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Clusters, Innovation and Entrepreneurship

Chapter 8

The ICT Cluster of Waterloo, Canada

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This chapter illustrates the approach and initiatives of the entrepreneurial university in Waterloo in building the region's information and communications technology (ICT) cluster. The creation of spin-offs seems to be encouraged by a series of policies implemented in the university, among students and academia. This case study is also a good example of collaboration between university and industry to meet the demands of the cluster labour market concerning skills. The adaptation of the university to the needs of industry, and the tight co-operation between industry and university in training and developing specific skills in students, have had a positive impact on the development of the cluster. This chapter also shows how flexible intellectual property regulations at the university play an important role in stimulating innovation, collaboration and business creation.

Introduction

The search for effective local economic development strategies has assumed greater significance over the past decade. Concern with the factors that sustain innovation in local and regional economies has led to a growing fascination on the part of policy makers with industrial clusters due to their perceived impact on competitiveness and innovative performance. Closer examination of the origins and development path of specific clusters provides some guidance for cluster policy. Also important is the relationship between large and smaller enterprises in clusters. Much of the cluster literature documents the role of lead anchor firms in grounding the cluster in a specific geographic location. At the same time, a key success factor in cluster development is the ability to spin-off and grow newer small and medium-sized enterprises (SMEs). Much of the cluster literature views large and smaller scale firms as integrally linked in terms of buyer-supplier relationships, with the smaller scale firms forming a critical part of the supply architecture of the regional economy. Yet evidence from more recent studies indicates that buyer and customer relationships with external partners can be equally important for cluster firms as their internal relationships. A number of these studies point to the role of niche clusters within the global economy, as individual clusters in photonics, for instance, have come to specialise in particular technology and sectoral niches. Another key issue involves the relationship between different levels or scales of governance in supporting cluster policy. While clusters are clearly defined as a local or regional phenomenon, there is growing recognition that vibrant and dynamic clusters draw effectively on a range of policy instruments from senior levels of government to sustain their development.

The case of the information and communication technology (ICT) cluster in Waterloo, Ontario, is instructive for developing a better appreciation of the implications of these factors for the process of cluster formation. This chapter draws upon a recent case study of the Waterloo, Ontario, ICT cluster – conducted as part of a larger Canadian study of industrial clusters – to explore these issues. The following discussion examines the origins of this vibrant regional economy and explores how a deeply rooted regional culture, historical patterns of trade and knowledge flows, and locally created institutions each contributed to the emergence of the region as a dynamic centre of high-tech activity. Along the way, it provides some valuable insights for policy makers interested in emulating the region's cluster-based success.

Nature and evolution of the cluster

The ICT cluster in the Kitchener-Waterloo-Cambridge (Waterloo) region, located an hour west of Toronto, is one of the most dynamic sources of high-tech activity in Canada. Although the present contours of the cluster can be traced back to the formation of the first software and computing firms in the 1970s, the Waterloo region has long been an important location for manufacturing in the Southern Ontario industrial landscape. Kitchener-Waterloo has been the home to major national and international corporations for more than a century, from Dominion Electrohome Ltd. to present day success, Research in Motion Inc. – manufacturer of the iconic "Blackberry". The region has had a pioneering presence in some of the major technological advances in North America, including automobiles, radio, processed foods, financial services, biotechnology and computing. Today, this history of technological leadership continues in fields such as internet-enabled wireless communications, software, aerospace, engineering, ecommerce, robotics, and laser technology.

The emergence and contemporary dynamism of the Waterloo ICT cluster owes its success to critical decisions taken by industrial leaders in the local economy in the years following World War II. The period between the wars saw the growth of complex engineering, metalworking, food and automotive-related industries in the region on the foundation of the traditional manufacturing base. One of the key local institutions to emerge in the interwar period was Waterloo Lutheran College, established in Kitchener in 1924. Although the college did not contribute directly to the high-technology development in that era, its offspring, the Associate Faculties, was the precursor to the University of Waterloo. The University of Waterloo is one of several colleges and universities in the region with strong ties to local industry. However, more than any other research institution in the region, it has exerted a singular impact on the regional economy. The period of post-war reconstruction in Canada and the growing recovery of the leading industrial powers brought home some important lessons for government and industry in Canada. In a world where national survival was predicated on technological capabilities, Canada was found woefully lacking by industrialists and government alike. Local leaders and institutions in Kitchener-Waterloo played a key role in translating those lessons into practical measures. The University of Waterloo, founded in 1957, emerged in response to the growing demand for more sophisticated and technical educational institutions.

Certain prominent members of the local industrial community in Kitchener-Waterloo played a strategic role in Waterloo Lutheran College through their membership on the Board of Governors and recognised the growing demand for trained technical personnel and the implications of this

demand for the employment requirements of the local economy. Recognising the need for more technical education in the regional economy, Ira Needles (president of B.F. Goodrich and chairman on the Board of Governors for the newly created Associated Faculties of Waterloo Lutheran College) proposed a unique solution in the form of *The Waterloo Plan*. This plan called for a new type of education to be offered on a co-operative basis with industry. In sharing the burden of technical training with industry, the university would be able to support twice the number of students (as one class rotated out to co-op placements in industry while another took its place in the classroom), provide a greater depth of education – both theoretical and practical – and build a closer relationship with industry in order to anticipate employment needs, secure additional funding and ensure that classroom education remained on the cutting edge. This proposal became the basis for the University of Waterloo's highly successful co-operative education programme, widely regarded as the largest and the best university co-op programme in North American and a significant asset to the region.

Chance also played an important role in the early development of the ICT cluster – as it often does. The original plan incorporating the Associated Faculties assumed that it would remain affiliated with Waterloo Lutheran College, which would provide the liberal arts and social science components of the new university's curriculum. However, when the Associated Faculties acquired university status, the original college decided not to participate in the new institution. This serendipitous development resulted in the establishment of the new university with the overwhelming bulk of its faculty and course offerings in the sciences, math and engineering. Waterloo is one of the few universities in North America with a dedicated Faculty of Mathematics. In its formative period the university was mainly concerned with training a pool of local talent and transferring knowledge to the local economy through its graduates. It set out to provide the best possible science, math and engineering curriculum possible. The co-operative education programme, adopted in part out of financial necessity and in part out of the foresight of its founders, rotates students to industry and back to the classroom on a regular basis. This reflexive relationship allows the curriculum to keep up with the ever-changing technological frontiers of industry, while strong industry support for the programme has funded the acquisition of technology to enhance classroom learning. It was thus that Waterloo became one of the first universities in Canada to enable students to actively explore and make use of innovations in the relatively new academic field of study – computing.

A key development in the emergence of the cluster occurred with the installation of the first electronic computer. In the late 1950s, Wes Graham was recruited to the university from IBM to teach a statistics course. With his background in computing, Graham quickly became involved in a project to

launch the new discipline of computer science at the University. The first computer arrived from IBM in 1960 – at a time when there were just over one hundred installed across the country – and it became the foundation of a computing centre that was continuously upgraded. By 1967, the University had an IBM 360/75, the largest computer in Canada. The first major ICT breakthrough at the University was an innovation in software – the WATFOR compiler. As soon as it obtained its first computer, the engineers who wanted to, and the mathematicians who could, started developing software. The only language available that allowed undergraduates to programme computers was FORTRAN, but it was too inefficient for practical use by large numbers of students and faculty. Faced with this limitation, students and faculty at the University invented the Waterloo FORTRAN compiler to speed up programming computations. This new technology, dubbed WATFOR, became the basis for one of the University's first spin-off companies and the first software company in Waterloo – WATCOM (1974) – now the parent company to several generations of subsequent spin-offs in the ICT cluster. The WATCOM spin-off established the basis for a new business model of the relationship between the company and the University. It allowed the founders of the company to retain ownership of their research and intellectual property and thus formed the basis for the University's current intellectual property policy. Furthermore, it provided an important example of the entrepreneurship which served as both a model and a stimulus for successive generations of university spin-off companies.

Geographically, Canada's Technology Triangle encompasses the four municipalities of Waterloo, Cambridge, Kitchener and Guelph. Overall, the region boasts 455 companies involved in the high-technology sector. The companies are spread across four sub sectors: information and communication technology, scientific and engineering services, advanced manufacturing, and the life sciences biotech and environmental sub sector. Of these, information and communications technology accounts for 62 per cent of the high-tech firms and employs 13 000 people or 45 per cent of the total in the high-tech sector (Communitech, 2005). Though there may be several firms involved in a particular market segment or technology niche within the region, they rarely compete directly with one another. This is a testament to the incredible diversity of high-tech activity in the region. The competitive advantage of firms is the uniqueness of their products. Since these products are so highly differentiated, most firms in the region compete globally on the basis of this technical excellence, rather than on cost.

Despite the relatively small size of the local community – the population of the Waterloo region was 438 515 in the 2001 census – the ICT cluster ranks among the top ten among census metropolitan areas (CMAs) in Canada and among the top thirty in North America on most indicators. The ICT manufacturing and service clusters are far from the largest in terms of number

of employees, with 7 165 and 11 615 in the 2001 census. However, their combined employment ranks second behind the automotive parts cluster in the regional economy and the location quotients for each are well above 1.00 (Tables 8.1). Where the ICT sector makes its most significant contribution to the regional economy is in value-added. In a very conservative measure of ICT firms in the region, Canada's Technology Triangle reported that in 2000 ICT companies generated over CAD 8 billion in revenue. Furthermore, between 1993 and 1999 this sector's revenue increased 120 per cent, assets increased by 163 per cent and equity increased 420 per cent, indicating strong actual and potential growth (Canada's Technology Triangle, 2004). While export figures don't specifically target ICT-intensive industry, the research also indicates that most of the ICT firms in the Waterloo cluster produce almost exclusively for North American and global markets. The majority of measured exports from the region came from advanced manufacturing – including ICT-intensive – firms. In 2000, the region exported CAD 8.9 billion worth of products, 55 per cent of the region's GDP that year. Export activity in Waterloo is so significant that measured by the dollar value of exports per employee it ranks third in comparison to all US metropolitan areas (Canada's Technology Triangle, 2004).

Table 8.1. **ICT manufacturing and services**

ICT	Kitchener		Ontario		Canada	
	Manufacturing	Services	Manufacturing	Services	Manufacturing	Services
Number of establishments	138	400	3 357	13 348	7 813	28 420
Total labour force	7 165	11 615	134 375	266 285	242 950	628 885
Average establishment size	52	29	40	20	31	22
Location quotient – employment	2.00	1.25	1.44	1.10	1.00	1.00
Average annual income (CAD)	43 648	43 349	48 942	48 241	45 589	44 445
Compound annual growth, 1998-2005 (%)	2.9	8.7	1.2	6.2	1.4	4.9
% Full-time employment	97.4	85.9	95.9	89.2	95.3	89.2
% Part-time employment	2.8	13.8	4.1	10.8	4.7	10.8
% Self-employment	1.3	3.7	1.3	6.1	1.5	5.3
Average age of labour force	39.2	37.8	38.3	37.6	37.8	37.8
% foreign born	30.1	25.4	43.3	35.6	35.0	26.5

Source: Statistics Canada, Census of Canada, 2001.

The nature of the commercialisation process in the region, and in particular, the role of the University of Waterloo as a key institution in transferring new knowledge into the region has evolved considerably over the

period. Whereas it played a more direct role as a knowledge generator in the 1970s and 1980s, the number of spin-offs and the results of a social network analysis (Xu, 2003) indicate that the degree of knowledge transfer through new firm formation has declined subsequently. Although the University remains central to the continuing development of the cluster, its primary contribution is no longer through the process of new firm formation. Relatively fewer firms have spun out directly since the late 1980s and the post-2000 slump in the demand for high-tech products and services resulted in a noticeable decrease in the availability of financing for start-ups and spin-offs. While the post-2000 downturn in the ICT sector has clearly had a negative impact on the regional economy, on the whole, it has much fared better than some of the other high-tech clusters in Ontario, such as the Ottawa-Gatineau region.

Success factors

The University of Waterloo continues to play three critical roles in the development of the region's ICT cluster. As a major research university, it is at the forefront of knowledge creation in a variety of fields. It also generates a key supply of talent that has contributed to the growth of a "thick" labour market in the local economy. Finally, through the process of knowledge creation and its strong support for entrepreneurship, the university has spun off several prominent firms in the area. While all three roles have had important effects on the shape of the cluster today, the one which attracts the most obvious attention to the local cluster is its role in spinning off high-tech firms. University or public research organisation spin-offs have long been a key goal of public policy makers and economic development officials. For one, they indicate the presence and creation of commercially viable research within a publicly funded institution and are therefore a mark of institutional success as well as a potentially positive return on public investment.

Several aspects characterise the nature of interaction between local high-tech firms and the University of Waterloo. First, while there are many formal relationships such as research contracts and funding of research chairs, much of the knowledge exchange is more informal than formal. Interviewees cite the University not only as an important source of tech transfer and specialised skills, but also as providing both international cachet to the region, and simple social/professional networks; "I contact my friends there if I have a problem". This informal approach underscores the "embeddedness" of the University in the local community, and many people emphasise the organic nature of the impact that the University has on the local community through the interaction effect between the various roles of the University – R&D transfer, skills provision, international cachet, and informal "knowledge networks".

There is, however, a distinct division between those firms that interact with the University and those that do not. For those with linkages to the University, there is a range in the depth and breadth of interaction. Larger firms tend to have more robust partnering relationships, often involving the funding of research chairs, long-term collaborative research projects, university faculty working within the firm, and full-time staff occupied with university and government interaction. Smaller firms, in contrast, tend to engage in short-term, problem-focused research projects. One of the primary reasons cited for not becoming more involved in university research is the amount of time required for commercialisation; while university research project horizons might be two to three years, firms often "need to work on things that need to be commercialised in 6-18 months". Others reported difficulty in accessing what was available, not feeling "in the loop", or had a perception that the research efforts at the University were focused on larger companies. Regardless of involvement with the University on an R&D level, however, almost every firm cited its critical importance as a provider of highly skilled and specialised talent.

The case of the Waterloo ICT cluster confirms that the presence of a robust local talent pool or "thick" labour market is indeed a central factor in the internal dynamics of the local cluster, and that the local college and universities have been the key actors in its development. A key explanation that firms provided for why they are located in Waterloo is that they have come to rely on such advantages as the local labour pool and the international cachet that the area carries in tech circles. They stress the interdependence of several key factors; the most often cited are the presence of the local universities, and the quality of the local talent pool. Most firms indicated that it was a distinct advantage to be located in Waterloo because it provided a ready supply of "smart and competitively priced" engineers and because the University of Waterloo is "one of the best universities in the world for computer engineering". In terms of the relative cost of building software in India, the US, Europe and Canada, Canada, and specifically Waterloo, is seen to be one of the best locations because of the quality and productivity of the local talent pool relative to its cost. The presence of large software and technology-intensive firms in the area, serves as a magnet and an anchor for the highly specialised labour pool. Firms stay in the area because they have invested in the local talent pool through in-house training which has generated tacit knowledge that is difficult to relocate. Some smaller firms indicated that it is "important to be close to [large anchor] companies that are leading edge" because they deepen the labour pool, and smaller firms can hire people that "used to work at RIM … Descartes … MKS, and others".

The University of Waterloo is considered to be the premier educational and research institution in the cluster, but it is only one of the post-secondary

institutions in the region that feeds graduates into the local talent pool. The majority of local high-tech firms require university educated employees, and in many cases, most of the staff has at least a B.Sc., many have M.Sc.'s, and a large number of firms have several staff members with a Ph.D., many in software engineering. While Waterloo is cited most often as the primary source of new hires, especially out of the software engineering programme, Wilfred Laurier University is regularly mentioned as a source for junior marketing and management people. Many firms, in both ICT manufacturing and software, have a mix of university-educated engineers and college-educated technicians, and report that they actively recruit from the local community college, Conestoga College, for their technical staff.

The influence of the local post-secondary institutions on the supply of highly educated and skilled workers in the labour force is identified consistently as a critical factor that drives the growth of the Waterloo cluster. Central to the education and training role that the University plays in the local economy is the co-operative educational programme that dates from the origins of the University. The University has the largest co-operative education programme in the world, with over 11 000 students (60 per cent of the student body) and 3 000 employers, 281 of them local, involved in the programme each year. Co-op programme offerings are extensive and are available in all faculties and departments, and over 100 different programmes. Many of the larger Waterloo firms, as well as global ones, have deep and enduring links with the co-op programme. At Sybase, an enterprise software company that spun-off from the original WATCOM Corporation, with over 250 employees in its Waterloo campus alone, 15 per cent of its current employees is Waterloo co-op students, and more than half of their Waterloo staff is former co-op students. Sybase also actively supports co-op activities at the high school level, and employees speak at local high schools, colleges, and universities about co-op education.

Three key benefits of the co-op programme were reported. First and foremost, it acts as a steady source of new hires, because firms know that the students have work experience, and they get the opportunity to evaluate them in the workplace before hiring them. Second, co-op students act as an important source of knowledge transfer; because they are exposed to new ideas in their courses and bring these ideas to their placements, "a lot of the students are on the cutting edge of the products that we're working on, so we definitely get the benefit from that". Finally, Waterloo co-op students have an international reputation for being of high quality, and as a result, local firms have to compete with global ones to attract the best students, though they retain the benefit of location. The growing international reputation of the University is reflected in the recently staged corporate recruiting drives by both Microsoft and Google, part of a broader upsurge in hiring within the

region. A recent survey of 173 CEOs completed by Communitech reported that 80 per cent of the local firms are currently hiring, with more than half expecting to add 20 per cent to their workforces in the next year.

The multiple roles of local universities and colleges as R&D and tech transfer facilities, as well as suppliers of highly skilled talent, underscores the idea of the "embeddedness" of the local educational institutions in the Waterloo cluster. Regardless of whether firms had formal or informal links to the University, most of them cited the existence of local universities and colleges as a critical element of the cluster's dynamics. Some firms that are heavily networked with a local university describe a deeply synergistic relationship that has emerged and endures as a result of the university being located in Waterloo. Even firms with tangential or no ties to the university – for example, those who only hire co-op students or who comment simply on the international cachet of the University of Waterloo – cite the presence of the university as a critical factor.

Most of the firms in the Waterloo high-tech cluster are engaged in R&D. The Waterloo Tech Industry Profile reported that 76 per cent of the firms have R&D staff located in the region totalling 2 300 people. Large firms accounted for 51 per cent of the total number of R&D staff. In addition to in-house staff, 22 per cent of the firms reported that they also use external sources for R&D (Communitech, 2005, 11). However, there is a wide disparity in the R&D capabilities of large and small firms. Large firms typically have robust in-house R&D units, although even the small ones typically have some type of in-house development group that either focuses on a core idea to get it market ready, or engages in small, limited one-off collaborative projects, or "skunk works".

The firms in the region indicate that they are typically more focused on product development than exploratory research. The emphasis is predominantly on solutions-focused, incremental innovations rather than research-intensive, first generation innovations. Product and process improvements are intended to make the product "faster, smaller, cheaper" and often involve development activities such as the modification of existing software platforms, product updates and new releases, applying the core technology to different applications within the same factory, or making software web accessible. This emphasis on performance improvement and fine-tuning reflects the trend toward what one observer labelled "little R, big D". However, there was also evidence of robust R&D capacity reflected in the strategic decisions of large multinational firms, which often choose to augment their R&D or other technological capacity through the acquisition of local firms. Of particular interest is the fact that, while several large local firms have acquired foreign (primarily European) firms, several large foreign multinationals have acquired indigenous Waterloo firms – Google being among the most recent – to augment their R&D capabilities.

Large, global firms that collaborate with the University on long-term, core research projects, report that the primary benefit of their collaboration is "getting the first look" at research results. They want to keep abreast of what is happening at the research level, even though they know they will not have any proprietary access to the intellectual property (IP). Long-term research is by nature exploratory and speculative, and if they see it being directly relevant to the firm's business strategy, they prefer to keep the project within the company to avoid a potential conflict over ownership of IP. Ongoing involvement in university-based research also gives them an inside eye on developing university graduates who they may want to hire. Firms also report the benefit of research collaboration with the University as increasing their global reach and perspective by "magnifying your insight into the global marketplace", because research professors are usually part of global networks of expertise in their particular research areas. The majority of firms, both large and small, that report R&D linkages with a local university indicate that it is primarily for short-term research, usually of a couple months' duration, on a "project by project basis as needed" and that the primary benefit of collaboration is the ability to do problem-focused research and small co-development projects that allow them access to university expertise and lab facilities.

In contrast to the line of theorising about clusters that emphasises the importance of dense networking relationships among local firms, it is readily apparent from talking to software and ICT manufacturing firms in the Waterloo cluster that the amount of inter-firm collaboration in the form of key customer or supplier relationships is relatively low. The focus of most economic activity – key customers, sources of supply, competitors, and important strategic partnerships – for the vast majority of firms occurs at the continental and/or global level. While larger firms tend to be more focused on the global level, smaller firms, regardless of whether their key customers are currently in Canada, also have a growing global reach, or continental or global aspirations.

Many of the firms in the cluster describe co-location with customers, suppliers, or strategic partners as either unimportant or irrelevant. Of the firms for which proximity to customers is important, only very few have key local customers with whom they are in regular contact, and many firms treat local and non-local customers much the same, communicating primarily by phone or e-mail regardless of proximity. One firm commented that the distinction between local and global is very artificial. Most local firms have an explicitly global focus because for many, even their largest customer contributes only a small percentage of total revenue. This means that they have to "compete locally on a global basis", and find that they have to establish some type of local customer interface capabilities to serve their global

customers. Customer relations – both marketing and support – occur at a virtual level. With "the Internet as the great equaliser", customers from all over the world can visit company websites to extract required downloads and access "24/7 customer support". Firms can choose to visit customers on site to deal with crises or complex issues, so proximity to customers is not a huge factor. Supplier relationships evince similar patterns as the vast majority of firms indicated that co-location with suppliers was not particularly important. Manufacturing firms tend to buy ready-made components, primarily from the US. While some firms do have local suppliers, they were not typically for key components, and when it was for a key component, the reason they sourced supplies locally was "because the type of technology they provide is more critical for us".

Role of SMEs

While there are some extremely large players in the area – Research in Motion (RIM), COM DEV, Open Text, AGFA, MKS, and Descartes Systems being the best known examples – most of the high-tech firms fall into the micro and small-sized enterprise category. Almost 70 per cent of high-tech firms in the Waterloo region employ between one and nine individuals, 20 per cent have 10-49 employees, and around 6 per cent fall into the 50-199 employee range. Only 3.6 per cent of the firms in the region employ over 200 people. Even more striking is the size distribution of establishments in both the ICT clusters – with 71 per cent of the establishments ranked as micro and small in manufacturing and 76 per cent ranked as micro in services. Unlike other concentrations of high-tech activity in Canada, the economy of the Waterloo region is not dominated by one particular sector, such as telecommunications or Internet-based firms. This diversity has enabled the regional economy to weather economic shocks – such as the post-2000 dot-com meltdown – that devastated employment in other leading ICT clusters across the country.

While firms may have some local partners who integrate their technology (or whose technology they integrate) into their product, key strategic partnerships, especially for larger firms, tend to occur overwhelmingly at the non-local level, and most often in the US and Europe. Key partnerships are often with a key customer or a key supplier because "your clients typically become your partners – your best sources of innovative ideas". Local partnerships, both formal and informal, tend to be rather weak and take the form of short, project-oriented collaborations, often on a contracting-out basis, with key local customers. These linkages tend to be "more relationships than formal alliances". From an analytical perspective, firm conceptions of what constitute a strategic partnership are inconsistent and the distinction between key suppliers or customers and strategic partners with whom they share common ownership or IP is not always clear, indicating that these

relationships are perhaps more fluid than is frequently understood. Local partnerships tend to occur primarily between smaller firms. Thus, the primary role of the SMEs in the cluster does not include the classical role of forming part of the supply base or architecture for the larger more globally oriented firms. The SMEs in the Waterloo cluster are typically outward looking themselves and although there is some evidence of sub-clustering at the local level, the relationships among SMEs are typically "soft" and informal.

It is rare, but there is some evidence of robust partnering activity between large globally oriented local firms and smaller ones. The relationships are both formal and informal, focused on taking up useful solutions that are generated by small local software firms, and are often initiated through common customers. One firm identified this as a key strength of the local cluster: "one of the values of being located here is that you have a lot of entrepreneurial small companies who are coming up with interesting solutions that we can attach to our offerings to round them out and bring them to market."

Impact of the cluster on entrepreneurship and employment

Since 1976, the number of high-technology enterprises in the area has grown to a critical mass, starting with a flurry of new firm formation that included a combination of spin-offs from the university, in-migration of firms from outside the region and independent start-ups. Of these sources, university spin-offs have had the greatest impact on the local economy. The University of Waterloo is among the best performing universities in Canada in terms of the number of spin-off companies it has produced. Since 1973, the University of Waterloo has spun off 59 individual high-technology firms, 28 per cent of the total number of high-tech firms born in the cluster (Xu, 2003). Some of the most notable spin-offs include Waterloo Maple Inc (1988), Open Text (1989), Virtek Vision Corp. (1986), Dalsa (1980) and Northern Digital Inc (1981). The University of Waterloo's Technology Transfer and Licensing Office identified 106 spin-off companies employing over 2000 people by the mid-1990s.

Using a somewhat different definition that included the transfer of intellectual resources, the PriceWaterhouseCoopers' study of regional economic benefits identified over 250 spin-off companies from the university (2001). Independent start-ups and second and third generation spin-offs also contributed greatly to the high-tech growth in this period. The recent Waterloo Region Tech Industry Profile reported that 52 per cent of executive respondents were alumni of local colleges or universities, with the majority coming from the University of Waterloo. In addition, 70 per cent were the founders of their own companies, with 31 per cent of these being serial entrepreneurs who had created and sold a number of companies

(Communitech, 2005, p. 13). Much of the university's commercialisation and spin-off success is attributed to its IP policy, which allows ownership of IP to rest with the creator, thus encouraging the individual (faculty or student) to commercialise the idea.

The Waterloo ICT cluster is thus distinguished from some of the leading ICT clusters in North America by the relative predominance of its small and medium-sized enterprises. However, the growth of the cluster can be attributed to the rapid expansion of some of its leading firms, particularly Research in Motion, as well as the slow, but steady increase in the number of smaller new firms. One minor, but significant issue for the cluster is balancing the needs and demands of the leading firms, for office and manufacturing space as well as personnel, while ensuring the adequacy of supply for the smaller firms that have less market power.

The promotion of entrepreneurship among the SMEs has not historically been a central focus of policy at either the national or provincial level. However, a number of more clearly local factors have contributed to enhancing the entrepreneurial skills and capacity of local SME owners and managers. The region is home to a relatively dense network of local business and industry associations that have demonstrated the ability to work together to promote the interests of the local cluster and provide a strong degree of mutual support to each other. The regional culture in the region is characterised by a robust "entrepreneurial spirit" supported by a small and transparent business community and well-developed business associations, as well as a vibrant social network and sense of community. This type of associational activity is evident in the growth of regional associations in the Waterloo high-tech community focused on facilitating the region's economic competitiveness and sustainability. Canada's Technology Triangle (CTT), the Communitech Technology Association, the local Accelerate Network (now part of Communitech) and the Waterloo Region Prosperity Council all play important roles in supporting regional economic development. Communitech, formed in the late 1990s to lobby the government in the interests of high-technology business, has been an important addition to the institutional infrastructure of the cluster in the Waterloo region. It was created as an initiative of a group of high-tech entrepreneurs with the specific purpose of establishing cutting edge infrastructure to support regional high-tech prosperity, expansion and global competitiveness. An often-cited benefit of Communitech membership is access to a pool of shared experiences and support through seminars, Peer2Peer sessions, networking events, and conferences. More recently, CTT, Communitech, the Greater Kitchener-Waterloo Chamber of Commerce and the Cambridge Chamber of Commerce have come together as the Prosperity Council of Waterloo region to collectively create an environment that supports opportunities for prosperity in Waterloo

region. Together they represent more than 3 000 businesses in Waterloo region. Prosperity, for the purposes of the Council, involves initiatives and policies that support wealth creation, supporting the objectives of enhancing the standard of living and overall quality of life in the region.

The University of Waterloo is also active in its support of entrepreneurial education and activities. The mandate of the recently established Centre for Business, Entrepreneurship and Technology (CBET) is to co-ordinate, develop, and support the several strands of UW's entrepreneurship activities, all of which are intended to facilitate the development of UW as an "Entrepreneurial University". More specifically, CBET is intended to research issues such as "how an entrepreneurial culture is created within a university, how faculty members commercialise their technology, issues of the relationship between academic researchers and the business community and issues relating to the impediments of facilitating a transfer of technology between those two communities". In terms of educational programmes, it has recently launched the Master of Business, Entrepreneurship and Technology (MBET), which attracts potential entrepreneurs from around the world, and teaches business skills critical to identifying, exploiting, and establishing new commercial opportunities, with an emphasis on innovative technologies. Undergraduate students can also participate in the Enterprise Co-op programme where they commercialise a business venture of their own rather than work for an existing firm.* Innovate Inc. is a department within the university that provides resources and counselling to faculty and student entrepreneurs, and aims to facilitate the commercialisation of knowledge created within the institution. Finally, the Institute for Innovation Research, affiliated with the Faculty of Engineering, is dedicated to the generation and dissemination of applied interdisciplinary research that advances understanding of entrepreneurship in technology-based enterprises, and to promoting entrepreneurship within universities.

Barriers to cluster development

Although the cluster in particular, and the Waterloo region more generally, are currently viewed as doing quite well, informed observers acknowledge that the region faces a number of critical challenges. One of the key challenges identified by a number of insiders is the fact that many of the leading firms today were founded in the late 1970s or 1980s, but that the pace of new firm formation has fallen off significantly in the past decade and a half.

* According to a university official, in the Enterprise Co-op Program, "a small number of students are encouraged to start their own companies during co-op work terms" and "we take about 10% a year of those people who think they've got it and we give them a very rough screening process where we explain to them that this will be the toughest co-op term that they ever have had. We give them a small amount of funding, somewhere between CAD 6 000 and CAD 8 000, and then we mentor them."

This has raised concerns within the cluster about its internal ability to continue to grow and expand. Closely related to this is the prominent role played by several leading firms in the cluster, such as RIM or Open Text that specialise in particular niche markets. While these firms are currently enjoying great success – RIM with the recent launch of the Blackberry Pearl device and Open Text with the acquisition of one of its leading competitors, Toronto-based Hummingbird, – they are vulnerable to sudden shifts in market demand or the emergence of new, unanticipated competitors. To date, this has not occurred and the future of the cluster looks secure, but it is a potential source of concern.

Another challenge that reflects the opposite side of the coin is coping with the cluster's current level of success. In a recent interview with the local high-tech association, the major issue that was identified was a looming shortage of software engineers due to the high projected level of hiring by cluster-based firms. The recent establishment of a major research facility by Google within the Waterloo region and their announced plans for future hiring, the continuing expansion of RIM within the Waterloo region and the fact that Microsoft views the Waterloo region, and the University of Waterloo in particular, as a major source of recruiting for its Redmond, Washington operations are placing considerable pressure on the ability of both the local post-secondary institutions to meet the demand for highly qualified personnel. The ability of the cluster to satisfy this increasing demand for personnel will be critical for its continued success; as noted above, the strength and "thickness" of the local labour market has been a key driver of its competitive success to date.

Somewhat less threatening, but still of concern, are a number of infrastructural issues that hover in the background of the cluster. While Waterloo is a major urban centre in southern Ontario, it does not enjoy direct transportation connections, especially by air, on it is own. It is located less than an hour's drive west of the Toronto (Pearson) International Airport, upon which it relies for international flight connections. However, the highway corridor connecting the Greater Toronto Area with the Waterloo region (Highway 401) is also the major transportation route for Ontario's substantial trade, especially in automobiles and auto parts, with the US Midwest. Traffic congestion in this corridor is becoming an increasing problem for the entire southern Ontario economy and represents a growing issue for firms based in the Waterloo region. This is a major challenge faced by the region in general, and the ICT cluster in particular, arising from the substantial urban sprawl occurring in the larger Greater Toronto Area and the spillover effect it has on the Waterloo region.

A final issue concerns the lack of political integration among the various municipalities that comprise the Waterloo region – particularly, Cambridge, Kitchener, Waterloo and Guelph. A province-wide process of amalgamating local municipalities in the late 1990s encountered major opposition in this

region and the proposed amalgamation was not imposed on the area. In addition to the four local municipal governments, there exist a number of county administrations in the rural area surrounding the municipalities, as well as a regional level of government superimposed on the municipal ones. The result is a certain fragmentation of administrative responsibility for issues such as region-wide transportation planning or local economic development and business attraction. It also results in a certain amount of duplication of government offices across the many separate jurisdictions in the region. Many of the business leaders in the cluster recognise this political fragmentation as a drawback for the region, but believe that the continuing strength and vitality of the local economy has generated sufficient positive feeling in the region to encourage the local governments to co-operate and work effectively together on common interests.

Role of policy

The case of the Waterloo ICT cluster demonstrates the long-term impact of expanding research infrastructure on the development of local clusters. However, it is important to recognise that, to a large extent, the cluster emerged as an indirect, and partly unintended, consequence of policies that were directed towards meeting other goals and objectives. The cluster concept has only become of interest to policy makers at all levels of government since the early 1990s. As the preceding narrative makes clear, the roots of the cluster lie more than forty years in the past, long before the current period of interest in this phenomenon as a policy instrument.

The case study also raises another issue that confuses many analyses of the origins of clusters – namely, the respective role of different scales of political jurisdiction in the genesis of clusters. While clusters are primarily seen as key features of local and regional economies, and most of the literature and case studies highlight the contribution made by local factors and industrial dynamics, the presence of the senior levels of government lurks in the background. A number of studies highlight the relationship between the cluster concept and others used to analyse the innovative capacity of regional and national economies, principally the innovation systems approach. The concept of "nested scales" describes the interacting set of effects that different levels of government exert on firms operating in a specific geographic location. From this perspective, clusters are seen as nested within, and impacted by, other spatial scales of governance, including regional and national innovation systems, each of which adds an important dimension, or layer, to the economic structures and government policies that impact firms within the cluster.

Various elements of each of these spatial scales may have significant effects on the innovation process and competitive dynamics within the cluster. For

instance, the national innovation system may play a preponderant role in establishing the broad framework for research and innovation policies, in providing a national system of research organisations, in establishing the rules of corporate governance that influence firm behaviour, in setting the rules of operation for the financial system that determine the availability of different sources of financing and time horizons for new and established firms, and finally, for setting the broad framework for the industrial relations, employment and training systems that influence job paths, inter-firm mobility and skill levels for the labour force. Levels of regional specialisation as encompassed in the concept of regional innovation systems play an important role in affecting cluster performance through the provision of the regional/state/provincial research infrastructure, specialised training systems, the broad education system, policies for physical infrastructure and the investment attraction function. At the local level, high levels of civic associationalism, particularly the business-higher education link, can exert a strong influence over cluster development. The local level also plays an important role in the provision of infrastructure, such as roads and communication links, as well as in the governance of the primary and secondary education system, which are significant factors for cluster-based firms in the attraction and retention of managerial talent.

In the case of the Waterloo cluster, the policies that exerted the greatest impact on the development of the cluster have been federal and provincial policies in support of post-secondary education more generally, and research funding, in particular. In Canada the provinces exercise primary responsibility for funding post-secondary education, but there have been broad cost-sharing agreements in place with the federal government since the 1960s. The precise mechanisms used to provide for the cost sharing blend elements of both revenue and expenditure policy instruments. In addition, the federal government has primary responsibility for funding and supporting post-secondary research in Canada through the three federal granting councils, but since the 1980s, this funding support has been augmented and reinforced by a growing number of provincial programmes. In the late 1990s the federal government created the Canada Foundation for Innovation (CFI) to fund the updating of research infrastructure at post-secondary institutions across the country, as well as the Canada Research Chairs (CRC) programme to create 2000 federally funded research chairs at universities (Wolfe, 2005). The increased focus of the province on providing direct support for research was underlined with the creation of a distinct Ministry of Research and Innovation in 2005, with the Premier of the Province as its Minister.

In addition, both the federal and provincial governments offer a wide array of other policies of benefit to individual firms in the cluster. The federal Scientific Research and Expenditure Development (SR&ED) Tax Credit, combined with provincial R&D incentives, offers one of the most generous tax

jurisdictions in North America for the conduct of research. Other federal programmes, such as Technology Partnerships Canada (recently suspended by the new federal government) have provided direct subsidies to firms conducting innovative research. One of the most widely accessed federal programmes is the technology adoption support provided through the Industrial Research Assistance Program (IRAP), administered by the National Research Council. The local IRAP representatives, or Industrial Technology Advisors (ITAs), in Waterloo work closely with the regional high-technology association, with their offices co-located with Communitech and the Accelerator. The provincial government, both prior to and continuing with the establishment of the Ministry of Research and Innovation has dramatically expanded its support for research funding over the course of the past decade – partly to provide matching funding for some of the federal programmes. More recently it introduced a number of key programmes and initiatives designed to accelerate technology commercialisation across the province with a focus around the new MaRS commercialisation centre located in the heart of the university and research hospital district of downtown Toronto (Wolfe, 2006).

Policy adaptations over time

As the preceding discussion of the evolutionary path of the Waterloo ICT cluster suggests, the origins of the cluster owe much more to the broad framework of federal and provincial policies supporting research and education than it does to the direct effect of policies explicitly designed to stimulate cluster development. None of these federal or provincial programmes were specifically designated as cluster initiatives or targeted at cluster promotion. The positive contribution they make to clustering at the local and regional level is a welcome, but indirect, and sometimes even unintended, consequence of their explicit programme goals or objectives (Wolfe and Gertler, 2006).

However, as the cluster has grown and developed, a number of recent initiatives have been directed at providing increased support for the firms in the cluster, as well as accelerating the pace of technology commercialisation and new firm spin-offs from the local universities. Both the federal and provincial governments have adopted limited cluster policy initiatives over the course of the past decade. Canada's National Research Council (NRC) has pursued an explicit strategy of developing clusters around several of its research institutes since the late 1990s. The strategy involves the deliberate effort to transfer technology out of its newly established research institutes and promote the growth of a cluster of related firms in the regional economy around the institute (OECD, 2007). The strategy has been applied to fourteen NRC institutes across the country, but there is no NRC institute in Waterloo and therefore the cluster development strategy has not been implemented in

this region. In its Innovation Strategy, released in 2002, the federal government expanded on this approach in announcing the objective of developing ten internationally competitive clusters across the country, but this strategy was never fully implemented and the objective has not been endorsed by the current federal government.

A more recent policy initiative launched by the Ontario government, the Biotechnology Clusters Innovation Program (BCIP) was directed towards the explicit goal of cluster promotion. The provincial Minister of Innovation launched Ontario's Biotechnology Strategy in June 2002. As part of that strategy, the government announced a new programme initiative: the Biotechnology Cluster Innovation Program (BCIP) with the goal of accelerating the development of Ontario's biotechnology clusters by supporting the commercialisation of infrastructure projects and the diffusion of biotechnology-related innovations into knowledge-based or traditional industry sectors. The programme consisted of two distinct phases. In the first phase, the government supported the development of plans that address the innovation capacity of Ontario's regional biotechnology clusters. The programme provided funding up to a maximum of CAD 200 000 on a matching basis, to regional consortia for the development of a Biotechnology Cluster Innovation Plan, including one in the Waterloo region. The second phase of the programme was designed to support the development of infrastructure such as commercialisation centres, research parks and other regional initiatives that promote entrepreneurship and innovation. Eleven regional consortia developed regional innovation profiles and corresponding regional cluster strategies in the first phase of the programme. Between late 2003 and early 2005, provincial officials held a series of seminars with representatives of the eleven consortia, as well as separate meetings with the individual groups. The original BCIP strategy developed for the Waterloo Region had little direct involvement from the ICT cluster or significance for it, given that the overwhelming focus of the initiative was on biotechnology. However, this changed in 2005 with the refocusing of the programme on a broader cross-section of industrial sectors and clusters.

In the provincial budget of May, 2005, the government launched the follow on phase of the programme in the form of a series of "regional innovation networks" (RIN). These are described as "multi-stake holder, regional development organisations established with provincial funding that support partnerships among business, institutions and local governments to promote innovation". The regional innovation networks are mandated to expand beyond their original focus on the life sciences to include other areas of innovation excellence, such as information technology, energy conservation and advanced materials, depending on their local strengths and opportunities. The networks are also described as constituting part of a multilayer commercialisation

network that includes the province, multiregional groups focused on key technology areas or industrial sectors and the original regional consortia, described above. The constituent parts of the network are to support two complementary sets of activities – those that build on and connect the components of the network and those that contribute to a more effective alignment of existing federal, provincial and local research infrastructure and related innovation assets. A key function of the networks is to increase the knowledge flow and build linkages between existing research institutions and firms in order to build industrial capacity for the uptake and adoption of new research and technology. The overriding goal of the RIN's is to increase regional innovation capacity by addressing commercialisation gaps in the existing level of support for small and medium-sized enterprises in regional networks across the province in innovation-intensive sectors and clusters, including Waterloo. The programme also aims to develop strong networks that can increase the accessibility of the public research infrastructure and resources for firms (Wolfe, 2006). While the transition from the earlier BCIP programme to the RIN's is still in its early stages, overall, the programme displays many of the positive features of bottom-up strategic planning. In the Waterloo context, the local RIN is building upon the cluster's past success, the existing strength of the post-secondary research infrastructure and recent new initiatives, such as the Waterloo Research and Technology Park (see below), to accelerate the commercialisation of new research results and sustain the process of new firm formation and growth within the cluster.

A related initiative designed specifically for the Waterloo region has been the establishment and marketing of the new Research and Technology Park. Support for the Research Park has taken the form of a partnership between the University of Waterloo, the Government of Canada, Province of Ontario, the Region of Waterloo, the City of Waterloo, and Communitech. The new Research Park is located on the northern boundary of the University of Waterloo and is already the site of several new buildings, one of which houses Communitech, the Accelerator Centre, the local IRAP offices, legal offices and other support functions directed towards the promotion of local firms in the cluster. Other buildings, both completed and currently under construction, will house some of the leading firms in the cluster or provide space for growing firms to expand into, as well as a number of amenities deemed to be attractive to employees in high-tech firms. The co-operative role played by all major levels of government plus the key cluster actors in designing, financing and developing the new Research and Technology Park is strong testament to the importance they all attach to the further growth of the cluster. A number of strategic planning exercises launched through the Prosperity Council and involving the key industry associations in the region are also directed towards supporting the growth of the cluster.

Future policy challenges

The crucial implications to be drawn from the preceding analysis are the necessity of developing a rich and thick labour market in the skills required to build the industries and technologies in the cluster, then to support the interaction within the cluster through the nurturing of strong social networks among government partners and industrial leaders, thus building a sense of civic engagement. This has worked well to date largely through the unplanned but highly effective interaction between the federal and provincial governments, strong support for building the local post-secondary research infrastructure in the region and providing increased research funding over the past ten years to those institutions.

The cluster as it is currently constituted faces a number of critical policy challenges. As noted above, the rapid pace of new firm formation in the region was stronger in the 1980s and early 1990s than it has been over the past decade and a half. Despite the increase in the number of experienced entrepreneurs in the region, some of whom devote considerable time to acting as angel investors and mentors to new firms, many key civic and business leaders in the region express concern over this recent decline in the pace of new firm formation. Given that the preceding pace of firm formation was largely unplanned, it is not clear that this deficiency can be remedied purely by policy measures. The recent expansion of the University of Waterloo's efforts in promoting entrepreneurship teaching and research, and the activities of initiatives such as the Enterprise Co-op programme and Innovate, Inc. within the university may help remedy this deficiency but it is still too early to tell. In addition, as noted above, one of the most effective mechanisms for providing these kinds of supports are through the peer to peer mentoring networks established and maintained by the local high-technology industry association, Communitech. Government policy could be designed to provide more direct and explicit support for these initiatives than it has in the past. There is also considerable scope for more effectively integrating the activities of the various local industry associations, discussed above, into the activities of the Waterloo Region RIN.

Another current policy challenge facing the cluster is the recent shortage of a sufficient number of graduates to meet the perceived demand for future hiring, both as a consequence of the internal expansion of leading firms, such as RIM, as well as the inward location of global firms, such as Google. Expansion of university programmes in the areas of high demand would appear to be the most obvious solution. This was done in the late 1990s through the provincial Access to Opportunities Program that aimed to create 51 000 new graduates in computer-related programmes, but there is some concern that recruitment of sufficient applicants into such programmes might prove more challenging than it was a decade ago.

Lessons for other clusters

The factors which contribute to the emergence of clusters in the first place and sustain the dynamism and growth of cluster-based firms remain of critical interest. The case of the Waterloo ICT cluster sheds light on several key issues related to the core question of location: if co-location with other firms is not a main driver of local economic growth and innovation, what accounts for the resilience or "stickiness" of the cluster? Local economic growth in the Waterloo cluster is a result of the interaction between location, institutions and a regional entrepreneurial culture. Whereas purely locational factors, based on demanding local customers, suppliers and competitors, do not fully account for the emergence or growth of the Waterloo cluster, the presence of key local institutions – primarily the University of Waterloo and a dense network of local civic associations – provide the glue that retains and sustains innovative high-tech firms.

The case of Waterloo Region's ICT cluster also provides support for the argument about the long-term impact of expanding research infrastructure on the development of local clusters. In the Waterloo case, the mobilisation by local business leaders to secure a charter for a new university, financed with federal and provincial funding, and their foresightedness in structuring a curriculum around math, sciences and engineering and creating a pioneering programme of co-operative education, all laid the groundwork for the future emergence of a dynamic and growing information technology cluster. However, one should not overlook the supportive role played by the senior levels of government whose expansion of support for the post-secondary education system in the 1960s made possible the establishment of a new university. It was the specific pattern of interaction between dynamic, visionary leaders at the community level with the increase in federal and provincial funding that created the local antecedents essential for the emergence of the information technology cluster (Wolfe and Gertler, 2006).

Whether intentional or inadvertent, one of the most effective public policies for seeding cluster development is a sound investment in building the research and skilled labour base in a region. The establishment of a strong local talent pool of highly skilled and knowledgeable workers both feeds the growth of the local firms in the cluster as increasing returns begin to take hold, and attracts outside firms to locate in the cluster in order to gain access to the local knowledge-base and the skills embedded in the local labour market. However, the presence of a strong local research infrastructure and a "thick" local labour market may not be sufficient on their own to spur the formation of a local cluster. The Waterloo ICT cluster owes its current success to the effective intersection of a strong sense of civic engagement with the rich knowledge resources afforded by its strong research infrastructure and talented local labour market.

The findings from this case study in Waterloo echo the findings from cluster studies in other regions and economic sectors across Canada, and suggest a different conception of what factors really matter in cluster formation and sustenance than some of the dominant theories in the literature. Concerning the dynamic relationship between local firms in the cluster, the findings indicate that for many of the most successful clusters the most important end-user markets and knowledge networks are continental or global (Wolfe, Davis and Lucas, 2005). The most significant local factor is a "thick" labour market that provides a steady supply of the highly skilled personnel for firms to draw upon. This factor combined with the development of strong social networks and a strong sense of civic engagement is crucial.

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