CHAPTER

HISTORY, CULTURE AND PATH DEPENDENCY: ORIGINS OF THE WATERLOO ICT CLUSTER

Jen Nelles, Allison Bramwell and David A Wolfe

INTRODUCTION

The search for effective cluster strategies remains an elusive goal, at best. Policy-makers at both the regional and local level remain fascinated with the potential of cluster-based economic development to accelerate the growth of their local and regional economies. While previous policy studies have provided extensive lists of the key factors or prerequisites associated with the growth of strong and dynamic clusters, they are less successful at prescribing the most effective policies to support the formation of clusters or stimulate their early development. Indeed, some of the leading practitioners in the field maintain that clusters cannot be created by policy fiat and the best that governments can hope to do is support their growth, once they have formed. However, closer examination of the origins and development of specific clusters suggest that the prospects for cluster policy are not quite so bleak. Central to this process is the relative importance of history and path dependence in the origins and development of these clusters. Particularly significant is the nature of path dependencies created by small, initial - often random events - as opposed to the role of conscious direct, policy actions in contributing to cluster development. The case of the ICT or high-tech cluster in Waterloo, Ontario, is instructive for

developing a better appreciation of the implications of these factors for the process of cluster formation.

The industrial 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 the country. Geographically, Canada's Technology Triangle (as the region is also known) encompasses the four municipalities of Waterloo, Cambridge, Kitchener and Guelph. The region boasts 468 companies involved in either the production or facilitation of high technology. In addition, the local economy is also home to strong firms and employment in automotive, advanced manufacturing, biotechnology, business and financial services, education, environmental science, food processing, furniture manufacturing, high tech, logistics and warehousing, R&D, and telecommunications (Canada's Technology Triangle, 2004). Currently automotive/metal manufacturing, education and business services sectors are the largest employers in the regional economy (The Institute for Competitiveness and Prosperity, 2003). The economy is quite diverse within each sector. Unlike other hotbeds of high-tech activity, 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 region to weather economic shocks - such as the post-2000 dot.com meltdown that devastated employment in other leading ICT clusters across the country.

Since its early days as a bustling manufacturing centre, the Waterloo region has been an important point on the Southern Ontario industrial landscape. Kitchener-Waterloo has been the home to major nationally and internationally successful corporations for more than a century, from Dominion Electrohome Ltd to present day success, Research in Motion Inc. 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, e-commerce, robotics and laser technology. 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 regions cluster-based success.

DIMENSIONS OF THE WATERLOO ICT CLUSTER

Despite the small size of the community,[1] the WaterlooICT cluster ranks among the top ten census metropolitan areas (CMAs) in Canada and top thirty in North America on most indicators. This section evaluates the position of the cluster relative to major competitor CMAs in Canada and North America, as well as the contribution of high tech industry to the local economy. The 2004 Waterloo Region Tech Directory lists over 400 firms active in the technology economy of the region (Silicon Valley North, 2004). While there are some extremely large players in the area – Research in Motion (RIM), COM DEV, Open Text, AGFA, Descartes Systems for example – most of the 468 high tech firms fall into the small-medium enterprise category. Almost 70 per cent of high tech firms in the Waterloo region employ between 1and 9 individuals, 20 percent have 10-49 employees, and around percent fall into the 50-199 employee range. Only 3.6 percent of the firms in the region employ over 200 people.

Most figures for total employment in the regional high tech economy tend to be very low in failing to account for advanced manufacturing, high tech financial services and biotechnology.

[1] The population of the Waterloo Region (consisting of Kitchener, Waterloo, Cambridge, and the townships of North Dumphries, Wellesley, Wilmot and Woolwich) was 438,515 in 2001 (Statistics Canada, CMA populations, 2001)

The adjusted data from this cluster study show that high tech firms in the Waterloo region employed 11,160 people in 2002. The PWC TechMap notes that 45% of total employment growth is in high tech sectors, suggesting that ICT-intensive industry will continue to gain on more traditional industries (PWC, 2001a). Work by ISRN researchers indicate that the region has an employment labour quotient (LQ) greater than 1[2] marking a significant concentration of high tech labour (Vinodrai and Spencer, 2004).

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 Canada's Technology Triangle reports that in 2000 ICT companies generated over $8 billion in revenue. Furthermore, between 1993 and 1999 this sector's revenue increased 120 percent, assets increased 163 percent and equity increased 420 percent indicating strong actual and potential growth (CTT, 2003).

While export figures don't specifically target ICT-intensive industry our research indicates that most produce almost exclusively for North American and global markets. The majority of measured exports came from advanced manufacturing – ICT-intensive – firms. In 2000, the region exported $8.9 billion worth of products, 55.0 percent of the region's GDP that year (CTT, 2003). This suggests that, if more accurate measures were available, ICT-intensive industries may account for a significant proportion of this activity. Export activity in Waterloo is so significant that on measures of dollar value of exports per employee that it ranks third in comparison to all US metropolitan areas (CTT, 2003).

The Waterloo ICT cluster ranks fairly consistently, in the top ten, in comparison to other Canadian ICT clusters. The following statistics are drawn from Vinodrai and Spencer's (2004)

[2] The Institute for Competitiveness and Prosperity finds an Employment LQ in Canada of 1.02 (0.88 for North America) while Vinodrai and Spencer (2004) find a Canadian LQ in ICT approaching 1.35. The latter data is likely more accurate in that it is based on a more nuanced definition of ICT industry derived from the initial SIC cluster definitions of this study.

work on cluster indicators for the ISRN project. On measures of critical mass and growth Waterloo ranks 6th (out of 27) behind Ottawa-Hull, Calgary, Toronto, Montreal and Vancouver with an employment LQ of 1.35 and 13th with an establishment growth rate of 4.0 percent (1998-2002). In terms of average annual incomes of ICT employees Waterloo comes in at around the median income, $50,000, in 9th place just ahead of Montreal.

The Waterloo cluster performs similarly on measures of knowledge intensity. The region ranks 7th in terms of the percentage of the ICT labour force with a Bachelor of Arts (B.A.) degree or higher. Over 32 percent of the labour force in the region has a BA or higher. However, this measure may not accurately reflect the knowledge intensity of the labour force because it does not capture those employees with college degrees. Many ICT firms in the region employ graduates from the Conestoga College technology and technologist program. Though not university graduates these individuals are arguably key knowledge workers. If this group of highly skilled individuals in accounted for over 57 per cent of the regional labour force consists of highly skilled personnel based on educational attainment.

Another measure of knowledge intensity, which uses Richard Florida's creative class index, finds that the Waterloo region's ICT workforce employs around 63.8 percent creative class workers. Further subdividing this measure reveals that 28 percent of the workforce is composed of those in science and technology occupations while 60 percent are considered knowledge workers Waterloo ranks 8th on this measure, just at the national average.

Other indicators of cluster performance are number of patents filed and dollar value of venture capital deals. In the period between 1998 and 2002 a total of 23 ICT patents were filed from the Waterloo region. On this measure Waterloo ranks 6th – behind Toronto, Montreal, Ottawa-Hull, Vancouver, and Oshawa but just ahead of Calgary.

The relatively small number of ICT patents filed over this period has several potential explanations. It could indicate a maturing cluster – the initial rush of radical innovations that characterized the earlier days of the cluster may be in the process of settling down. Indeed, our qualitative work suggests that most firms in the region are engaged in incremental innovation, improvements on earlier products and processes. Another possible explanation is that patents are being filed out of head offices outside of the region. A study commissioned by the Canadian Federal Department of Foreign Affairs and International Trade identified 196 foreign-owned firms in Waterloo in 2001 – the third highest absolute number of firms of any CMA in Canada (Matthew Fischer & Associates, 2001). Many prominent firms from the US and Europe have research and development operations in the region and may file any patent applications from home office locations. Finally, it is also possible that because of the definition of ICT patents the numbers do not capture patents filed in crossover sectors.

Venture capital numbers are also low for the region. With considerably under $1 billion in VC deals in ICT between 1998 and 2003 Waterloo ranks 5th in Canada. Again, this figure may not accurately reflect cluster performance. Many firms in the region are small to medium sized enterprises with low operating costs and financed by own source revenues. Most venture deals in the region have been with larger firms involved in the production of a physical product or component. Another factor could be the entrepreneurial nature of many firm founders. Some, but not all, prefer to maintain control over their operations rather than give equity to VCs. In any case, Waterloo performs relatively well on this indicator given its size and the level of development of the cluster.

An analysis of these indicators suggest that, while Waterloo is not a global powerhouse in the ICT industry as of yet, the region and the industry has excellent potential for growth. The

diversity of the regional economy and amongst ICT-intensive firms bodes well for long-term stability and innovative capacity. While the region has a ways to go to seriously compete with Canadian capital cities on these indicators it is, nevertheless, an interesting case study - of a small Southern Ontario city that has developed a significant presence in the ICT industry.

CLUSTER FORMATION AND PATH DEPENDENCY

The concepts of path dependency and lock-in imply that the technological trajectory of specific regions and localities is historically determined by the factors that influence their economic development over time. The presence, or absence, of key institutional elements of the local or regional innovation system may affect both their innovative capacity and their potential to serve as nodes for cluster development. Similarly, the ability, or inability, of the local or regional economy to develop the underlying conditions of trust and social capital that contribute to the presence of a learning economy may create a condition of lock-in to a specific innovation trajectory.

The concept of path dependence originates with the desire of evolutionary economists to account for the factors which determine the selection mechanisms that exist within the process of technological choice and the natural trajectories that emerge from those patterns. Since the approach was formulated in the mid-1980s, it has been applied across a range of disciplines, including economic geography, innovation systems analysis, studies of the welfare state, and increasingly within the historical institutionalist school in political science and sociology. The concept of path dependence was initially elaborated to explain how and why certain technologies emerge and prevail over competing technologies in periods of rapid innovation when the marketplace is characterized by a number of alternative technological designs. Paul David

defines a path-dependent sequence of economic changes as one in which important influences upon the eventual outcome can be exerted by temporally remote events, including those dominated by chance elements, rather than systematic forces. He suggests that in a dynamic process, positive feedbacks are generated by strong technical complementarities on the supply side of markets, and/or the interdependence of customer preferences operating on the demand side. These may arise as well from learning effects and habituation associated with the sunk cost effects of new technologies – such as those involved in learning how use a new program (David 1997, 17) .

Evolutionary economists, historical sociologists and economic geographers have expanded on the original application of the concept. While the specifics of the application vary across this range of disciplines, social scientists suggest that path-dependent analysis shares several common features. In the first place, it involves the study of causal processes that are sensitive to a series of events which occurred in the early stages of the causal sequence. Events that occur early in the sequence tend to exert a disproportionate influence over the long term development path of the sequence. Secondly, these early events involve a high degree of chance or contingency that cannot be explained purely on the basis of the starting conditions or initial factor endowments. Similar starting conditions may lead to a wide range of possible outcomes. This fact makes it particularly difficult to forecast patterns of development based on the initial conditions. Finally, once the chance events have occurred, the path-dependent sequence exhibits a more deterministic pattern, involving a large degree of irreversibility. In economic and geographic systems, the degree of irreversibility is strongly reinforced by the effects of increasing returns to scale (Mahoney 2000, 510-11; Davis 2004).

The complementary concepts of path dependence, increasing returns and lock-in have obvious relevance for understanding the historical paths taken by production regions. Once a region establishes itself as an early success in a particular set of production activities, its chances for continued growth tend to be high. While this may be to some extent reducible to the success of dominant 'lead' firms in the region, the aspect of this process of greater interest has more to do with the collective processes and forces at work: local social and economic institutions and, yes, culture. In recent years, economists such as Paul Krugman and Brian Arthur have drawn upon this rich tradition of earlier ideas within economics and geography to fashion more formalized models of territorial development. Krugman's (1991) specifies the types of supply side externalities that generate localized increasing returns. The first source is the large, deep pool of specialized labour created by the concentration of firms within the similar industries in the same location. The second arises from the fact that a local concentration of firms in the same industry can also support a larger number of specialized local providers of intermediate inputs and services, and thus reduce the cost to firms. Finally, the co-location of similar firms in a region can generate positive technological externalities or spillovers that can flow more easily among the similar firms than over longer distances (although Krugman is more skeptical about this externality). Overall, Krugman endeavours to show that the phenomenon of increasing returns is a key aspect of the process of industrial clustering that leads to a pathway of increasing sectoral specialization in particular regions over time.

While Krugman's work focuses on the way in which scale economies and positive externalities can feed the process of industrial clustering, Brian Arthur's work focuses more specifically on the way in which agglomeration externalities contribute to the concentration of firms in specific regions. Arthur's interest in the question of industrial location grew out of his reading of Jane Jacob's classic work, *Cities and the Wealth of Nations*. He was "greatly taken by her haunting accounts of places and regions that had got 'passed by' historically in favour of other places and regions that had got ahead merely, it seemed, because they had got ahead" (Arthur 1994, xviii). . His seminal paper, written in 1986, provides a basis for explaining

industry location patterns. The challenge lies in dealing with the degree of uncertainty introduced by agglomeration economies and determining which locations will win out when firms want to congregate where similar firms are located. His model accounts for both historical accidents and agglomeration dynamics.

> The process is path-dependent . . . in that a slightly different order-of-choice history early on could sway the outcome to a different location becoming dominant. An attractive location will likely be favoured by many firms early in the choice order, and therefore it has a larger probability of predominating. Attractiveness, interacting with historical accidents of choice-order, determines the outcome (Arthur 1994, 58–59).

CULTURE, FIRM BEHAVIOUR AND INSTITUTIONS IN THE WATERLOO CLUSTER

The legacy of Waterloo's cultural roots, firm behaviour and core institutions are clearly visible in the contemporary cluster. While the proportion of German population in Waterloo is diminishing the cultural community that dominated the region during its formative periods has clearly contributed to the modern regional culture. The very fact that the region has such expertise in high tech manufacturing and high value-added ICT industries owes a lot to an early regional specialization in engineering-intensive industries. Furthermore, firm organization and behaviour seems to parallel the small and medium sized enterprise (SME) model favoured by German – often family-run – firms.

The cluster also owes much of its continued success to local institutions with roots back to the early twentieth century – most notably, the University of Waterloo. The University of Waterloo is one of several colleges and universities in the region with close ties to local industry. However, more than any other it has had a singular and formative effect on the regional economy – decisions about the shape and emphasis of university programs seem, in hindsight, to have had

a decisive influence on the future of the region. The following section traces the influence of these regional characteristics on the current economic landscape.

German Roots and Regional Culture: The Foundations of an Entrepreneurial and Globally-Oriented Cluster

This paper argues that the ethnic German composition of the community helped to shape the early industrial character of the region. Expertise in manufacturing produced a vibrant and diverse economic centre. The socio-cultural makeup of the community helped retain successful firms and engage the population in regional governance. Though the ethnic makeup of the Waterloo region is now much more diverse, some of the qualities associated with Germanic culture continue to influence the local industrial landscape, firm structures and strategies, and patterns of local associational activity.

The earliest industries to emerge in the region included brewing/food and beverage manufacture, textiles, wood processing and working and rubber manufacturing. Although there was a mix of different industries between the two main towns of Kitchener and Waterloo, Kitchener (or Berlin, as it was called until 1916) specialized in rubber and woodworking as well as their related industries (boot making and furniture building, etc.), while Waterloo was home to industries such as distilleries, breweries, textile mills and heavy agricultural manufacturing. These industries and towns grew through the late nineteenth century with the establishment of the Grand Trunk Railroad connection to Toronto, as well as the construction of the large hydroelectric plant at Niagara Falls that brought cheap power to the region.

Part of the early manufacturing success of Berlin and Waterloo is attributable to the ethnic roots – and hence local culture – of the region. Initially settled by Pennsylvania Mennonite

farmers – quickly surpassed in population by German-speaking immigrants – these towns formed the urban center of ethnic-German settlement in Ontario in the nineteenth century. Early industrial success derived from the skill sets of early inhabitants and socio-cultural factors that contributed to the 'stickiness' of the region. The ethnic German population brought an expertise in engineering and artisanal manufacturing – a product of the industrial character of German manufacturing. Local inhabitants either formed their own companies or used their knowledge as laborers. A quick scan of the earliest firms in the region reveals a certain degree of technical expertise – Breithaupt tannery, Hoffman's planning mill, Vogelsang's button factory, Wegenast's saw and planing mill, Merner's iron foundary, Ziegler's cabinetmaking – particularly with respect to power generation and transfer.[i]

What is remarkable is that these, and later companies, remained in the region despite compelling pressures to relocate to larger industrial centers. Of the 102 manufacturing businesses established between 1850 and 1914, entrepreneurs of German origin founded approximately 73 per cent. Though striking, this number is commensurate with their share of the total population (Walker, 1987). What's more significant is that entrepreneurs, as well as workers, were attracted to Berlin and Waterloo by the German-language press, musical societies and other clubs, and distinctive denominational churches. These socio-cultural factors bound these entrepreneurs to the community and the regional economy when, for purely business reasons, they might have moved away. This cultural attraction contributed to persistently high levels of local firm ownership and to considerably higher associational engagement within the community relative to Ontario towns of similar size.

The interwar years saw the growth of more complex engineering, metalworking, food and automotive related industries on the foundation of the traditional manufacturing base. Several

insurance companies established in the 1880s also grew and thrived during the 1920s. The growth of the insurance companies served as an important source of employment and a cushion against the boom and bust cycles of the economy. The more modern sectors – insurance, automotive and metalworking industries – contributed to the relatively rapid recovery from the decline of the Great Depression and they continued to contribute to high growth as key sectors furnishing the manufactured requirements of World War II.

German regions are celebrated for their technical excellence in key engineering industries – the automotive sector, electronic, machine tool and printing machinery. The skills that ethnic German individuals brought to the community clearly helped shape the industrial character of the region towards more advanced manufacturing techniques from the mid-1800s to 1945. Now that the Waterloo region is home to a significant agglomeration of high tech firms, it is tempting to overlook the continuing influence of the German tradition of engineering expertise. One need only look at employment statistics and regional skill sets to see that, while IT is on the rise, it is the advanced manufacturing component of family of high tech firms that is really dominant. In 2001 construction and manufacturing accounted for the majority of employment in the region – 34.3 per cent (CTT, 2004). Advanced manufacturing firms also account for a large percentage of exports and GDP.

The influence of German cultural tradition is not limited to advanced manufacturing and engineering-intensive industry. Some of the same characteristics of firm strategies and structures found in successful German regions are also present in Waterloo. Another feature of the Waterloo economy often associated with German regions is niche production and competition on *technical excellence* rather than cost (Cooke and Morgan, 1998). Production activities in the region are often decentralized and engage a dynamic group of highly skilled workers. Evidence

for this can be found in the incremental and customer-driven innovation process where solutions-based research will involve different skill sets and workers depending on the nature of the project.

High tech firms in the region fall into several different categories such as wireless, systems and peripherals, applications, networking, security, data compression, among others. Though there may be several firms involved in data compression technologies within the region, they rarely compete with one another. One respondent noted: "There may be a lot of software firms here, but nobody does the same thing". 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. This feature of local production culture also distinguishes Waterloo from other major high tech clusters.

Firm strategies carry the imprint of Germanic cultural influences, but so do firm structures. The prevalence of small and medium-sized enterprises, particularly founder owned and operated ones, is also evidence of German cultural origins. The high tech economy of Waterloo is overwhelmingly characterized by SMEs – particularly in the IT sectors. Cooke and Morgan argue that the *Mittlestand*, or mid-size company, is the backbone of successful German regional economies. From our empirical research in Waterloo it is clear that some characteristics of the *Mittlestand* – family/founder ownership, an emphasis on customized production, the role of system integrators, and some networking characteristics – do apply to the high tech SME landscape in the region.

Beyond explicitly German companies, many high tech firms in the region tend to have adopted the practice of streamlined administrative structures, private ownership and founder

operators. From one perspective this could be the result of the *type* of high tech production these firms are engaged in. After all, many produce in niche markets, require a relatively small number of highly skilled individuals for production, and require little in the way of capital. Most have aspirations to grow revenues, but not the physical size of their companies. However, interview data suggests that many high tech SME entrepreneurs are hostile to the idea of incorporating their firm into a larger concern through mergers and takeovers and value the creative control that the position of founder-operator affords. This is one relatively prevalent characteristic of the Waterloo entrepreneurial culture that may be related to the ethnic German culture of *Mittlestand*. Cooke and Morgan identify certain types of relationships that characterize the associational strategies of *Mittlestand* firms. One aspect of *Mittlestand* networking is that it is often mediated through associations – business associations, tech transfer centres etc. This type of associational activity in the WATERLOO high tech community through Communitech and peer-to-peer networks conforms to this mode of operation.

The legacy of Waterloo's ethnic German origins is evident today in a shared sense of community embeddedness. Entrepreneurs in the region tend to be active in sustaining the quality of life and business in the region. Whether through philanthropy in support of local cultural infrastructure or education or through involvement with various associational bodies, many local entrepreneurs are also community leaders. Originally it was the Germanic socio-cultural features of the region that fostered community engagement. Though only a few vestiges of this socio-cultural environment remain, the tradition of community embeddedness and engagement is still very strong relative to other communities of similar size. Like their forbearers local entrepreneurial firms have chosen to remain in Waterloo rather than relocate to larger centres of high tech activity. Part of this has to do with the economic advantages that the region –

particularly the pool of highly skilled labour – however, almost all the respondents mentioned a high quality of life and community as significant reasons for staying.

The Evolution of the University of Waterloo: Designing an Institution that Shaped an ICT Cluster

In our interviews with high tech firms in the region the University of Waterloo invariably came up. Whether the firm engaged in collaborative research with individuals in the university, was a spin-off, used faculty or grad students as formal or informal consultants and problem solvers, funded a chair, employed co-op students or just acknowledged the various engineering, math and computer science programs as a source of talented labour UW was always mentioned. In short, regardless of levels of interaction, most actors in the region regard the University of Waterloo as the institutional core of the high tech economy.

The University of Waterloo has played a number of key roles in the development of the region's high tech economy. The University of Waterloo is a major research university and is at the forefront of knowledge generation in a variety of areas, and therefore is a major source of knowledge creation in the area. It is also a key source of talent that feeds the local labour pool. Finally, in the process of knowledge creation the university has spun off several prominent firms that have established themselves in the area. All three roles have had important effects on the shape of the cluster today.

University or public research organization (PRO) 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. Spin offs also play a key role in cluster literature in that they tend to be indicative of regional specialization in a given area supported in an arguably self-reinforcing process by supportive regional institutions.

The University of Waterloo is among the best performing universities in Canada in terms of the number of spin off companies it has produced [*have the stats somewhere – in the process of locating them, will add in later]. Furthermore, the types of spin off the university has produced can generally be classified in high tech, ICT-intensive firms.

The region is host to three educational institutions in addition to the University of Waterloo. The University of Guelph (1964), Wilfred Laurier University (1960) and Conestoga College (1967) specializing in agri-biotech, business and technical trades respectively have all spawned high tech spin-offs. However, of these, the University of Waterloo has undoubtedly been the most significant. Since 1973, the University of Waterloo has spun off 59 individual high technology firms, 28% of the total number of high tech firms born in the cluster (Xu, 2003: 63). Some of the most notable spin-offs[ii] include Waterloo Maple Inc (1988), Open Text (1989), Virtek Vision Corp. (1986), Dalsa (1980) and Northern Digital Inc (1981).

One of the sources of the University's spin off success is often claimed to derive from its intellectual property policy. Where at many universities the institution claims ownership of commercially viable intellectual property, at the University of Waterloo ownership of IP rests with the creator, thus encouraging the individual (faculty or student) to commercialize the idea. The combination of a permissive IP policy and regional entrepreneurial culture often result in new venture formation.

Some interesting observations emerge from the nature of the commercialization process in the region. The role of the University of Waterloo as a key institution in the cluster has

evolved over the period. Whereas it played the key role of knowledge generator in the 1960-80s, the level of spin-offs and the results of social network analysis (see Xu, 2003) indicate that knowledge transfer within the region is on the decline. The findings from our interview questions on the impact of the university on local firm innovation echo this finding. Although the University of Waterloo continues to play a key role in the development of the cluster, its primary contribution is no longer through new firm formation. The post-2000 slump in the demand for high-tech products and services had a negative impact on the regional economy, but on the whole it has fared better than other high-tech clusters, including Ottawa-Hull. A noticeable decrease in available financing affected the rate of start-ups and spin-offs. However, as one observer noted, while times in the region are tough, the wave of restructuring has not caused the magnitude of upheaval felt by the recent reversal in other tech communities such as Silicon Valley, Vancouver and Ottawa (Crowley 2002).

While the university has undoubtedly contributed much to the local high tech economy through successful spin off firms perhaps its most important contribution lies in its role in training a significant proportion of the local labour force. University of Waterloo graduates make up a major proportion of the high tech labour force – of the incredibly valuable human capital in the region [* I think we could use some stats here about how many firms mentioned talent as a significant local asset as well as, if we can find some, on how many UW grads are employed in the region – working on it]. Not only are graduates well trained within the university, they often come replete with practical experience gained through co-op placements in firms all over North America (but, for the most part, in firms in the region). Furthermore, many graduates are highly innovative and entrepreneurial – two qualities emphasized in normal stream undergraduate

courses and specifically targeted through special limited enrolment programs and departments designed to provide a business background and resources to potential entrepreneurs.[iii]

The fact that the University of Waterloo has developed such an expertise in training and graduating highly talented, innovative and entrepreneurial individuals in math, computer science and engineering is no coincidence. These areas of expertise developed over several decades and were the product of cultural context, certainly, but more specifically of purposive decisions taken by the innovative and visionary architects of the university and its early math and engineering departments. Thus the current character of the regional economy owes a lot to decisions made in the 1950s and 60s about the mandate and mission of the first regional university.

The roots of the University of Waterloo stretch back to the establishment of Waterloo Lutheran College in Kitchener in 1924. Although the college did not contribute to the progress of high technology development in that era – it was an arts college and seminary – its progeny, the Associate Faculties, played a key role as a precursor to the University of Waterloo and several of the key actors in the University of Waterloo story were educated there. The college was created and located at the insistence of local business leaders and its maintenance (both financially and academically) became a genuine community project. The Waterloo College project indicates the extent to which the two communities of Kitchener and Waterloo had developed a common regional and progressive identity based on local growth and its Lutheran origins a product of the local cultural community.

The College continued to grow and graduate students throughout the 1930s even as the Great Depression raged. It was the aftermath of WW II that in many ways inaugurated progress towards the foundation of a local university. The postwar experience brought home some important lessons for government and industry in Canada, and the leaders and institutions of

Kitchener-Waterloo played a key role in translating those lessons into practical measures. The University of Waterloo, founded in 1957, owes its foundation to a confluence of local and national demand for more sophisticated and technical educational institutions.

The industrial race of the Cold War revealed serious gaps in the Canadian post-secondary education system. In a world where national survival was predicated on technological capabilities, Canada was found woefully lacking by industrialists and government alike. In 1956 Canada's leading businessmen, scientists and educators convened the National Conference on Engineering, Scientific and Technical Manpower at St. Andrews-by-the-Sea, New Brunswick to discuss the extent of Canada's technical and engineering manpower shortage and to consider and recommend remedial action (McLaughlin 1997). Their conclusion warned that "the problem of the universities has become an emergency of grave concern to the certain disadvantage of our progress as a nation, and can only be solved by energetic and immediate assistance and cooperation of all governments in Canada, of business and industry and of private benefactors" (Axelrod 1982, 24). This signaled a rapprochement in the previously distant relationship between industry and higher education – a new collaborative engagement in the crafting and support of the postsecondary educational system. Significantly, the certain prominent members of the industrial community in Kitchener-Waterloo already had a relatively close relationship with the college – membership on the Board of Governors – and anticipated both the demands of the national economy for trained technical manpower and trends in local employment requirements.

It was no coincidence that on August 27th, two weeks before the National Conference was set to commence, Ira Needles (president of BF Goodrich and chairman on the Board of Governors for the newly created Associated Faculties) addressed precisely this issue in a speech at the local Rotary Club. In recognition of the technical manpower shortage and the growing

needs of industry, but also cognizant of the financial limitations and lack of experience many educational institutions faced, Needles presented a relatively unique solution in the form of *The Waterloo Plan*. This plan called for a new type of education to be offered on a cooperative 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 another would take 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 cooperative proposal would go on to form the basis for the University of Waterloo's highly successful co-op education program, widely regarded as a significant asset to the region.

The *Waterloo Plan* emerged from a confluence of the national concern with the status of university education and the demands of local industry. Although Waterloo College served the basic educational needs of the community in the areas of arts, humanities and theology, a movement had been underway for a short time – led by local industrialists – to expand the curriculum to include sciences, math and engineering programs. With no local source of engineers or technicians local firms found themselves competing with the firms in major manufacturing (and educational) centres, such as Toronto, for talent. Local industrialists also realized the urgency of creating technological competencies and innovative capacities in the context of the Cold War. Furthermore, many felt that the future competitiveness of the region was closely tied to the establishment of world-class educational facilities. These concerns led to the creation of the Associated Faculties of Waterloo College (which shortly after became the University of Waterloo) – a school that would teach a scientific and technical curriculum.[iv]

The University of Waterloo serves the regional economy in two important ways: by providing a pool of local talent and by transferring cutting-edge knowledge, either in the form of entrepreneurial spin off companies or through patenting, licensing, consulting or joint research projects. In its formative period the university was mainly concerned with the former aspect of its regional role – it set out to provide the best possible science, math and engineering curriculum possible. One of the training innovations adopted by the nascent institution was cooperative education – the first and most successful of its kind in Canada. The rotation of students to industry and back to the classroom solidified already tight relations with local industry. The reflexive relationship allowed the curriculum to keep up with the ever-changing technological frontiers of industry while industry support of the program funded the acquisition of technology to enhance classroom learning. It was thus that UW became one of the first universities in Canada to enable students to actively explore and make use of innovations in a relatively new field – computing.

While local industry certainly had an interest in the development of the University of Waterloo as a source of talent it soon became clear that it would not produce the technologists – a professional degree – that local firms required. Relatively early on the university's leadership decided to abandon a degree in technological arts and concentrate instead on research intensive areas such as engineering, science and math. The architects of this decision were Don Wright, the first dean of engineering, Ralph Stanton, chairman of the math department, and Wes Graham, the director of the new computing centre at the University of Waterloo.

The decision to structure the university curriculum with emphasis on research in engineering rather than simply providing a training program for technologists was the beginning of the university's high tech future. Wright understood that future developments in engineering

would be very closely tied to the development of methods and modelling in mathematics (Wright, 2001). As such, he hired Ralph Stanton, a mathematician from the University of Toronto to head up the math department and mandated that all engineering students take classes in finite mathematics and numerical analysis. Numerical analysis enabled engineers to solve problems and model scenarios that had previously been impossible using contemporary mathematical methods. Under Stanton and Wright's supervision the engineering program was one of the first to employ and teach these techniques – it was on the crest of what would be a new wave in engineering. This technique was somewhat simplified with the use of complex calculators and the engineering and math students at UW were using electro mechanical calculators starting in the mid-1950s.

The next leap forward was initiated with the installation of the first computer. In the late 1950s Stanton recruited another key player in this story, Wes Graham, from IBM to teach a statistics course. With his background in computing Graham quickly got involved in a project to initiate a computer science program. The first computer arrived from IBM in 1960 – a time when there were just over 100 in Canada – and became the foundation of a computing centre that was continuously upgraded by Graham, its director, though his extensive network of contacts. By 1967, the university had an IBM 360/75, the largest computer in Canada. It was so large that it filled a room the size of a gymnasium and was designated as a backup for NASA's Apollo space missions.

In Graham's view students should use computers as they do pen and paper and was committed making sure that they could access and use the new machines. His vision for the computer science department revolved around these goals – access and usability – and therefore

developed a focus on software rather than the traditional 'engineering' and hardware development aspects of computing.

The first major ICT breakthrough at the university, and one that sealed its role as the key regional high tech institution, 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 instrument available that allowed undergraduates to program 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 of the university invented the Waterloo FORTRAN compiler to speed up programming computations. This 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 parent company to several generations of subsequent spin-offs in ICT (for example **name some).** The WATCOM spin off significantly established a business model with a relationship between the company and the university that allowed the company to retain ownership of its research and intellectual property and thus formed the basis for the university's current intellectual property policy.

The development of the University of Waterloo has profoundly affected the shape of the regional economy. The decisions made during its formative years laid the groundwork – in terms of determining regional expertise, capabilities and talent pool – for the regions high tech economy. Its foundation was based on the skills requirements of the national (and to some extent, local) economy, supported by regional industry and its mandate and mission shaped by a group of visionary leaders. While the University of Waterloo is now one of many vibrant centres of knowledge creation it, more than any other university or college in the area, had the most

profound formative effect on high tech industry in the region and is rightfully considered the institutional centre of this ICT cluster.

CONCLUSION

The Waterloo case provides clear evidence in support of the argument made by Kenney and Patton about the long-term impact of expanding research infrastructure on the development of local clusters. However, it also raises another issue that frequently confuses many analyses of the origins of cluster – namely, the respective role of different scales of political jurisdiction in the genesis of clusters. While clusters are overwhelmingly seen as key features of local and regional economies, and most of the literature and case studies reviewed thus far highlight the contribution made by local factors and industrial dynamics, the presence of senior levels of government lurks in the background. John Zysman's contribution to the literature on path dependency and divergent national trajectories, as well as Meric Gertler's work on the broader importance of culture, reinforces the point that local development occurs in a broader context shaped by national institutions (2002). Thus clusters can be seen as nested within, and impacted by, other spatial scales of analysis, including regional and national innovation systems, each of which adds an important dimension to the process of knowledge creation and diffusion that occurs within the cluster. Various elements of each of these spatial scales of analysis may have significance for the innovation process. 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 organizations, 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 (Wolfe and Gertler 2004).

REFERENCES

Arthur, W. Brian. 1994. *Increasing Returns and Path Dependence in the Economy*. Forward by Kenneth J. Arrow. Ann Arbor: The University of Michigan Press.

Axelrod, Paul. 1982. *Scholars and Dollars: Politics, Economics and the Universities of Ontario, 1945-1980*. Toronto: University of Toronto Press.

Baine, Janet. 2001. "Guelph out of the Triangle," *Silicon Valley North GTA* 6(5) Feb: 8.

----------. 2000. "Canada's Technology Triangle shrinks and takes a new shape," *Silicon Valley North* 4(5) July: 36.

Bank of Montreal. 2000. "Canada's Technology Triangle: The Future Looks Bright," BMO Economics. Autumn.

Bathelt, Harald. 1991. *Schlüsseltechnologie Industrien: Standortverhaltern und Einfluß auf den regionalen Struckturwandel in den USA und in Kanada*. Berlin: Springer-Verlag.

Bathelt, Harald and Alfred Hecht. 1990. "Key technology industries in the Waterloo region: Canada's technology triangle (CTT)," *Canadian Geographer* 34 (3): 225-234.

Bathelt, Harald, Anders Malmberg and Peter Maskell. 2002. "Clusters and Knowledge: Local Buzz, Global Pipelines and the Process of Knowledge Creation," DRUID Working Paper 02-12. Copenhagen.

Bloomsfield, Elizabeth. 1987. "Building Industrial Communities: Berlin and Waterloo to 1915," in Walker (ed.) *Manufacturing in Kitchener-Waterloo: A Long Term Perspective*. Waterloo: University of Waterloo.

----------. 1987. "The maturing industrial economy: Kitchener-Waterloo, 1915-1945," in Walker (ed.) *Manufacturing in Kitchener-Waterloo: A Long Term Perspective*. Waterloo: University of Waterloo.

Bradford, Neil. 2003. "Cities and Communities that Work: Profiles of Innovation," CPRN paper F-71 August.

Canada's Technology Triangle. 1996.

Canada's Technology Triangle. 2004. *Community and Statistical Profile*. Waterloo.

David, Paul. 1997. Path Dependence and the Quest for Historical Economics: One More Chorus of the Ballad of QWERTY. Discussion Papers in Economic and Social History, No. 20. Oxford: University of Oxford.

Davis, Charles. 2004. "Path Creation and Destruction in Industries, Regions and Firms: Strengths and Limitations of the Concept of Path Dependence in Innovation Studies." Paper presented to the Annual Meeting of the Innovation Systems Research Network, Simon Fraser University, Vancouver, May 12-15.

Kevin Crowley. 2002. "Weathering the storm; Waterloo Region's Tech Sector thrives despite industry's global downturn," *Waterloo Record*. October 24.

Eastwood, Donald. 1987. "The University of Waterloo, High Technology and New Firm Creation," in Walker (ed.) *Manufacturing in Kitchener-Waterloo: A Long Term Perspective*. Waterloo: University of Waterloo.

English, John and Kenneth McLaughlin. 1996. *Kitchener: An Illustrated History*. Toronto: Robin Brass.

Institute for Competitiveness and Prosperity. 2003. "Presentation to the Prosperity Forum, Waterloo Region." February 4.

Knafelc, Paul. 2003. "A comparison between the socio-economic performance of Canada's Technology Triangle – the Waterloo Region and Ontario's Census Metropolitan Areas," Community Benchmarks prepared for the Prosperity Forum. February 4.

Krugman, Paul. 1991. *Geography and Trade*. Cambridge, Mass.: MIT Press.

Leibovitz, Joe. 2003. "Institutional Barriers to Associative City-region Governance: The Politics of Institution-building and Economic Governance in 'Canada's Technology Triangle,'" *Urban Studies*. 40:13 (December): 2613-2642.

Levesque, Peter. 1993. "Canada's Technology Triangle: Designing a Role for Regional Government in Emerging Advanced Technology Based Economy" [MA Dissertation]

Mahoney, James. 2000. "Path Dependence in Historical Sociology." *Theory and Society* 29: 507-48.

McLaughlin, Kenneth. 1997. Waterloo*: The Unconventional Founding of an Unconventional University*. Waterloo: University of Waterloo Press.

McReady, Doug. 1985. "Economic Impact of Wilfred Laurier University and University of Waterloo on the Kitchener-Waterloo Region" Occasional Papers in Business and Economics Waterloo: Wilfred Laurier University.

PWC. 2001a. “Canada’s Technology Triangle Techmap 2001” Waterloo.

PWC. 2001b. “University of Waterloo: Regional Economic Benefits Study.”

PWC. 2001c. “Regional Economic Benefits Survey.” August.

Roy, Jeffrey. 2000. “Government and Governance in high-tech localities: Ottawa-Carleton and Canada’s Technology Triangle” [PhD dissertation] Ottawa: National Library of Canada.

----------. 1998. “Canada’s Technology Triangle” in John de la Mothe and Gilles Paquet, eds, *Local and Regional Systems of Innovation*. Boston: Kluwer.

Stanton, Raymond. 1997. *Visionary Thinking: The Story of Canada’s Electrohome*. Kitchener: Canadian Corporate Histories.

Walker, David. 1987. *Manufacturing in Kitchener-Waterloo: A Long Term Perspective*. Waterloo: University of Waterloo.

Xu, Stephen Xingang (2003) “Knowledge Transfer, Interfirm Networking and Collective Learning in High Technology Cluster Evolution: A Network Analysis of Canada’s Technology Triangle” [Master of Applied Science (Management Science) dissertation] University of Waterloo.

Zeidenberg, Jason. 1995. “Lost in the technology triangle,” *This Magazine* 28(5): 33-7.

[i] Most of these concerns used steam or water power, later hydro electricity.

[ii] There is some confusion in the literature about firm formation in the region about what constitutes a university spin off. Many include firms founded by university alumni or students in this category regardless of the source of the core technology or intellectual property. In the interest of precision we employ a more rigorous definition. A university spin off company is “a commercial entity that derives a significant portion of its commercial activities from the application or use of a technology and/or know-how *developed by or during a university funded research program*. The new enterprise is created either (1) to license a University invention, (2) to fund research at the University in order to further develop a technology/invention that will be

licensed by the company, or (3) to provide a service using University-derived expertise" (University of Alberta Research Services Office, 2003). Accordingly, Research in Motion, a firm often credited as a UW spin off is counted in this paper as an independent start up. It was founded while both principles were still students at the university but as a consulting firm unrelated to their areas of study. Because no technology or IP was transferred at the time of foundation RIM is not a university spin off, irrespective of any research contacts it currently has with the institution.

[iii] The Enterprise Co-op Program enables students to start their own venture in lieu of doing a co-op placement with an established firm. The program focuses on creating a local network of contacts and mentors to support the venture though the university does not directly support the actual venture. The Masters in Business, Entrepreneurship and Technology (MBET) is a graduate degree program that attracts potential entrepreneurs from around the world. Its mission is to provide business skills critical to identifying and exploiting commercial opportunities with emphasis on technological, innovative and entrepreneurial energies that are the foundation of the University of Waterloo's reputation. 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.

[iv] The original plan in incorporating the Associate Faculties was that it would remain associated to Waterloo Lutheran College. However, when the Faculties achieved university status the original college declined participation in the new institution. Later, Waterloo Lutheran College did achieve independent university status as Wilfred Laurier University.