn in 2001. The dramatic fall in its revenues forced the company to cut its workforce by 19,000 or nearly two thirds, in Ottawa and San Jose. Despite this cutback, the company has continued to target the development of new technologies, with two key acquisitions in the first five months of 2002. The most recent target, Scion Photonics, specializes in

advanced waveguide technology that could be instrumental in the next generation of fibre-optic components and modules. One consequence of the job cuts and acquisitions has been to tilt the balance of the companies operations towards its California base, although the proportion of the workforce cuts in Ottawa has been less dramatic than in other parts of the company (Tuck, 2002).

Its rapid success, as well as the strong research base in the region, is both spurring the growth of a host of locally spawned companies, as well as attracting researchers from other parts of the province to relocate to Ottawa to participate in its expansion. The local industry leaders have recently formed the Ottawa Photonics Cluster (with the support of Photonics Research Ontario, one of the provincial Centres of Excellence) to promote the interests of the segment. After considerable lobbying effort, the National Research Council was successful in obtaining federal funding for the creation of the new Photonics Fabrication Facility in Ottawa to be associated with the NRC's Institute for Microstructural Sciences. It will assist in growing the photonics industry by providing development and prototyping facilities, training personnel and providing an R&D resource for firms and university researchers. More recently members of the Ottawa area photonics research community announced the formation of OPRA (Ottawa Photonics Research Alliance) that will pool the efforts of four academic institutions and two government laboratories in the national capital region to pursue further research in photonics systems, devices, materials and more basic scientific research. It includes more than 120 active researchers and it estimates that there is currently more than $100 million invested in the public research infrastructure for photonics in Ottawa (Research Money, 2002).

It is clear that the size, rapid pace of growth and reputation for innovation and industry leadership are attracting considerable attention from all over the continent. American investors such as Greylock Capital and Worldview Technology Partners are rivalling Canadian counterparts Celtic House and GTI Group in investing in the Ottawa photonics cluster. In 2001, 52 % of the $900 million in venture capital investments that flowed to the Ottawa region were made in photonics firms. Major investments in recent years have

included California-based Mohr Davidow Ventures' US $12 million stake in Quake Technologies. In an interview in the *Ottawa Business Journal*, Mohr Davidow Ventures partner, Rob Chaplinsky was quoted as saying,

> "It used to be Ottawa entrepreneurs would look down to Silicon Valley and try to replicate deals that already existed. They had a myopic view of the whole entrepreneurial world. If you were in Silicon Valley, rest assured you're seeing all the deals. If you were in Ottawa, you're only seeing a narrow focus of the deals. However, with this new optical transition emerging, there's only five epicentres in North America that are the hubs of the world - Ottawa, Silicon Valley, Dallas, North Carolina and New Jersey. With Ottawa pioneering the optical wave with Nortel and JDS Uniphase, all of a sudden it's coming in with a competitive advantage. The tables have turned. You have to know what's going on in Ottawa if you want to know what's going on in the deals." (Ottawa Business Journal, December 4, 2000)

3.3 ICT Cluster in Canada's Technology Triangle

While considerably smaller and less prominent than the ICT clusters in the GTA and Ottawa, the region that comprises Canada's Technology Triangle has been attracting much attention in the past few years. Communitech currently estimates that there are 400 high technology firms in the Kitchener/Waterloo area, employing 16,000 workers. Starting from a smaller base, the key firms located in the region have passed a critical milestone where several have emerged as the anchor firms for the software and communications segments. Research in Motion (RIM) one of the run away success stories of the region now employs 2000 people versus just a few hundred five years ago and its annual revenues have grown to $294.1 million from $8.7 million in 1997. It recently opened a new 120,000-square-foot assembly plant, four times the size of its former factory. It has rapidly emerged as a leading firm in the region and established a leading position in its segment of the North American market. In the most recent quarter, however, its revenues have eroded as it faces new competitors and questions have been raised about its ability to maintain its dominant position (Simon, 2002).

Despite this recent downturn, the company remains representative of the considerable growth that has occurred throughout the sector in the Waterloo region. It is beginning to build upon itself to the point where the existing firms are contributing to generating

growth in new firms. The overall size of the ICT sector is still small compared to other sectors within the community, such as the automotive or financial sectors, but three years from now it will be different. There is a clear expectation on the part of community leaders and industry representatives that Kitchener/Waterloo and the rest of the Technology Triangle will see more of the kind of development that has occurred in the Ottawa/Carleton cluster.

Overall, the CTT region has a well-diversified economic structure, characterized by a higher than average weighting in manufacturing. Twenty-eight per cent of total employees in the Kitchener area work in the manufacturing sector, well above the share of eighteen per cent for the province as a whole. Within the manufacturing sector, the two leading sub sectors are machinery and equipment and automotive assembly and parts, followed closely by the information and communications technology cluster. The computer and electronic product manufacturing industry has increased employment since the early 1990s. Over the latter half of the decade, it grew at twice the national rate. A recent analysis of the region's employment concentration using a location quotient methodology similar to that of ICF Consulting revealed that the region has the second highest location quotient among major urban areas in Canada for the computer and electronic product manufacturing industry. The concentration of employment in the broadcast and wireless communication equipment segment is particular strong.

In the eyes of most participants in the cluster, its strength and dynamism is due primarily to the critical role played by the University of Waterloo and the other key educational institutions in the region. The large number of computer science, general math, engineering and technology-related graduates produced by the University of Waterloo, Wilfred Laurier University and Conestoga College have transformed the region into a breeding ground for electronics manufacturing, software development and other activities crucial to the ICT sector. The crucial nature of the linkage between the post-secondary educational institutions and the anchor firms in the region, such as Research in Motion, was clearly spelled out in a talk by Michael Lazaridis, the President of RIM, to a Canadian Urban Institute Conference on Competitive City Regions in the Knowledge

Economy. According to Lazaridis, the most important resource in the knowledge-based economy is people, not technology, and education is the key to creating new supplies of this resource. The best place to locate a knowledge-intensive company, such as RIM, is next to a good university, such as Waterloo. Making the most of this resource requires that firms must take care of the people involved by offering them rewarding careers tot convince them to remain in the local community, making the community a safe and interesting place to live, and ensuring that the strengths of the community are well promoted (Lazaridis, 2000, 10).

Representatives of the CTT cluster point to its recent success in luring key graduates back to the community and in attracting the kind of attention that Cisco's takeover of Skystone Systems generated for the Ottawa cluster. Members of the cluster pointed to a key article published in *Canadian Business*, "High Tech's Homecoming Kings" as indicative of this trend. One case in point is myCIO.com, a Silicon Valley Internet start-up that is also a subsidiary of Network Associates, the eighth largest software firm. They recently decided to establish an R&D Lab in Waterloo led by a former University of Waterloo graduate. The decision to open the lab in Waterloo instead of Silicon Valley was driven by the desire to be closer to the strong labour pool found in the region. Increasingly, larger companies and venture capitalists from other parts of Canada and the US are investing in the Waterloo region and expanding their operations because of the attractiveness of the region's talent pool and the growing strength of the local base of ICT companies.

3.4 Linkages with Universities and Colleges

3.4.1 Research Infrastructure

One of the great strengths of the ICT cluster in Ontario is the depth of support that it derives from a comprehensive set of federal and provincial programs and institutions. This mesh of programs both ensures a solid research base within the post-secondary education sector, encourages and facilitates increasing linkages between the university (and college) research systems and the private sector, and supports private sector research primarily through the tax system. The first of these factors was widely seen by most of the cluster member interviewed as critical to the ongoing health and competitiveness of

the sector. The universities are seen 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. Industry representatives feel that specific programs such as the coop programs at Waterloo and others have been effective at moving students into industry settings.

The strength of the university research infrastructure is important for the clusters in two respects – one as a key source of new ideas and future products for domestic companies, both in terms of spin-offs and knowledge transfer; and second, as a factor contributing to the reputation of the key sector clusters, in Ottawa-Carleton, the GTA and Kitchener/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) was cited several times in the interviews, but Alcatel, Lucent and others were also referred to. The growing presence of these large multinational players, especially in the optical networking and telecom segments was 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 its research infrastructure. In the case of the Ottawa-Carleton cluster, this is not seen just as a product of the university research base, but also the strong presence of the National Research Council's facilities in the capital region, its contribution to existing firms and its growing record at spinning off its own startups.

The interviews also indicated that 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. Several mentioned 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 (Section 4 provides a more detailed discussion of these programs. 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 Labs program at the Universities of Toronto and Waterloo. This represented a major initiative for Bell Canada that has traditionally relied on Nortel and the former Bell Northern Research Laboratories as the primary source of their corporate research base.

Several of representatives of the business and industry association sectors cited the strong entrepreneurial culture at the University of Waterloo and the encouragement which faculty receive to develop and exploit their innovations as a critical factor in the growth of the ICT cluster in Canada's Technology Triangle. Interviewees in the Kitchener/Waterloo area agreed 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. One interviewee explained that the region is reaping the benefits of investments in the post-secondary research and education base that were made thirty to forty years ago.

3.4.2 Provision of Highly Skilled Personnel

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. In 1995, universities in the province granted almost 2,400 computer science and electrical engineering degrees. Enrolment in disciplines related to the ICT sector has been steadily increasing. First year enrolment in computer science, electrical and computer engineering and related engineering fields rose to 6,083 in 1997. The vitality of the post-secondary education sector in expanding this stream of graduates is essential to the continued growth of the ICT clusters. A number of new federal and provincial initiatives address this issue directly. Foremost among them is the Access to Opportunities Program designed to increase the number of students enrolled in computer science and related engineering programs by 17,000 students a year. To accomplish this the province committed over $150 million in new funding over three years by providing an annual grant of $5,000 per engineering student, $3,500 per computer science student and $2,000

per college student. Ontario will also match private sector contributions towards startup costs, up to $9,800 per student. Virtually all 17 universities and 25 colleges have submitted proposals under this program. The Council of Ontario Universities noted that the universities have exceeded this target and the program has resulted in the creation of 23,000 new places. There may, however, be an issue of how fast they can absorb the funds or find the staff to mount courses to train the new students.

However, a number of interviewees pointed to concerns about the capacity of the universities to continue to provide the steady stream of research and potential innovations that feed the pipeline for the ICT sector. This concern is reinforced in a recent brief from the Council of Ontario Universities to the Ontario Legislature. Ontario universities have fallen behind those in other provinces in their share of federal research support: from 45% in the mid-1980s to 37.8% in 1996-97. A related problem faced by the universities is attracting and retaining sufficiently high-level faculty to train the incoming flow of students. The COU estimates that the current student/faculty ratio is the highest in Canada and 20% higher than the average for the other nine provinces. Some computer science departments are facing possible enrolment caps to deal with these kinds of problems. Furthermore, 29% of university faculty is between the ages 55 and 64, meaning the system faces massive retirements just as enrolment demand peaks.

This concern is borne out by another review of recent statistics on university funding provided by the Council of Ontario Universities. Ontario ranks ninth out of ten provinces in provincial operating grants per FTE enrolment. COU anticipates that 11,000 new and replacement hires are needed over the course of this decade to meet coming retirements, anticipated increases in demand and improve student/faculty ratios. And they must undertake this effort just as they are facing increasing competition from industry and the US to recruit and retain high-level faculty. US states increased their support for higher education by an average of 28 % between 1995-96 and 1999-2000 (with California and Florida as high as 50 and 52 % respectively), while Ontario's support fell by 8 % in the same period. The differences in funding levels make it much more difficult for Ontario universities to recruit and retain top quality faculty, expand their research capabilities and maintain and renew their physical infrastructure.

4.0 Institutions and Initiatives Supporting the Ontario ICT Clusters

In addition to the strong research base found in Ontario's universities, the ICT clusters also benefit from the depth of the research base in the private sector research laboratories and institutes and the high level of institutional support provided through a range of federal and provincial policies and institutions. Ontario, which produces 40 per cent of Canada's GDP, is home to 45 per cent of its ICT employees and accounts for 48 per cent of national R&D spending. Several recent reports on different aspects of the province's industrial base, single out the broad level of support available for the performance of research and development in the province as a key competitive advantage that it enjoys with respect to competing jurisdictions in North America.

The report for the Greater Toronto Marketing Alliance (GTMA) analyzed the tax benefits that research performers derive from the combination of the federal government's Scientific Research and Experimental Development Tax Credit with the Province of Ontario's R&D Super Allowance. The combined tax incentives provided by these two programs afford greater incentives for R&D spending than any of the leading industrial countries. The cost to the Ontario treasury of tax support through the R&D Super Allowance is currently estimated at $100 million per annum. Ontario provides additional tax incentives to stimulate industry funding of university research, as well as ICT related tax incentives, including the Ontario Innovation Tax Credit and the New Technology Tax incentive. The other report, completed for the GTMA and Smart Toronto, by Deloitte Touche in 1999 noted that ICT firms in Ontario spent $1.7 billion on R&D in 1997, while R&D spending at Ontario universities amounted to another $1.1 billion.

In addition to the tax advantages provided by both levels of government, a number of direct spending programs provide strong assistance for research spending in general and the ICT sector in particular. The federal government is a key sponsor of research spending in the natural sciences and engineering. The latest estimates from Statistics Canada indicate that total federal government R&D expenditures in Ontario on the natural sciences, including engineering, in 1998 amounted to $735 million. However, the federal government spent an additional $727 million in the National Capital Region,

primarily in federal government laboratories and agencies (the bulk of which are located in Ontario). The comparable figure for R&D spending by the provincial government was $175 million (Statistics Canada, Cat. No. 88F0006XIB, No. 1, 2001).

4.1 Federal Institutions and Programs

CANARIE: CANARIE was created as an innovative way for the federal government, research community and private sector to collaborate in stimulating the development of the information highway in Canada. Its programs include: theTechnology and Applications Development Program (TAD), created to stimulate development and early commercialization of new networking technologies and applications; and the Advanced Network Application (ANA), created to stimulate innovative applications that use CANARIE's advanced research network. CANARIE works with more than 120 university and industrial partners and has helped fund more than $600 million in research projects related to the next generation Internet. It has also helped generate $125 million in matching R&D funding from the province of Ontario (Domicity 2002).

Communications Research Centre (CRC): is the federal government's leading communications research facility, responsible for conducting R&D to develop the Canadian communications infrastructure and support Canadian telecommunications firms in their efforts to remain globally competitive.

National Research Council (NRC): The National Research Council with a total workforce of more than 3,000 has 22 research institutes from coast to coast, one of which is the Institute for Information Technology (IIT) located in Ottawa and Atlantic Canada. IIT's mission is to assist industry through collaborative R&D programs in areas such as interactive information access, multimedia, information organization, optical communications, wireless communications and personal communications systems. Collaborations can be one to one with a company or multi-party with several organizations pooling resources to share costs and risks. The Institute also has close working relationships with universities through visiting graduate students and making

specialized facilities available to university researchers. Another NRC institute, the Institute for Microstructural Sciences, also located in Ottawa, develops the base for enabling technologies necessary for future hardware developments in information processing, transmission, acquisition and display. IMS has research programs in optical communications, wireless communications, multimedia components and other special applications.

Since 1995, the NRC has also operated the Regional Innovation Centre in Ottawa to promote innovation and economic growth in the Ottawa Region. The Centre links NRC resources with industry, academia and government to build a regional system of innovation and entrepreneurship in Ottawa. The Centre has helped develop innovative programs that stimulate job creation and economic growth such as Vitesse that trains young scientists to meet the needs of Ottawa's high-tech sector and the Regional Innovation Forum that brings together industry leaders to address challenges to growth. The Centre has helped many scientists at NRC to launch spin-off companies based on the results of their research. An online resource – SpinoffCentre.com – provides the information and tools that entrepreneurs need in the early stages of company development. The Regional Innovation Centre also works closely with OCRI, the Ottawa Centre for Research and Innovation, on a number of initiatives described in Section 5 below. Many of the programs at the Centre have become models for NRC to implement across Canada. NRC is also responsible for the Industrial Research Assistance Program (IRAP) which helps small and medium sized Canadian firms create and adopt innovative technologies that yield new products, create high quality jobs and make industry more competitive through direct technical assistance and cost shared financing of innovative technical projects.

Natural Sciences and Engineering Research Council (NSERC): NSERC is the national instrument for making strategic investments in Canada's science and technology capability. NSERC supports university research through research grants and project research through partnerships of universities with industry, as well as advanced training

of highly qualified people. The latest figures available from NSERC indicate that its spending on ICT-related research in Ontario amounted to $13.5 million in 1998-99.

Canada Foundation for Innovation (CFI): The CFI was established in 1997 by the federal government as a five year effort to strengthen Canadian capability for research by ensuring that the state of the research infrastructure in the countries universities and hospitals was on a par with the best available internationally. Up to the time of the federal budget in February, 2000 the CFI had awarded $450 million out of a total allocation of $1 billion to post-secondary institutions, research hospitals and not-for-profit organizations to modernize their laboratories, equipment and technologies. In the February budget, the Minister of Finance increased the allocation for this initiative to $1.9 million and extended the life of the program to 2005.

Networks of Centres of Excellence (NCE): Researchers in Ontario universities, industry and government working within the ICT sector are involved in a number of national research networks financed under the Networks of Centres of Excellence, as follows: including the Canadian Institute for Photonic Innovation, the Canadian Institute for Telecommunications Research, and Micronet (Microelectronic Devices, Circuits and Systems).

Canada Research Chairs: This program was originally announced in the Throne Speech and then elaborated in the February, 2000 budget. It provides $900 million over five years to establish and sustain 2000 Canada Research Chairs by 2004-05. The funds are to be allocated among Canada's universities based on a formula derived from their respective shares of grants awarded by the three research granting councils. About half of the positions will be allocated to attract established world-class researchers and the other half will support researchers who have demonstrated the potential to achieve world-class standing in their fields. Many of these chairs will be created in Ontario universities in the ICT disciplines and will enhance the research base in that sector.

Technology Partnerships Canada (TPC): The aim of this program is to encourage the development and commercialization of products and technologies. Target technologies

are biotechnology, information technologies, advanced manufacturing and processing and advanced materials. A number of TPC grants have been targeted at leading firms in Ontario's ICT clusters. In July, 1999, the Minister of Industry announced a $33 million grant to the IBM software lab in that will help position Canada as a location of choice for electronic commerce research and development. The TPC investment in IBM *Net.Commerce*, being developed at IBM Canada's Software Solutions Laboratory in Toronto is expected to advance Canada's position in the competitive e-commerce sector. In April, 2000, the Minister of Industry also announced a $33.9-million investment to enable Research In Motion (RIM) Limited to develop innovative technologies to be incorporated into future communications devices that will operate on next-generation wireless networks. TPC's contribution was part of a $113-million research and development project, which will help RIM accelerate its R&D efforts to provide new and advanced technologies for the rapidly expanding wireless world.

4.2 Ontario Institutions and Programs

In addition to the strong foundation for research support provided by the federal government, Ontario also provides considerable support to the ICT sector through its current mix of science and technology programs. Three successive administrations in the province over the past decade and a half have recognized the growing importance of research and development in general, and the ICT sector in particular, for the economic well-being and future growth of the province (Wolfe, 1999). As a consequence, they have established a series of programs that provide additional support for the province's research infrastructure. A recent inventory of Ontario government S&T programs detailed a listing of 39 different programs spread across the various provincial ministries that support the performance of research and development in a wide range of academic fields.

Ontario Centres of Excellence: The oldest of the province's R&D programs currently are the Centres of Excellence. Originally established in 1987 as part of the Premier's Technology Fund, the four current centres provide a strong base of funding designed to make new connections between the needs of Ontario industry and the best university

research. In 1999-2000, the Centres of Excellence funded work by more than 2,000 researchers involved with industry related projects in Ontario universities and had over 18,000 companies and individuals participating in the OCE knowledge network. In that year over 600 highly qualified personnel were produced by the initiative and two thirds of them went to work in Canadian industry (50 per cent in Ontario).

Two of the Centres in particular have a research mission directly relevant to the needs of the ICT sector. One of these is Communications and Information Technology Ontario (CITO) whose mandate extends across three of the key sub sectors of the ICT sector: communications, information technology and digital media. CITO's purpose is to strengthen the global performance of Ontario's ICT industries by acting as a catalyst for the process of innovation - helping nurture ideas into commercially relevant products and processes. CITO's programs support ideas from the advanced research stage through applied research and onto commercialization. In 1998-99, CITO contributed $8.6 million in support of 106 projects at Ontario's universities and colleges and their research partners committed an additional $2.5 million in support of specific projects.

The other Centre of Excellence with a mandate of direct relevance to the ICT sector is Photonics Research Ontario. PRO supports programs in three areas – basic, applied and collaborative – to catalyze and enable Ontario's industrial research and development in photonics. Its research program is grouped into a number of evolving themes that include the following of relevance to the ICT sector: light-matter interactions; high-intensity laser source development; nano-optics and materials; and optical communications, processing and sensors. In addition, it supports a number of themes in the biophotonics area. PRO supported research has played a critical role in the growth and development of the Ottawa Photonics Cluster, identified as one of the region's top economic growth generators. This cluster now consists of more than 60 companies employing more than 20,000 people.

Ontario Research and Development Challenge Fund (ORDCF): Another key program initiative is the Ontario R&D Challenge Fund that was created to promote research excellence and partnerships between business and research institutions. The

main priority of the ORDCF is to attract and keep top scientists and researchers in Ontario. To qualify for funding, proposals must be supported by a private/public sector partnership agreement and a minimum of one third private sector financing. Since its inception in 1997, the Challenge Fund has committed $317 million to 77 research projects. Investments by the Fund and its institutional and private sector partners now total more than $740 million. In the budget for fiscal year 2000-01, the provincial government increased the amount of funding available for the Challenge Fund by $50 million. Total investment by the Challenge Fund will be $500 million over ten years. Other contributions by institutional and private sector partners will direct a total of $960 to these projects.

Ontario Innovation Trust: As well as increasing the Challenge Fund, the province has allocated an additional $500 million to the Ontario Innovation Trust, to help institutions establish state-of -the-art research facilities by matching funds made available from the Canada Foundation for Innovation. The 2000 provincial budget increased the OIT's original $250 million endowment by an additional $500 million for a total investment of $750 million. To date the OIT has committed $381 million to 296 research infrastructure projects across Ontario.

The **Ontario Research Performance Fund** also provides $30 million annually to colleges, universities and research institutes to cover the overhead costs of doing research. In addition, The **Premier's Research Excellence Awards** is investing $75 million over 10 years to help world-class researchers at universities, colleges, hospitals and research institutes attract talented people to their research teams. The funding for ***PREA*** was doubled to $10 million annually.

Connect Ontario: CONNECT ONTARIO is a SuperBuild Growth Fund initiative to develop a network of 50 smart communities across Ontario by 2005. Ontario will invest up to $50 million in broad-based partnership initiatives that create a high tech network of 50 connected smart communities across Ontario. A further provincial investment of $32 million will make land-related (geospatial) information available to and usable by

connected smart communities. This component of Connect Ontario, called GeoSmart, will integrate land-related data across the province and will facilitate geospatial business applications required by most communities and many large and small businesses.

Interactive Digital Media Fund: The Interactive Digital Media Growth Fund is a five-year, $10 million initiative announced in the 1998 Ontario Budget. Its purpose is to invest in strategic initiatives and activities that will spur the growth of, and increase the number of jobs in small IDM firms and the overall IDM industry in Ontario. Projects supported by the Fund must have commitments of resources from business partners and the support and involvement of small IDM firms, and must demonstrate they can deliver industry-wide benefits. To date, the IDM Fund has supported six projects.

Ontario Research and Innovation Optical Network (ORION): A $57 million investment by the province over five years, ORION will be a high speed, state-of-the-art network to be used by researchers, educators and scientists to conduct advanced research and to develop and test new technologies. It will provide a 'next generation optical network' that will allow researchers from different institutions across Ontario and from the public and private sectors to work together and with colleagues around the world on collaborative research and development projects and new research tools and technologies. It will serve as a showcase for the best in new network applications and technologies.

Telecommunications Access Partnerships (TAP): The government introduced the Telecommunications Access Partnerships initiative in its May 1996 Budget, to support broad-based partnership projects to speed development of the information highway and improve access to it in all regions of Ontario. TAP was very successful in supporting a broad range of projects from most regions of the province. The government has discontinued funding under the program, but TAP projects approved up to and including Round 8 were funded over fiscal years 2000/01 and 2001/02.

Strategic Skills Investment: Strategic Skills Investment is a $130 million program. The program supports the best projects that accelerate the introduction of forward-looking

skills development collaborations between business and training providers. Up to the end of 2000, 34 new training projects had been selected and $156 million leveraged from project partners in business and education.

5.0 Institutions of Collaboration, Social Capital and Learning

Recent case studies of local, social learning exercises in Ontario's ICT clusters (Toronto, Waterloo, and Ottawa) provide some evidence that the strength of the clusters in these communities draws not just upon their corporate and research foundations, but also a highly networked form of social capital. In two of the clusters, Ottawa and Toronto, recent analytical exercises offer insights into the factors that contribute to, or impede, the success of such undertakings; while the Waterloo case offers a different perspective on the benefits of effective mobilization at the community level. In both Ottawa and Toronto, major cluster studies were launched in partnership with the Province of Ontario's Office of Urban Economic Development to chart the competitiveness of the leading clusters in the local economy and their prospects for growth (ICF Consulting, 2000a; ICF Consulting et al., 2000b). In both cases, the method of analysis used was similar; however, the broader process in which the visioning or foresight exercise was grounded differed dramatically.

In the case of Toronto, the study was done by a US consulting firm in partnership with local consultants and under the direction of the Economic Development and Planning Offices of the City of Toronto. There was little in the way of the broader participatory mechanisms to engage key members of the community in the effort, nor did it involve the committed, creative and collaborative leadership described above as essential to the success of such exercises. In part, this approach reflects the absence of a strong cohesive leadership in Toronto committed to the economic success of the entire city-region, as well as the lack of key 'civic entrepreneurs' in either the economic or political sphere. It also reflects the fact noted at the outset of this paper that the ICT and other high technology clusters form a much less substantial proportion of the local economy than they do in the other two instances. It may also be a function of the fact that a much greater proportion of the lead firms in the ICT cluster in Toronto are Canadian branches

of US multinationals and thus the strength and dynamism of the local cluster is much less integral to their long-term competitiveness than in the case of the two smaller clusters in Ottawa and Waterloo, both of which have a much larger proportion of indigenous firms in key leadership roles. This, in turn, is related to the fact that, given Toronto's stature as the financial and industrial centre of the national economy, many of its key business leaders focus their attention at the national or continental scale, rather than the local or regional one. Another contributing factor may arise from the difficulties of coordinating interests across the broad range of economic sectors represented in the local economy and the spatial scale of the city-region. However, the inability to mobilize creative and collaborative business leaders from the economic sphere and the failure of civic entrepreneurs to emerge from other areas of community life has undermined the ability of the region to take full advantage of its foresight or 'visioning' exercise.

The competitive study of Ottawa differed dramatically from the outset, but this difference reflects the different social makeup of the clusters in the region. A key factor that differentiates the Ottawa clusters from those in Toronto and other regions in North America is the strength of the local 'institutions of collaboration' and the high degree of social capital that they generate (Wolfe, 2002). The linchpin of these institutions is OCRI, the Ottawa Centre for Research and Innovation, a not-for-profit organization dedicated to helping the city's technology community shape its economic future. Founded in 1983 as a collaborative effort among partners from industry, the regional municipality, the local institutions of higher education and federal laboratories, OCRI currently has about 700 members and a budget of $4.5 million. OCRI recently took over the economic development role of the municipal government that provides it with $2 million annually to fund this aspect of its activities. OCRI sponsors a wide range of corporate programs that involve up to 120 events annually and afford the members of the Ottawa area clusters with virtually unlimited networking opportunities. OCRI is also involved in a dense network of partnerships with many of the federal and provincial organizations discussed above aimed at strengthening the region's innovation capabilities. These partnerships include provincial Centres of Excellence, CITO, MMO and PRO, working relationships

with the Ottawa-Carleton Manufacturers Network and the Ottawa Photonics Cluster, and joint ventures with the NRC's Regional Innovation Centre and Vitesse program.

OCRI was also closely involved with the Economic Generators Initiative in 1999-2000 that was launched under the auspices of The Ottawa Partnership, a group of public and private leaders committed to advancing the local economy. The mandate of TOP "is to provide leadership and advice at a strategic level, on action required to improve and growth Ottawa's economy" (ICF Consulting et al., 2000a, p. i). TOP was formed by an agreement between the City's key economic development agencies on the need for a board to coordinate and align the various activities underway in the region. The membership of TOP includes the chairs of the region's business and economic development agencies, and representatives of its municipal council, the higher education sector, and the business community at large. The TOP leadership decided to undertake a detailed study of the region's 'economic generators' as one of its first priorities and to use the study to prepare a strategic plan for the further development of the key engines driving the local economy. The analytical exercise differed from that undertaken in Toronto in the strong level of interest and participation evidenced by the local business community. One of the consultants involved in the study commented in a local paper that the level of community involvement was higher than in any comparable study he had done in the US or Canada.

More than three hundred individuals participated in the work of the various cluster groups that formed part of the visioning exercise and helped formulate a total of thirty three specific goals intended to promote the growth of the seven key clusters identified as the growth generators for the regional economy. The exercise also produced a higher-order set of flagship initiatives designed to work across the individual clusters to benefit the regional economy as a whole. These included a branding and marketing campaign for the region; a Smart Growth initiative to align infrastructure planning more effectively with the needs of the leading clusters; the creation of 'technological listening posts' drawing upon the knowledge resources of the region – the National Research Council's local laboratories and the post-secondary institutions in the region – to identify future

technology scouts, strategic planners and research leaders from around the world, to disseminate information to the local clusters on developments in cutting edge research and development, competitive opportunities, and potential threats emerging in the form of new technological challenges; plans to wire the entire region with dark fibre and provide broadband access for all citizens in the region; and a reskilling program to broaden the pool of highly qualified labour available for local firms among others.

The high level of participation in the Economic Generators Initiative engendered great expectations in the region about the results that would follow from the presentation of the report in June 2000. Unfortunately, the report was issued just as the high tech sector in entered a serious downturn sparked by the severe cutback in capital spending in the global telecommunications industry. As noted above, two of Ottawa's leading clusters, the telecom equipment and photonics clusters were acutely impacted by the downturn. While the recession undermined much of the optimism that marked the regional economy when the report was released, The Ottawa Partnership, in cooperation with local economic development agencies and the municipal council, forged ahead with planning for many of the cluster and flagship initiatives outlined in the report. Ten of the thirty three cluster initiatives have achieved tangible results. New steps have been taken to strengthen the region's photonics and biotechnology clusters with the formation of the Ottawa Biotechnology Incubation Centre (OBIC) and the Ottawa Photonics Research Alliance (OPRA) respectively. Municipal leaders feel that substantial progress has also been made in advancing a number of the flagship initiatives, including the branding campaign, the Smart Growth effort, preliminary plans to provide broadband access throughout the city and the formation of StartingStartups (a venture capital company) and TalentWorks (a reskilling program). TOP leaders remain optimistic these measures are contributing to the region's future as the economic upturn gains strength and an update of the earlier cluster study is planned for the fall, 2002 (Chappell, 2001).

A third key technology community also affords an illustrative example of the benefits of increased associativeness at the community level. The regional government of Waterloo actually includes three separate municipalities who have been working more closely

together over the past decade and a half to support the transition in the region's economy from a traditional manufacturing and service (insurance) basis to the emerging high tech industries of software, wireless telecommunications and optics. The first initiative was launched in 1987 when the economic development agencies of the communities, who had previously been competing against each other for inward investment, agreed to form Canada's Technology Triangle (CTT) as a joint marketing initiative to capitalize on the region's traditional manufacturing base and its emerging high technology strengths. While the record of CTT has been somewhat mixed, its formation signified a growing reflexiveness on the part of the communities' leaders in terms of their awareness of the need to transcend traditional political and organization boundaries. The creation of CTT led a decade later to the creation of Canada's Technology Triangle Acceleration Network (CTTAN) as a new institution designed to help early-stage growth firms become investment-ready and to form a link between startup firms and equity investors. CTTAN is not a venture capital firm itself; rather, it is intended to provide an investment mediating and facilitating service. In the view of one recently concluded study of the region, "CTTAN represents an important landmark in regional institutional development because for the first time . . . private sector actors and government officials became directly involved in the process of partnership formation" (Leibovitz, 2000, p. 68). CTTAN was latter merged with Communitech and currently operates as its Business Accelerator Program.

Another significant indicator of the growing strength and vitality of the civic leadership in the regional economy came with the formation of its own industry association, Communitech, in June, 1997. Communitech is an industrial association founded by a number of leading companies in Kitchener Waterloo, including Open Text, Research in Motion, Descartes Systems, Mortis Kern Systems, and a number of others. Currently, Communitech has about 240 members, including a large number of service firms in the legal and accounting field. About half of its members are technology firms. Communitech was established because of Tom Jenkins, the CEO of Open Text. He argued that there was a good opportunity in Waterloo to build on the existing strengths of

the region, including its talented labour pool, excellent quality of life, strong research base and steady stream of technology coming out of the University of Waterloo. Though Jenkin's leadership, forty people were convinced to put up money to establish Communitech and retain a full-time president. His point was that success feeds on itself and a strong industry association would help support the further growth of the emerging clusters in the regional economy.

Communitech works in association with the economic development offices in the different communities that make up the regional cluster and in conjunction with the local companies that are gaining a larger profile. Its explicit purpose is to advance the needs of the technology-oriented firms in the region with respect to the different levels of government in the areas of training, marketing and export development and the provision of infrastructure. Communitech runs an array of programs similar to those sponsored by OCRI in Ottawa. It includes Peer to Peer groups, a mentoring program, advocacy activities on behalf of the high tech cluster, seminars and events and the Business Accelerator Program described above which has assisted over 120 entrepreneurs since early in 2000 and helped to raise $65 million in capital. As in the case of OCRI and TOP in Ottawa, the creation of Communitech in Waterloo symbolized an approach to regional governance that transcends traditional jurisdictional boundaries and attempts to establish new policy networks between the community and the provincial and national levels of government. The association has contributed to the creation of a 'buzz' about the technology potential of the region and attracted interest from as far afield as Silicon Valley.

6.0 Conclusion

The three case studies documented above draw the attention of both scholars and policy makers to the need for national institutions to provide the enabling, accommodative space within which particular regional social learning phenomena may arise. They demonstrate the capacity for local variability within both national and regional systems of innovation, based on the histories and inherited structures of each community and the actions of individuals and organizations within them. In this sense, then, we can understand the spatial construction of social learning dynamics, including those that socially 'produce'

community-led innovation strategies, as occurring through the interaction of national and subnational regulatory forces and the agency of individuals. One of the key insights of this analysis is the attention that it places on the role of key actors at the local level in promoting effective cluster development strategies within the framework of existing national and regional policies and research infrastructure. A key aspect of these local community development exercises involves the creation of social capital among the relevant groups and individuals. Building trust among economic actors in a local or regional economy is a difficult process that requires a constant dialogue between the relevant parties so that interests and perceptions can be better brought into alignment. As two of the above case studies suggest, talk and confidence are more likely to succeed when they occur in a setting that is geographically localized and that small, repeated low-cost experiments can generate interactive learning between parties in a shared environment. Regions and communities interested in stimulating local economic growth may find these experiences critical to the process of promoting cluster-based development.

7.0 References

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