

**REGIONAL CLUSTERS IN A GLOBAL INDUSTRY:
THE DEVELOPMENT OF THE ICT INDUSTRY IN CANADA**

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1. INTRODUCTION

This paper is the first attempt to synthesize the lessons learned from the study of the information and communications technologies industry (ICT) in six regions across Canada (Waterloo, Ottawa, Calgary, New Brunswick, Cape Breton, and Quebec). It represents the start of the third and final phase of the ISRN Cluster Study in which we compare cluster characteristics and dynamics across particular industries and regions. The first of these ICT case studies was reported in May 2002 and we now have at least preliminary descriptions for all six. Our analysis is based primarily on data communicated through papers, conference presentations, and personal correspondence. A seventh case study is presently underway in Vancouver and will be added to this analysis when it is complete. For the purposes of this comparison the ICT industry is broadly defined to include a wide range of manufacturing and service firms, systems integrators and component producers, and software and hardware firms involved with advanced telecommunications, wireless applications, and photonics/optics.

For each case study the principal investigators posed the question: is it a viable cluster? That is, does a particular co-location of firms, financial and legal services, research and training institutes, business and civic associations, and public supports promote sustainable endogenous

innovation and industry growth, and if so, how? The question has a counterpart at the level of individual firms: does locating within a cluster help a firm access resources and markets, deal with economic uncertainty, and adapt to market changes? There are three steps to answering these questions: first the PIs identified the actors that provide key inputs to the industry, the actors that serve as a market for key outputs, and the actors that facilitate interaction within the region; they then identified linkages between these actors, including both formal participation in supply chains, research consortia, and civic associations and informal relationships established through shared employment and educational histories and personal exchanges between key individuals and finally, the authors attempted to measure how these interactions affected the capacity of individual firms and the industry as a whole to remain locally vibrant and globally competitive. This final step was perhaps the most difficult as it required the PIs to identify intangible factors such as civic capital and culture that sustain a creative and entrepreneurial business environment. Since answers to these questions have already been presented for each of the cases examined in this paper, we will only highlight those events and conditions that we believe to be critical to each case.



Our objectives build on these earlier questions by focusing on common themes that cut across regional differences. We should note that although we refer to all of the case studies as clusters, that term remains a hypothesis, one that we do not directly address in this draft because some of the analyses are still underway. Future drafts, however, will examine whether or not particular case studies are “real” clusters. Our ultimate goal is to recommend policy interventions and management strategies relevant to the development of ICT clusters across Canada. To do this we first briefly summarize the initial and present conditions critical to the creation and early growth of each cluster. We then highlight the key variables critical to the sustainability and

growth potential of these clusters and present a number of broad policy implications. As this is our first analysis and some of the data is preliminary, our suggestions remain tentative and are intended to elicit feedback from individual authors and the larger ISRN community. We expect to refine our analysis and develop specific policy recommendations over the next year.

2. INDUSTRY DESCRIPTION

Firms in the information and communications technologies sector can be grouped broadly into telecommunications, other ICT services, software and hardware. The NAICS, which characterizes industries in North America, defines the sector in terms of equipment and component manufacturing, good-related services, and intangible services. This sector is a large and burgeoning sector in most technologically advanced economies. In 2001 it accounted for an average of 8.3 percent of GDP in the 28 countries of the OECD, and demand for ICT goods and services reached \$2.1 trillion in these countries in the same year (Davis, OECD, 2002).

Canada's economy is slightly more ICT-intensive than the OECD average. The Canadian sector included 31,000 establishments and 542,000 employees in 2000. It had revenues of about \$132 billion and accounted for 10 percent of Canadian exports (Davis, Industry Canada, 2001). The Canadian ICT sector grew about four times faster than the Canadian economy as a whole until 2001, and accounted for nearly 20 percent of Canadian GDP growth between 1997 and 2001 (Industry Canada, 2002). Employment in the ICT sector grew 3.5 times as fast as employment economy-wide (*ibid.*). In addition, employees in this sector earned about 50 percent more than the average wage. This sector is also characterized by a high degree of R&D activity. In 1998, the top 20 IT firms in the world spent on average 7 percent of their revenues on R&D (Davis, OCEd, 2002).

Because of its already significant and increasing contribution importance to firm formation, industrial growth and economy development, the ICT sector has been the focus of policy initiatives in regions throughout the world, and none less so than in Canada. Investments in Centers of Excellence, the National Research Council, Technology Partnerships and networks such as CANARIE are evidence of the significant emphasis placed on this industry by both the public and private sector.

To identify the elements that contribute to the emergence of an ICT cluster, most scholars have looked to Silicon Valley. Several authors (for example Arora, Gambardella, Torrisi 2000 and Rosenberg, 2002) have analyzed the emergence of international high tech clusters in regions such as Ireland, India, Israel, Taiwan, China, Cambridge (England) etc. Although it is difficult to identify a single recipe for success, these cases do exhibit regularities such as the availability of a highly skilled, technical labour pool, an openness to external markets, an export orientation, and core technical competencies as being the most significant contributory factors to the comparative advantage of these regions. Future drafts of this paper will compare our Canadian clusters with their international counterparts.

3. THEORETICAL FRAMEWORK

The ISRN cluster study rests primarily on two bodies of literature: one discussing Regional Innovation Systems and the other discussing Clusters. As both have previously been described in many ISRN publications, we need only highlight their salient points. The central theme of each is that in a global marketplace, local input factors and inter-firm dynamics are critical to a firm's ability to innovate and thereby gain competitive advantage: although economic borders are disappearing, geography still matters. The literatures overlap on numerous

points: both claim that clusters are the result of historical path dependencies seeded by particular initial conditions, and both argue that knowledge flows within and between clusters are critical to fostering and sustaining innovation. Each literature, however, stresses a different side of innovation. To make a very rough distinction, the cluster literature focuses on the competitive pressures that drive innovation, that is, primarily on why firms innovate, and the RIS literature focuses on the social and interactive nature of innovation itself, that is, primarily on how firms innovate.

The cluster literature claims that innovation is primarily driven by local competition and sophisticated demand. It argues that industrial agglomeration, or clustering, creates a competitive and demanding environment that compels firms to innovate and helps them acquire the needed tools and resources. A cluster's viability depends on a mixture of local inputs, or factor conditions, that are high in quantity and quality and low in cost, local suppliers, competitors, and customers that are demanding, sophisticated, and specialized, and a regulatory, tax, and policy environment that encourages appropriate investments and sustains technological upgrading. One therefore expects a healthy cluster to exhibit significant factor condition advantages as well as a vibrant and competitive local market.

Although the RIS literature agrees with much of this analysis, it focuses on the nature of innovation itself, claiming that innovation is a complex social and interactive activity that requires firms to learn from each other and other institutional actors and to collectively manage economic and technological uncertainty. It argues that regional agglomeration enhances learning by facilitating close interactions among firms and supporting institutions needed to produce and apply knowledge and skills. It also argues that this interaction helps firms manage uncertainty by creating social norms, conventions, and habits, "untraded interdependencies," that guide and

constrain firm activities. A cluster's viability depends on it sustaining a "thick network of knowledge sharing" and a high degree of common purpose among its members. One therefore expects a healthy cluster to exhibit a significant local knowledge base and strong institutional linkages and cooperative activities.

Much attention has been given in the literature to the forces that lie behind cluster formation and growth. Some have argued (and the evidence we present below supports this notion), that the processes of starting and sustaining a cluster can be quite different and are driven by different parameters. Saxenian, Gambardella and Bresnahan (2001), believe that starting a cluster involves first, "building the economic fundamental for an industry or technology, and second, finding the spark of entrepreneurship to get it going" (p. 8). In other words, while "increasing returns and external effects can keep a cluster going, the initial spark is more difficult to obtain and more risky to pursue" (ibid. p. 12). External benefits such as access to particular technologies that arise from the presence of other firms or support structures like venture capital (VC) play a limited role in the early stages of cluster development but are often critical to later stage cluster growth.

In their synthesis of the early findings of ISRN's cluster study, Wolfe and Gertler (2003) identified both sets of characteristics as being crucial to the creation and growth of some of the clusters under investigation. They summarized them in the five L's of Learning, Labour, Leadership, Location, and Legislation and concluded that cluster dynamics were influenced by both market and non-market factor conditions and complex learning dynamics. One of the characteristics they identify, however, appears to disagree with both sets of cluster literature. A number of the case studies lacked both the vibrant local market and the unique local knowledge base. This caused Wolfe and Gertler (2003) to adopt Peter Phillips' distinguished between

“regionally embedded and anchored” clusters and “entrepôt” clusters. In the first type, much of the cluster’s innovative activities depend on an interactive creation and application of a unique local base of knowledge and skill. In the second type, much of this knowledge is acquired externally through traditional market transactions from sources outside the cluster.

This distinction brings to light one of the key challenges of identifying and describing industrial clusters in Canada: understanding how clusters are influenced by linkages and interdependencies with outside markets and institutions. Sharing a border with the world’s largest and most innovative national economy creates a number of advantages and disadvantages for Canadian industry. All of the clusters discussed here are located within a short distance of the large and highly competitive US market, a market that can distort our perception of local cluster dynamics. Most of the clusters generate a significant portion of their revenues from exports, primarily to the US, which means that the most important supply chain relationships often extend beyond the local region. These external relationships can easily overshadow linkages with local organizations that sustain information and labour flows within an industry and lead us to the questionable conclusion that that local ties are irrelevant.

Similarly the relative youth and instability of some of these clusters, and the lingering effects of the recent economic downturn, particularly in the telecommunications industry, also present challenges for those attempting to analyze the industry. Because many of these clusters have not yet stabilized their institutional relationships, it is sometimes difficult to distinguish whether the absence of strong inter-firm linkages is evidence that a cluster is weak or that it is immature. This has direct policy implications, for if the cluster is not viable then efforts to support it should be redirected to more successful local industries; but if the cluster is merely at an early stage of development, one could argue that supports should be maintained or intensified.

These challenges are amplified when attempting to draw policy implications from a comparison of clusters at very different stages of development.

To frame our comparison and guide our analysis we identified ten variables as important in some or all of the ICT clusters. Following Wolfe and Gertler (2003) these include both market and non-market factor conditions, local and non-local linkages, and social assets and relationships. These consist of (1) labour/talent, (2) the local knowledge base, (3) commercialization activities, (4) firm formation and growth, (5) financing, (6) product diversity, (7) local institutional linkages, (8) non-local institutional linkages, (9) business knowledge, and (10) public policy. We examined the role of each of these variables in the initiation and development of the clusters and highlight those we believe were critical.

4. FACTORS IN CLUSTER FORMATION

We begin our analysis with a brief description of each cluster and a summary of the key initial factors in its formation. Each of these clusters differs in age, size, firm composition, technological focus, and historical antecedents. The individual studies are also at various stages of completion. Two of them are complete: Quebec City, and Calgary; and four are still in progress: Ottawa, Waterloo, New Brunswick, and Cape Breton. We begin with the most established cluster, Ottawa.

4.1. Ottawa

Comprising approximately 1200 firms and employing over 70,000 personnel, Ottawa's ICT cluster is the largest and most mature of the six we are comparing. It is also the healthiest. The industry consists of large indigenous companies, foreign-based multinationals, and local



SMEs, and is a diverse mix of systems integrators and component producers serving both domestic and foreign markets. The cluster's outputs have evolved from the manufacturing of traditional telecommunication equipment in the 1960s to include a wide range of photonics applications today. Throughout this evolution Nortel Networks has remained one of the cluster's key anchor firms. In the late 1990s the sector had a 17 percent annual growth rate, generated close to \$15B in exports, and was home to 90 percent of industrial telecommunications research in Canada (ICT Clusters in Canada, 2002). This research is supported by two local universities, Carleton University and the University of Ottawa, and by the numerous federal and private laboratories located in the region. The cluster is also supported by active civic organizations.

Four factors in particular were critical to the birth and early development of this cluster: (i) the concentration of research infrastructure in the region; (ii) the existence of a large and influential anchor firm; (iii) efforts of the federal government to attract multinational firms to the region; and, (iv) the intentional building of informal and formal linkages between the region's various actors. The Ottawa cluster, and particularly its recent development of photonics applications, is highly dependent upon strong public sector investment in R&D through the National Research Council, which began following the Second World War and continued with the creation of the Communications Research Centre in 1969. In 1961, Bell Northern Research (BNR), decided to locate its new facilities in Ottawa to be close this research concentration. This move had been triggered by AT&T's divestiture of Northern Electric in 1956 and the subsequent transfer of transistor technology to BNR. Since its establishment BNR, now Nortel Networks, has acted as an important anchor firm, bringing in engineering and research talent needed to push new technologies forward and create spin-off firms and helping to train the business managers who later helped these firms to grow. Some of these spin-offs, such as Mitel, Newbridge, and

JDS Fitel (now JDS Uniphase), became important participants in the cluster. The federal government's active recruitment of multinational companies to the area in the 1960s and 1970s also attracted important new entrants, such as Digital and IBM. One sign of this cluster's health has been its continuous ability to attract multinational firms to the area including, Alcatel, Cadence Design, Cisco, Nokia, and Siemens. It was a lack of cohesion between research institutes, the education sector, and local firms however, that led to the establishment of the Ottawa-Carleton Research Institute (OCRI) in 1983 with a mandate to create linkages between these entities. OCRI has since played an important role in linking firms, research institutes, and government and coordinating development strategies of the cluster..

4.2. Calgary

The Calgary wireless cluster is a relatively young cluster with just over 100 firms and 12,000 employees. More than 50 percent of its firms have been launched since 1995. The industry primarily manufactures electronic equipment and had \$4.6 billion in exports in 2000, a third of the Alberta's export revenues that year. There are two major training centres in the region, the University of Calgary and the Southern Alberta Institute of Technology. There are also three research centres with strong links to the cluster: the University of Calgary, the University of Alberta, and TRILabs, a research consortium in information and communications technology.

Two factors were key to the birth and early growth of the clusters: (i) local market demands for wireless technology; and, (ii) the existence of an anchor institutions which generated cutting edge technology and attracted skilled talent to the region. The initial driving force behind Calgary's wireless cluster was Alberta's old and gas industry, which was an early

local demanding customer and important investor. The province's sparse population and rugged terrain made wireless communications a necessity for exploration and drilling. The cluster would likely not have emerged, however, without the decision by Alberta Government Telephones (AGT) and Nova Corporation to create NovAtel Communications in 1982 which subsequently developed a wireless network. AGT was a monopoly owned and operated by the Alberta government, and Nova Corporation, a regulated utility, was North America's largest volume carrier of natural gas and the operator of North America's largest radio telephone system. NovAtel was instrumental in building up a critical mass of engineering talent in wireless technologies in the region. When the firm later dissolved in 1992 it released its highly skilled employees into the local labour force. This attracted new firms into the region. Many of these employees also created start-up firms.

It is important to note that the dissolution of NovAtel was carefully managed by the Alberta government to ensure that the firm's knowledge and skills were redistributed and continued to benefit the local economy. Although the public sector education and research institutions did not lead this cluster, they were quick to respond to its emergence and local institutions including the University of Calgary and the Southern Alberta Institute of Technology became an important source of talent. These institutions work closely with local firms on research and education. While much of the underlying science and basic technology is imported, a number of research initiatives have been launched to support the industry, including the founding of the University of Calgary's Department of Geomatics Engineering, the creation of the TRILabs Wireless Laboratory in 1991, and The Alberta Informatics Circle of Research Excellence in 1999 to support research chairs and student fellowships in advanced ICT.

4.3. Quebec

There are presently 22 firms in Quebec's photonics cluster, an increase from 9 in 1999. These are supported by three major training centres (the Université Laval and two Cégeps), three research centres (the National Optical Institute, the Defense Research and Development Canada, and the Centre d'optique photonique et laser. In addition there are four venture capital firms and 10 other support organizations. The cluster generated \$214 million in sales in 2003, 80 percent of which was exported outside the region. Research and development expenditures grew from \$17 million in 1999 to \$31 million in 2001. This has subsequently fallen to \$21 million in 2003. Twenty-two percent of these revenues were generated by research institutes and 78 percent by local firms. Firms are highly innovative, with 94 percent claiming to have produced world first innovations. Approximately 79 percent of firms indicated that internal R&D was important for their innovative activities. The entry strategy for new start-ups is to develop complex and highly customized products, closely linked to research coming from public institutions.

Three factors were key to the birth and early growth of the cluster: (i) a concentration of local research and training institutions which anchor the cluster; (ii) a strong record of spinning-off new firms from public research; and (iii) ongoing linkages between the research institutes and local firms. The cluster is highly dependent upon the strong local science base and strong cooperation between public sector research institutes and local firms.

Expenditures by the Defence Research and Development Canada have been an important driver of advance optics, and their discovery of the CO₂ Laser 1960 began a build up of local expertise in this field. This expertise was further embedded with the creation of the National Optical Institute in 1985, an industry-university-government partnership conducting in-house application oriented R&D, and the founding of the Centre d'optique, photonique et laser at the

Université Laval in 1989. The Université Laval also provides 66 percent of the scientists working in the sector. Le Cégep de la Pocatière and Le Cégep de Limoilou initiated technical training programmes in optics for the industry in early 2001. The transition from research to industrial application began in the early 1980s with the creation of many of the cluster's present large firms: Exfo, ABB Bomem, and Gentec. Firm formation is largely internally driven and few firms are attracted from outside the region. There have also been a number of civic cluster promoting initiatives in the late 1990s which have now been amalgamated into a new regional economic development organization, Pole Quebec Chaudiere-Appalaches, an umbrella organization overseeing the promotion of 5 industry clusters..

4.4. Waterloo

The Waterloo ICT cluster comprises a diverse mix of firms in software, wireless technologies, and advanced manufacturing. Published reports put the number of ICT firms in the region anywhere from 300 to 900. There are three universities in the region, which are important sources of knowledge, talent, and, in the case of one university, spin-offs. There is also one community college, which trains a number of the region's technicians. Three civic organizations have played an important role in the cluster's development: Canada's Technology Triangle (f. 1987), Canada's Technology Triangle Accelerator Network, and the Communitech Technology Association (f. 1997)

Four conditions provided many of the inputs and networking opportunities that gave birth to the ICT cluster: (i) preexisting broad industrial strengths; (ii) strong institutional linkages; (iii) a strong research and educational institution; and, (iv) a strong labour pool. The ICT cluster in Waterloo grew out of a strong industrial base in advanced manufacturing, a strong local

university focused on engineering, math and computer science, and a civic culture that supported linkages among firms and between firms and public institutions, particularly universities. Local industry was instrumental in the founding of the University of Waterloo in 1957, arguing that the region needed facilities to create local competencies and train skilled personnel in mathematics, science, and engineering. This was also the primary impetus behind the university's decision to create a co-op program. Given this beginning, it is not surprising that the university was one of the first to offer courses in the new discipline of Computer Science. Many of the region's first IT firms were spin-offs from the university. For all of these reasons, the university is an important anchor institution.

Waterloo's first ICT firms were created in the early 1970s when a number of firms began developing software and hardware to support networking and communications applications. Two of the early new firms were WATCOM and Dantec Electronic, which were both spun-off from the University of Waterloo in 1974. During the next two decades independent start-ups and second and third generation spin-offs contributed greatly to the cluster's growth. The late 1980s witnessed a dramatic growth in firm formation, led largely by spin-offs from the university. A smaller growth took place in the mid to late 1990s, led by second and third generation spin-offs and the amalgamation of existing firms in the region. From the late 1990s to the present firm formation has slowed and are primarily third or fourth generation spin-offs.

4.5. New Brunswick

The New Brunswick cluster has just over 200 firms, which are highly concentrated in the province's three largest urban centres, Saint John, Moncton, and Fredericton. These centres account for 79 percent of the firms and 94 percent of the revenues and employees. The cluster

consists of telecommunication firms, software developers, IT services, multimedia, and IT-based advanced training. The average age of the firms is 8 years and approximately 43 percent of them were established between 1993 and 1997. Most firms are independent and locally owned with less than 20 percent being transplants from outside the region. The ICT industry presently rivals tourism in terms of wealth generation in the province. Growth has been extremely rapid in recent years with revenues increasing by 117 percent from 1999 to 2001. Most of this growth has been among independent firms. Fifty-two firms qualify as Gazelles, i.e., they grew at a rate of 20 percent per year for at least 5 years, from a base of at least \$100,000. Revenues and employment remain highly concentrated in a small number of firms with the 10 largest firms employing 51 percent of the workers and earning 55 percent of the revenues. The cluster is highly export oriented with 63 percent of its revenues coming from outside Atlantic Canada. The US accounts for more than 30 percent of the cluster's revenues. The largest exporters include 11 foreign-based branch plants and subsidiaries.

New Brunswick's ICT cluster can be traced to four triggers: (i) the upgrading of local ICT capabilities and infrastructure; (ii) a strategic public-private partnership to promote the ICT industry and attract new firms to the region; (iii) the presence of an anchor firm which led local innovation; and, (iv) low labour costs. Between the 1960s and the mid 1980s the New Brunswick government and local firms gradually upgraded their capabilities, which created a local market for ICT product and services. In the mid 1980s the provincial government identified ICT as an industry with potential to bring economic growth to the region. NBTel, the government owned and operated New Brunswick Telephone Company, invested in digital infrastructure and developed a number of leading edge technologies. The provincial government also upgraded the province's ICT infrastructure and improved citizen accessibility to the internet. The simultaneous

effort to attract new firms to the region focused on call centres was based primarily on the province's new digital infrastructure and low labour costs. The University of New Brunswick was an important source of talent, training many of the region's computer scientists. It also conducted contract research for the industry. The cluster's subsequent development was heavily impacted when NBTel merged with three other provincial telephone companies in Atlantic Canada to form Aliant and reduced its involvement with product innovation in the region.

4.6. Cape Breton

Work on the Cape Breton ICT cluster is presently ongoing and therefore we are presently lacking detailed information on the industry. We have included it, because it is a rare example of an attempt to intentionally create a cluster in an industrial vacuum in order to revive a failing local economy. The one key trigger to the clusters birth has been government intervention, supported by low labour and business costs. This intervention was precipitated by the closure of last coal mine and steel plant in 2001. The federal and provincial governments had been supporting those industries since the 1960s to prevent economic collapse in the region. The recent strategy for economic development has been to use a mixture of financial incentives to attract non-indigenous firms into the region. Once those incentives were exhausted, however, many firms exited. Most of the present employment in the ICT industry is in call centres and data entry firms, which are partially attracted by low labour and business costs.

To conclude, these brief summaries show that a variety of triggers gave rise to ICT clusters across Canada. Many if not most of which were related to each region's existing industrial and knowledge assets. The uncertain result of the federal government's attempt to create an ICT cluster in Cape Breton attests to the difficult of creating *ex nihilo*. Although many

of these clusters are now export oriented, local markets frequently provided an early stimulus to growth. Public sector research and training institutions play a particularly important role in many of the clusters, particularly Waterloo, Ottawa and Quebec.. This suggests that present attempts to create an ICT research base in New Brunswick in order to help that cluster grow are correct. The supply of talent is especially critical to cluster growth. We also see that local knowledge links will not sustain firm innovation in a global economy, and that these links often occur in tandem with international knowledge links. Local links at times serve as a path for transmitting outside knowledge to local firms.

5. PRESENT CLUSTER CONDITIONS AND CONSTRAINTS ON GROWTH

The previous section indicates that cluster development is inextricably linked to a region's existing economic strengths. Largely determined by the region's economic and industrial legacy, these strengths serve as the fundamental building blocks for cluster formation and have a large bearing on the characteristics and evolutionary path the cluster then follows. In many respects, this analysis is akin to the nature versus nurture argument: to what extent are cluster characteristics influenced by inherited regional assets and what role, if any, can government play in nurturing regional innovation and cluster development? Our case studies contain examples of governments and public institutions responding to and supporting cluster growth and examples of them triggering cluster formation. This section identifies some of key current conditions defining our six case studies, the degree to which they are influenced by the initial triggers discussed above, and present constraints on cluster growth.

5.1. Labour/Talent

The quantity, quality, and cost of labour/talent is one of the key triggers to cluster formation, one of the key factors in cluster growth, and one most frequently mentioned benefits of cluster membership. This is an essential factor in almost any industry but is particularly salient in high-tech, knowledge industries in which the differentiating factor between firms is often the quality of its employees. In industries where firms compete internationally, as they do in ICT, continuous access to a highly educated, highly skilled, creative and innovative workforce, or alternatively to a low-cost workforce, is the singularly most important factor separating thriving clusters from those that stagnate particularly in the wake of a labour shortage.

The continuous attraction and/or retention of talent in a given region is undoubtedly critical to a cluster's ongoing success. An abundance of labour brings with it several positive externalities. For example in the cases of Calgary and Ottawa the availability of highly skilled and specialized labour was a strong attraction for outside firms. In addition, inter-firm labour mobility, which assists in knowledge diffusion and dissemination, is made infinitely easier where the regional workforce is of considerable density. This is seen in the reference to the Calgary "foot soldiers," a term that reflects the high degree of inter-firm labour mobility in the region.

Our analysis found that access to a strong labour pool, by which we mean an adequate supply of the necessary skills required to meet the needs of local industry, was a common factor characterizing the six ICT clusters in this investigation. Regions such as Waterloo, Quebec and Ottawa enjoy an abundance of highly skilled and experienced labour, many of whom are engaged in R&D related activities. In places such as Calgary, not only is there an adequate supply of labour, but the workforce appears to be comprised of highly skilled, highly specialized employees, which consequently influences the characteristics of local firms, who are also found to be particularly specialized operating in a niche sector of the ICT market.

In regions such as Cape Breton and New Brunswick, the local labour pool was a major factor in cluster growth. Cape Breton's comparative advantage is to be found in its relatively low cost, which contributes to the generally low cost of doing business in the region. New Brunswick enjoys an adequate supply of relatively skilled workers, who are sufficient to meet the current needs of local industry in the region, but one could project that the lack of "higher-end" employees such as those capable of undertaking R&D activities will inhibit this region's ability to move up the value added chain.

As our case studies show, the role of labour/talent can change over the life of a cluster, particularly as firms attempt to increase and diversify their technological capabilities in order to access new markets. As a cluster matures firms often require a greater range of skills from their employees, as this is an essential component of improving firm capabilities. This often causes a cluster's competitive advantage in labour to shift from low cost to high skill. A region's ability to make this transition depends on cooperation between firms, universities, colleges, civic associations, and local governments. These actors need to work together to forecast and meet future labour needs. Successful examples of such partnership include Calgary, Ottawa, and Waterloo. This challenge appears to be one of the factors motivating the New Brunswick cluster to strengthen ties between universities and firms. While educational institutions usually react to cluster formation and growth, they are necessary partners in the attraction, training, and retention of local talent and have considerable influence over the evolution of the labour market.

5.2. Local Knowledge Base

Strongly linked to the availability of labour is the presence of universities, colleges and other educational institutions. The Waterloo cluster probably stands as the foremost example of

how a university can contribute to regional industrial development even though its role in the region is seen to have changed over time. One of the most important contributions of the university in Waterloo has been the success of its Co-op Program, which facilitates strong links between firms and the university and assists in workforce development, knowledge exchange, and institutional learning. Although the university's role as the generator of cutting-edge spin-off firms has diminished with time, it currently plays a critical role in attracting and generating talent, in helping to brand the region, and in contributing to the social capital and networking capabilities that exist locally. In other regions, the role of the university is different or less important. Calgary appears to be an excellent model for examining how to forge tangible and productive research collaborations between the university and industry, whereas in regions such as New Brunswick and Ottawa, the universities have played a less important role to date (relative to other factors) and are deemed to be "followers", not "leaders" of cluster development particularly with respect to their contribution to regional R&D capabilities.

Another factor that is linked to the availability of labour and to university strengths is the degree of R&D activity in a region. R&D activity is seen to be most robust in clusters such as Ottawa and Quebec, where innovation capabilities appear strong, but are not always directly translated into commercialization opportunities and/or economic development. That said, both of these clusters are characterized by high levels of investment in both public and private sector R&D and a strong regional R&D infrastructure exists. For regions where R&D activity has been less notable, namely Cape Breton and New Brunswick, it appears that policy makers are currently in the process of addressing this deficiency and are investing increasing amounts in building up the R&D and innovative capabilities of the region.

While the existence of “knowledge pipelines” between local firms and knowledge producers outside the cluster are clearly critical to sustaining regional competitive advantage, these pipelines often work in tandem with a strong local knowledge base. A local knowledge base also helps to build and maintain international “knowledge pipelines” and assists firms interpret and apply this knowledge. Clusters that rely solely on knowledge sources from outside the cluster often lack the capacity to react to radical shifts in technological or market demand. The presence of strong regional research institutions also provides highly specialized consultants and attract highly talented workers to a region. One of the strengths of the Quebec cluster continues to be strong links between public research institutions and local firms. This has expanded into strong networking links throughout the industry and region. One of the positive developments in the New Brunswick cluster is the recent initiative by the National Research Council to create a local research centre in ICT affiliated with the local university. This will help create a local knowledge base, and most important increase the R&D linkages between the university and local firms.

5.3. Commercializing Activities

The commercialization of new knowledge originating primarily in universities and research consortia has been particularly important to cluster growth in Quebec, Ottawa and Waterloo. These clusters have taken different paths to commercialization, however, with Quebec bringing new knowledge into the marketplace through research partnerships and Waterloo performing that task through the creation of university spin-off firms. In established clusters, such as Waterloo, we have witnessed a recent slowdown in commercialization activities. As clusters mature they tend to reorient their R&D mechanisms towards existing technological

strengths. This not only reduces the region's ability to develop new products and markets, but it leaves the cluster vulnerable to being technologically surpassed by distant rivals. In addition to supporting incremental firm innovation, a local knowledge base drives the cluster's innovative capacity by providing it with new knowledge. Existing firms need to continue seeking out commercialization opportunities and supporting the spinning-off of all opportunities to new firms. The decline in the university's role in new firm formation in Waterloo may suggest a maturing of the cluster, however, it may also indicate a reorientation of the local knowledge base to a secondary role.

5.4. Firm Formation and Growth

University spin-off firms are only one example of firm formation. The formation of new firms is necessary for cluster formation and development and has been crucial to the growth and diversification of our case studies. While the example of Waterloo shows that the sources of these firms may change over time, it is critical that regions maintain mechanisms to support and encourage early stage spin-off and start-up firms. These firms play a large role in bringing new technologies to the market and diversifying the cluster. They allow a cluster to experiment with new products without risking existing strengths and enable it to flexibly and quickly respond to changes in markets and key technologies. A region also needs to possess the skills and resources needed to grow these firms. A failure to support all stages of firm formation and growth will limit a cluster's ability to grow and make it vulnerable to merger and acquisition activities involving outside competitors. Two of the main constraints on growth are later stage financing and business skills. All of our clusters have weaknesses in these areas.

5.5. Financing

High levels of R&D and the potential for innovation and discovery that accompanies it often attract a supply of investment money and venture capital funding. This is particularly apparent in Ottawa (and to a lesser extent in Quebec), which has seen significant growth in the amount of VC funding flowing into the region in recent years. Venture capital funding, however, can bring with it certain disadvantages. In Ottawa, many SMEs continue to cite lack of funding as a deterrent to growth. Furthermore, for those who have received funding, there is an increasing pressure to provide investors with a lucrative exit strategy, which often forces firms to engage in M&A activity, which limits their ability to grow organically and realize their potential. All of our clusters, with the possible exception of the Cape Breton cluster, claim to have adequate early stage financing for new firms. Many, however, lack financing for firm growth. This is the case in Calgary, Quebec, and New Brunswick. While the Ottawa cluster has been home to Canada's most active venture capital community in ICT, the recent economic downturn has resulted in a significant reduction in this activity. While most clusters are looking to private sources of finance, the Cape Breton cluster has relied heavily on government financing. It is still uncertain whether investments intended to support a cluster are efficient allocations of public resources although similar initiatives involving public VC funds have success in international clusters such as Israel.

5.6. Industry Diversity

Our clusters differ in their degree of product diversity and in the degree of industrial diversity or overall specialization. The wireless cluster in Calgary is generally described as having strong niche characteristics, which as discussed earlier, brings with it certain positive

externalities such as access to a highly specialized pool of labour. There is growing concern, however, that should large multinational corporations decide to occupy this niche sector, local firms in Calgary would be unable to withstand such international competition and would find themselves squeezed out of the market.

While a number of our clusters have grown by specializing in particular product areas this also leaves them very vulnerable to market shocks. This is perhaps most evident in the case of Ottawa where the lack of industrial diversity and the degree of emphasis on telecom and photonics rendered the cluster vulnerable when this sector experienced a significant downturn in recent years. Conversely, the Waterloo cluster has the advantage of a diverse industrial mix and offering a broad array of products to the market. In New Brunswick, the diversity is found more in the increasing mixture of small local firms and larger foreign firms both of which are engaged in different sets of activities and demonstrate different levels of innovation. Factors such as a diverse industrial mix undoubtedly contribute to the ongoing strength and sustainability of these clusters. Both Calgary and Ottawa are presently trying to diversify their product lines by extending photonics applications to a wider range of industries. Such diversification enables a cluster to weather downturns in particular industry segments.

5.7. Local Institutional Linkages

In a number of our clusters weak links between local firms make it difficult to increase cluster strengths because the firms are not able to pool their innovative capacity or build up regional complementarities. Weak local supply linkages also militate against a firm's perception of belonging to a cluster and therefore prevent the development of common purpose with other cluster members. Where market linkages do not exist, firms build relationship through

intermediary organizations, such as research institutes or civic associations. These intermediaries often anchor the cluster and are a crucial node in cluster linkages and a key portal for knowledge flows. This is clearly evident in Ottawa with OCRI and in Waterloo with Communitech. The various civic associations that have attempted to build cluster strengths in Quebec have been hindered by the fact that potential participants do not yet see the benefit of cluster membership. In New Brunswick the National Research Council is attempting to fill the role of cluster mediator.

5.8. Non-local Institutional Linkages

A very distinctive characteristic of ICT clusters in Canada is their strong international outlook and export orientation. This element is discussed in further detail below as it is an important consideration with respect to whether these cases fit the strict “Porterian” definition of a cluster, and could also constitute a significant area for policy initiatives. All of the case studies cited strong export orientation and international links as being critical to the current and future success of the cluster.

As a result, many of these ICT firms appear to have relatively weak local linkages (in terms of suppliers, competitors etc.) and the majority of the customers appear to be located outside of the region, if not, outside Canada. There are several explanations as to why this could be. The first is that this is rather characteristic of small open economies and, in viewing the Canadian economy through a regional lens, one could define each of these regions, in and of itself as being relatively small and open. The second reason is that this is characteristic of ICT in general. This is a highly export orientated industry where geographically disperse supply and

value chains are the norm and firms that are embedded locally are none-the-less connected to global networks of suppliers, customers and competitors.

This strong export orientation is essential to the future sustainability of these clusters whose growth depends on the ability of firms to identify and exploit international markets. Accessing international customers and suppliers and keeping track of international competitors requires numerous skills and resources that not all clusters have. Outside of market opportunities, the export profile of these firms has also contributed to the international reputation and branding that clusters such as Waterloo and Ottawa currently enjoy. International branding and marketing is shown to be an increasingly important regional asset particularly in a globally networked industry such as ICT. Not only does this increase the competitive reputation and profile of regions, it also plays a role in attracting new firms and labour (particularly evident in the case of Ottawa where several multinational firms located in the region as a result of its reputation and its critical mass of companies and talent), thus contributing to the agglomeration effect.

5.9. Business Expertise

One of the key constraints on cluster growth and on the ability of firms to establish non-local linkages is a lack of management and marketing skills. Because many of these skills depend upon tacit knowledge that is best acquired through hands-on-learning, the supply of managers relies heavily on in-house training carried out in large firms. The lack of such firms in Cape Breton, New Brunswick, and Quebec constrain the availability of business skills. Small firms in these clusters lack the in-house talent needed to grow and are unable to attract that talent to their region. Calgary has recently relied on Nortel to train many of the managers in the region. This supply may disappear as Nortel alters its business focus. With their more diverse mixture of

industries and broader economic base, Waterloo and Ottawa are able to provide the on-the-job management training necessary to feed the entire cluster.

5.10. Public Policy

Whereas Government was not found to have played a critical role in regions such as Waterloo, in places such as Cape Breton, cluster development was greatly influenced by government intervention. As with other factors, public policy must adapt to meet the shifting needs of evolving clusters. Since policies impact all of the factors mentioned above, it is clear that it is important to maintain close links between cluster participants and policy makers at various levels of government. While policy makers usually have a responsibility to multiple regions and industries, they need to be informed of particular needs. Numerous examples abound of the unintended negative consequences of policies on clusters. Quebec's recent cut in provincial R&D tax credits may severely impact the research investments presently driving the region's photonics/optics cluster. Policies that direct educational and training initiatives and impact intellectual property guidelines, or research funding are particularly important. Specific policies to support a cluster must also be flexible enough to adapt to cluster evolution. For example, in Cape Breton and New Brunswick there is presently an over-reliance on foreign direct investment for economic development and employment and a failure to target indigenous innovation and or entrepreneurship, although latest efforts are designed to address this problem.

5.11. Conclusion

To conclude, the factors that presently affect the growth and development of ICT clusters in Canada are derived in large part from the factors that triggered the initial emergence of the

clusters. Although many of these clusters do not fit the strict “Porterian” definition of a cluster, owing to the lack of substantial local linkages, there is growing evidence of networking and civic capital in almost all of these cases. In terms of strict cluster analysis, Ottawa is the case that most closely resembles a Porterian cluster. It is a mature cluster with a critical mass of firms and all the positive externalities that accompany the latter stages of cluster development. Local champions are visible, anchor institutions still exist, there are a number of active serial entrepreneurs who make significant contributions in terms of knowledge sharing and acting as angel investors, and there is strong evidence of networking, civic capital and entrepreneurship. While other regions cannot emulate Ottawa’s R&D advantages they can learn from some of its strengths in civic capital and firm formation.

6. Implications for Public Policy

The above analysis highlights a number of challenges to cluster sustainability and constraints on cluster growth and teaches us that there is no “one size fits all” policy solution to ICT industrial development. This is owing to the fact that no one factor determines the birth and/or growth of an ICT cluster. Rather it is the dynamic interplay and interdependence of multiple factors that determines its evolutionary trajectory. These factors are largely determined by a region’s assets and therefore have a varying degree of importance in shaping the cluster’s characteristics. The critical point is for policy makers, in addition to generating new regional assets, is to identify, harness and leverage the existing regional strengths in their efforts to develop high-tech industries. The objective of this section is to discuss potential policy initiatives that might contribute to cluster growth.

6.1. Creating and Attracting a Talented Labour Force

Labour exists in different capacities and at different levels in each of our six case studies and tends to reflect the particular needs of industry in each stage of development. In Quebec, Ottawa and Calgary, there is an abundance of highly skilled personnel capable of engaging in R&D activities, whereas in regions such as Cape Breton and New Brunswick, the labour pool is generally found to be less skilled and may be a significant constraint on firm creation and growth and on the expansion of firm capabilities. The small size of the Cape Breton, New Brunswick, and Quebec clusters mean that there are few large firms to provide hands-on training and experience that managers and marketers need to effectively grow firms and access export markets. In later stages of cluster development experienced management labour may be a more important constraint on growth than technical labour.

This brings us to consider regional comparative advantage with respect to labour. In some cases the competitive edge is gained by the availability of adequately skilled labour, at relatively low cost, whereas other regions (such as those involved in R&D) boast stocks of a highly skilled labour. The important point is for policy makers to ensure that whatever type of labour is available in the region, it is sufficient to meet the current and future needs of local industry.

From a policy perspective there are a number of considerations to take into account when seeking to address workforce requirements and development. The first is what it takes to generate the right kind of workforce. Looking again to international software clusters, one notes that a prominent feature in countries such as Ireland was a sustained and long-term approach to educational policy. Workforce development is not just about meeting the current needs of industry, but it is also about generating the right kind of workforce for the ICT industries of the future. This requires continuous, long-term investment in education at all levels, but with

particular emphasis on tertiary education, and an emphasis on the right kinds of areas – that is on vocationally oriented, skill based programs in areas such as science, math and engineering.

Talent generation and availability, however, is not just about educational institutions. There is a growing body of literature that points to the importance of quality of place, lifestyle and diversity in attracting and retaining talent. This work argues that the economic success of regions is increasingly linked to their ability to attract a diverse mix of people, which in an age of increasing labour mobility, involves attracting talent from beyond national and international boundaries. In this respect, Canada stands to benefit from its high quality of life and relatively liberal immigration policy.

6.2. The Role of Government

The role of government is quite often the subject of debate with respect to cluster development. Porter argues for example (**ref**) that the role of government is circumscribed by fundamental market conditions and that government interventions will likely fail if they remain the only source of national competitive advantage. According to this theory, government can raise the odds of a region gaining competitive advantage but lacks the power to create the advantage itself. Similarly, Cooke (**ref**) argues that successful regional innovation systems can be assisted, though not produced *ex nihilo* by government policy.

That said, in several of the cases examined here, governments played an important role in assisting the development of regional ICT clusters, although what that role consisted of varies greatly across regions. In Ottawa for example, the federal government contributed significantly to the growth of the ICT cluster by investing substantially in public R&D facilities, whereas in Waterloo, cluster development was more an industry driven phenomenon than a government led

initiative. In Calgary public firms played a crucial role in creating the wireless cluster. Whereas government involvement was more general in these cases, in regions such as New Brunswick, direct sector specific government intervention is observable, particularly during the McKenna era. One could conclude from these cases, therefore, that in the absence of an industrial base of related industries, or where prerequisite conditions for ICT cluster development appear to be lacking, there is a strong argument for government intervention to create the necessary conditions.

The question remains as to what form this government intervention should take. Again the literature points to a role of facilitating and enabling. Governments should reinforce the potential for successful path formation that a region possesses, i.e., strengthen its capacity to succeed in areas where it holds a competitive advantage (ref). In many respects, it's a case of government laying the foundation and providing the right kind of infrastructure and environment in which firms can flourish. In adopting a cluster based approach to economic development, government policy should identify the myriad of regional assets that exist and devise initiatives that best harness and mobilize those assets. This also involves a concerted effort to leverage and compliment private sector strengths, creating the right incentives for innovative firms to become embedded in the region.

6.3. Supporting Educational Institutions

As one might expect, a strong network of educational institutions is a key element in any successful high tech cluster. In some of the clusters in question, (e.g., Waterloo), the university played a critical role in triggering the emergence of the industry and in acting as an anchor institution. One can observe, however, a change in the role of the university in the region over

time. Universities are not only sources of new invention and innovation, hotbeds of R&D, and the generators of human capital; their role in the regional economy has now extended beyond that and is the subject of much commentary and debate.

Another essential element of university involvement in cluster development is the degree to which the university is viewed as porous and its general level of accessibility. The presence of a university in a region is a necessary but not sufficient condition for cluster development.

Tangible links between the university and industry, be they in the form of research collaborations, coop programs etc., are necessary to build a region's innovative capacity. In agreement with Doutriaux (2003) we find that universities often act as catalysts for cluster development by training local talent and contributing to the local knowledge base, but they are rarely the key drivers of cluster growth. As a final point, these relationships must take the form of a two-way exchange. It is not sufficient to view the university as a repository of knowledge, skills and research, increasingly the success of economy thus making a strong argument for a two-way exchange. Programs that support research through public-private matching grants, are one way to encourage this exchange. The creation of university-industry research centres and research consortia are also beneficial, but it is critical to include industry participation from the beginning and ensure that firms have a stake in the centre's success.

6.4. Developing a Local Knowledge Base

Given that high tech clusters must innovate to stay internationally competitive, the R&D capabilities of a region are obviously a critical consideration. R&D can serve both as an initial factor that triggers firm formation and cluster development, as in the case of Ottawa, and as an equally important ongoing factor that contributes to a cluster's ability to develop and sustain its

competitive advantage. It is apparent again from our studies that the R&D capabilities and activities of these clusters varies greatly. In some cases R&D is primarily undertaken by firms in-house or in government research facilities whereas in other cases, the university plays a leading role as a source of R&D activity.

Another important consideration is the varying degrees of research versus development in each of these clusters. Firms in Waterloo appear to be primarily engaged in activities that constitute development as opposed to fundamental research. The opposite can be said of scientifically based clusters such as Quebec where activities based primarily on research are further removed from direct market application. Again, however, R&D constitutes a necessary but not sufficient condition in cluster development. Regions such as Quebec that can boast high levels of fundamental research struggle at times to capitalize on the commercial opportunities this presents. R&D strengths do not therefore always translate directly into industrial and economic development. That said, in an industry that is increasingly globalized, the innovative capabilities of a cluster and its ability to generate, develop, and apply cutting edge technologies is essential for ongoing success. The level of R&D can be a reflection of the broader innovative capacity of a cluster and a reflection of the make up and quality of the regional workforce. Government initiatives should therefore aim to encourage and support R&D activities, both in the public and private sector, and should ensure that the region harnesses and derives the maximum benefit from these activities in terms of economic development.

6.5. Fostering Anchor Institutions

Our analysis of these six case studies identifies the presence of an anchor institution as being a key factor in both the emergence and sustainability of a region or cluster. Again, the

manner in which this manifests itself differs from region to region. In some cases, the anchor institution was a large private firm (Nortel Networks in Ottawa) or a large regulated public company (NBTel in New Brunswick and NovAatel in Calgary) and in other cases it was a university (University of Waterloo) or government laboratory (Defence Research and Development Canada in Quebec).

Regardless of what the anchor institution was, its presence brings many advantages. Firstly, it provides stable employment, quite often for a large number of people. It also helps to establish international export links, which as discussed earlier, is a critical factor for ICT clusters in Canada. Many of these anchor institutions played a pivotal role in workforce development and training, spawning many well known entrepreneurs (cite Ottawa example, Terry Matthews and Michael Cowpland, two of the founders of Mitel, met while working at Nortel Networks) and providing people with a range of both technical and managerial expertise of world class standard. These institutions can also have a direct impact on local industry as a source of demand for local suppliers, and are the starting point for many (and often more successful) spin-off companies.

6.6. Creating Institutional Linkages

According to the Porterian definition (1990, p. 149), “a cluster consists of industries linked through vertical (buyer/supplier) or horizontal (common customers, technology, channels) relationships.” Key features of clusters are internal networking, linkages and formal and informal interactions. A common strand in both the economic and sociological literature is the notion of local linkages forming a defining geographic basis of a cluster. We find that several of our clusters do display high levels of internal networking (Calgary, Ottawa and Waterloo), information interactions and linkages. Linkages exist in a variety of forms in each of our case

studies and warrant particular attention because they contribute significantly to our understanding of the characteristics and dynamics of ICT cluster formation in Canada.

The essential consideration regarding linkages in the case of ICT clusters in Canada is the non-local dimension of industries. Each of these studies consistently cited global linkages to be as or more important than local linkages. This obviously begs the question as to why this is the case? Is this due to the limited size of the Canadian economy, which forces firm to pursue export oriented growth, or is this more a characteristic of ICT in general? The answer probably lies in a combination of both factors, but regardless, this is a point that warrants significant consideration and further study.

Linkages are found to exist between firms in related industries (such as photonics and telecom in Ottawa). Linkages are also found inter-industry, between firms in the same sector (who may or may not compete with one another), between public and private sector actors, and between educational institutions and other regional stakeholders. The most important links however are to markets, particularly international markets as many of these firms appear to supply non-local markets. If having the ability to export is essential, which it certainly appears to be according to each of these studies, then policy makers need to examine various ways in which they might facilitate and enhance access to global market and international linkages.

6.7. Other Factors

Each of the factors described above was found to be an important determinant affecting the growth and development of ICT clusters in each of our case studies. There are also a number of other variables, which government can influence, that were also found to play a role. One such element is the existence of an entrepreneurial climate and culture in a region. This is closely

linked to the levels of civic capital, which is found to have considerable strength in regions such as Ottawa and Waterloo. These strengths often manifest themselves via industry association and other networking groups, which play an important role in the diffusion of knowledge and expertise among firms. Organizations such as OCRI, played a critical role in facilitating networking opportunities among firms in Ottawa and this model has now been replicated elsewhere. This kind of networking activity also helps to build up the international cache and global reputation of a region.

Other factors which were found to be important was the availability of venture capital for firms at all stages of development. This is an area where government intervention has quite often been successful (e.g. in the case of the Israeli and Irish software industries) and is certainly worthy of policy consideration. Finally, quality of place was found to be contributing factor in the evolution of these ICT clusters as it has a strong influence on the attraction and retention of talent on which the future of these clusters most definitely rests.

7. Conclusion

This paper examined the key factors behind the emergence of ICT clusters in six regions across Canada. Our analysis found that each of the clusters in question evolved from initial conditions derived primarily from their particular regional endowments and industrial legacy. As a result, the clusters have evolved along different trajectories and are currently at varying stages of maturity with observable differences in their characteristics and propensity for success.

Our analysis did, however, uncover certain similarities between the clusters and indeed similarities to their international counterparts. One such factor is the importance of a highly skilled and educated workforce. Another critical factor, again characteristic of successful ICT

clusters throughout the world, is openness to external markets and a strong export orientation. We have also identified different strengths and weaknesses in each of these regional industries and would therefore advocate the argument put forward by Arora and Gambardella (forthcoming, 2005) that to support cluster growth, policy makers should identify, support and leverage a region's existing comparative advantages. Another important element of this analysis has been the important distinction between the role played by local and non-local factors. We have found that both local and non-local dynamics operate in each of these clusters and are by no means mutually exclusive. Local dynamics appear to manifest themselves primarily through knowledge flows and networking mechanisms, generally referred to as a region's civic capital. Non-local factors appear to refer to market dynamics and the importance of global networks between suppliers, customers and competitors in the ICT industry. A firm's ability to build and maintain long-distant market linkages with suppliers and customers is based partially on its ability to access local business expertise and knowledge. Similarly, a firm's ability to identify and absorb knowledge from outside the region is based partially on its links with the local knowledge base. This suggests that the "regionally embedded" and "entrepôt" cluster models represent the opposite ends of a spectrum rather than a clear dichotomy. Our findings also suggest that the traditional dichotomy between public and private interventions fails to capture the complex interaction between governments and firms needed to create and grow clusters. In most of our case studies a mixture of public and private firms, government and university laboratories, educational institutes and in-house firm training all contributed to cluster development. The important question is not whether public or private initiatives drive cluster growth, but whether these initiatives complement each other and build on existing regional strengths.