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# ELUSIVE QUEST OR EMERGING REALITY: Niagara's ICT Innovation Cluster

## INTRODUCTION

Over the past two decades, industrial restructuring, increasing automation and mass digitization of production and service-delivery processes have been central to economic growth and social prosperity around the world. It is a reshaping of the world's economic landscape not unlike the shift from an agro- to a factory-based economy in the late 1800s or the shift to mass production in the mid-1900s. But this new focus has brought with it threats of economic stagnation and industrial decline, job losses, growing income inequality, suffocating poverty and social disintegration to our cities and regions.

One of the central indicators used by scholars and policy analysts to measure a region's capacity to navigate these turbulences is the state of its information communications technology (ICT) sector – also referred to as the "digital technology" or simply "tech" sector. One significant way for regions to think about their tech sector is not as a stand-alone sector distinct from say, manufacturing, agribusiness or tourism. Rather, the tech sector is foundational to the resilience and adaptive capacity of all sectors of the economy and the very well-being of society. In short, digital technologies are all-purpose platforms supporting a range of economic and social activities. As Tobias Lütke, Chair of Canada's 2018 Economic Strategy Roundtables as well as CEO and Founder of Shopify put it, "the digital sector is not an industry. It isn't a strategy. It's an essential tactic that should be embedded into every industry. The competitive advantage of any Canadian company will be connected to its digital advantage" (Innovation, Science and Economic Development Canada 2018). Furthermore, according to the Canadian federal government's Ministry of Innovation, Science and Economic Development, the digital sector "is made up of a combination of manufacturing and service industries that use creativity, talent, and digital skills to capture, transmit, and display data and information electronically. This includes information and communications technology and digital media industries"(ISED 2018).

In Niagara, there has been a longstanding debate about the local realities of this global shift towards a knowledge-driven and digitized economy. Optimists cite significant advances in ICT firms across a range of industries, and an emerging ecosystem of business start-ups and supporting organizations. For sceptics, however, Niagara's pursuit of a digital sector is an elusive quest. They see instead a region that is little more than a peripheral digital wasteland stuck in the far corners of Ontario's technology landscape with little or no chance of competing for brains and financial capital with digital centres of gravity like Waterloo or Toronto. As with most arguments, however, the truth is somewhere in the middle.

After 10 years of such debates, it is time to more closely examine the evidence. The purpose of this policy brief is twofold: First, we provide a portrait of recent trends in the ICT sector in Niagara relative to similar mid-sized regions in southern Ontario. In doing so, we highlight some of the industry-specific strengths and potentials of the ICT sector as well as identify existing limitations. Second, we draw some inferences from the underlying currents of these trends to provide an analysis of areas in the ICT sector requiring more policy attention to cement the basic infrastructure and resilience of the region's emerging knowledge economy. In doing so, we highlight some considerations for key actors in the sector – firms, incubators, accelerators, post-secondary institutions,

venture capitalists, policy makers and interested residents – actors with vested interest in Niagara's technological resilience, economic adaptability and overall social prosperity.

The discussion is structured as follows: First we provide a brief description of the research method. Second, we highlight key industry-specific trends in the ICT sector. Third, we draw policy inferences from these trends and then explore key attributes of the ICT sector and how Niagara could take the next steps in building a more vibrant ecosystem and thus carve out a greater niche in Canada's growing technology-based and knowledge-driven economy and digitized society.

## RESEARCH METHOD

The analysis in this report is the result of the integration of statistical data and in-depth interviews. We define information and communications technology (ICT) as a broad range of industries comprising technologies related to communications media (including wireless signals), computers, along with software, apps, digital platforms, data storage, management and dissemination, and audiovisual systems. ICT gadgets, conduits and platforms include "the Internet, wireless networks, cell phones, and other communication mediums" (www.techterms.com/definition/ict). These technologies and their related systems together support the access, storage, transmission and management of information and devices. This means that a region's ICT capacity reflects its ability to build the critical physical, digital and human infrastructure to support a wide spectrum of activities in a knowledge-driven economy.

For purposes of data analysis, we focus on a set of 13 industries (see Table 1) listed under the four-digit NAICS codes as well as relevant NOC codes, sourced from EMSI's Labor Market Analytics. We look at jobs by industry, jobs by occupation, business counts including by size; and median wages. Industry data cover the period 2011 to 2019 and occupational data from 2011 to 2018. Locations quotients (LQ) are also reviewed as they indicate an area's level of specialization in industries that have a location quotient above 1.5. Nevertheless, an LQ score of 1.0 or more reveals sufficient industry-level density that points to considerable local competencies in that area. LQs indicate a region's job concentration in the sector relative to total jobs concentration in that sector across Ontario.

We compare St. Catharines-Niagara with a select number of CMAs within southern Ontario: Hamilton, Guelph, Waterloo, Windsor and Toronto[1]. Although Toronto is an outlier by virtue of its immense population size compared to the other cases, its presence in the study serves to highlight strategic considerations for how Niagara might position itself within the Golden Horseshoe's digital technology corridor.

Statistical data is backed up by in-depth interviews with key actors across Niagara's digital tech sector, including those in the region's incubators and accelerators, as well as entrepreneurs, venture capitalists, officials in post-secondary institutions and research centres, and a number of economic development offices. A total of 18 interviews were conducted over a one-year period (June 2018 to May 2019). They were asked to identify the prospects and challenges facing the ICT sector in Niagara and Ontario as well as possible governance arrangements that might fully leverage the potentials and address the existing gaps in the sector.

[1] We use the St. Catharines-Niagara CMA for comparative purposes with other CMAs in Ontario, although it does not include Grimsby or West Lincoln.

## DATA ANALYSIS

**Table 1** provides a portrait of Niagara ICT sector jobs by industry for the year 2019. The computer systems design and related services industry stands out as the most potent sector by a wide margin with 1,514 jobs. This figure is particularly critical given the centrality of this industry to the general vitality of the digital sector in terms of core competences and requisite capacities that feed into other industries in the sector. Niagara also boasts six other industries that have more than 100 jobs each.

**Table 1: Niagara ICT Sector 2019 Jobs by Industry**

| NAICS | ICT INDUSTRIES | 2019 JOBS |
|---|---|---|
| 3341 | Computer and peripheral equipment manufacturing | 125 |
| 3342 | Communications equipment manufacturing | 45 |
| 3343 | Audio and video equipment manufacturing | 34 |
| 3344 | Semiconductor and other electronic component manufacturing | 52 |
| 3346 | Manufacturing and reproducing magnetic and optical media | 5 |
| 4173 | Computer and communications equipment and supplies merchant wholesalers | 149 |
| 5112 | Software publishers | 261 |
| 5173 | Wired and wireless telecommunications carriers (except satellite) | 263 |
| 5174 | Satellite telecommunications | 0 |
| 5179 | Other telecommunications | 31 |
| 5182 | Data processing, hosting, and related services | 109 |
| 5415 | Computer systems design and related services | 1,514 |
| 8112 | Electronic and precision equipment repair and maintenance | 129 |
| | Total ICT Jobs | 2,719 |

Niagara's relatively weak performance in industries such as audio and video equipment manufacturing, manufacturing and reproducing magnetic and optical media, and satellite telecommunications should not only come as no surprise to a reader familiar with the region but should not be a source of major concern given their peripheral status to a vibrant digital innovation ecosystem at the regional scale.

Table 2: Percentage Change (2011 – 2019) in Niagara ICT Sector Jobs by Industry

| NAICS | TECH INDUSTRIES | 2011 JOBS | 2019 JOBS | % CHANGE |
|---|---|---|---|---|
| 3341 | Computer and peripheral equipment manufacturing | 18 | 125 | 586.3% |
| 3342 | Communications equipment manufacturing | 2 | 45 | 2173.7% |
| 3343 | Audio and video equipment manufacturing | 0 | 34 | 0.0% |
| 3344 | Semiconductor and other electronic component manufacturing | 77 | 52 | -32.1% |
| 3346 | Manufacturing and reproducing magnetic and optical media | 64 | 5 | -92.2% |
| 4173 | Computer and communications equipment and supplies merchant wholesalers | 104 | 149 | 43.7% |
| 5112 | Software publishers | 147 | 261 | 78.0% |
| 5173 | Wired and wireless telecommunications carriers (except satellite) | 285 | 263 | -7.8% |
| 5174 | Satellite telecommunications | 3 | 0 | -100.0% |
| 5179 | Other telecommunications | 28 | 31 | 12.5% |
| 5182 | Data processing, hosting, and related services | 78 | 109 | 39.6% |
| 5415 | Computer systems design and related services | 857 | 1,514 | 76.7% |

More importantly, we get a clearer context of Niagara's performance in the digital sector when we take a look at **Table 2**, which provides a longitudinal portrait of percentage changes between 2011 and 2019 in digital sector jobs by industries. Some of the key industries in the sector reveal significant and promising trajectories of knowledge-intensive growth activities led by communications equipment manufacturing industries making a giant leap of 2173.7 per cent, and computer and peripheral equipment manufacturing increasing by 586.3 per cent. It is important to note that the large percentage growth in communications equipment manufacturing industries is relative. Although the percentage change is high, it was not a major increase in real job numbers compared to NAICS 5415 and 5112. The 39.6-per-cent growth in data processing, hosting, and related services seems relatively modest in comparison to the other industrial growth trends but has significant implications for the region since local competencies in data generation, storage, management and processing are profoundly critical to the predominantly intangible products and services of the knowledge economy.

A more instructive lens of analysis is provided when total percentage changes in ICT sector jobs by industry in Niagara are compared with those of Ontario as a whole (see **Table 3**). Niagara registers a total growth of 51.8 per cent in ICT jobs whereas the province as a whole grew only by 20.7 per cent. The communications equipment manufacturing industry – Niagara's giant leap of 2173.7 per cent – is set against a backdrop of an Ontario-wide decrease of 56.7 per cent. The reason behind such a phenomenon deserves closer investigation as it could reveal certain trends emerging in yet unacknowledged competencies. Equally noteworthy is Niagara's growth trend well above the provincial percentage growth averages in industries like computer and communications equipment and supplies merchant wholesalers, computer and peripheral equipment manufacturing, computer systems design and related services; and data processing, hosting, and related services.

The fact that geographically peripheral areas of the province such as single-industry towns and much of the provincial north could be affecting the province's overall growth trend is a context worth highlighting. Nevertheless, Niagara cannot be dismissed as a marginalized periphery in the province's digital landscape as demonstrated by the past 10 years' growth trends.

**Table 3: Comparison of Niagara and Ontario's 2011 – 2019 Percentage Change in ICT Sector Jobs by Industry**

| NAICS | ICT INDUSTRIES | NIAGARA % CHANGE | ONTARIO % CHANGE |
|---|---|---|---|
| 3341 | Computer and peripheral equipment manufacturing | 586.3% | 14.9% |
| 3342 | Communications equipment manufacturing | 2173.7% | -56.7% |
| 3343 | Audio and video equipment manufacturing | 0.0% | -11.3% |
| 3344 | Semiconductor and other electronic component manufacturing | -32.1% | 10.1% |
| 3346 | Manufacturing and reproducing magnetic and optical media | -92.2% | -55.1% |
| 4173 | Computer and communications equipment and supplies merchant wholesalers | 43.7% | 3.3% |
| 5112 | Software publishers | 78.0% | 112.3% |
| 5173 | Wired and wireless telecommunications carriers (except satellite) | -7.8% | -28.3% |
| 5174 | Satellite telecommunications | -100.0% | -21.5% |
| 5179 | Other telecommunications | 12.5% | 13.8% |
| 5182 | Data processing, hosting, and related services | 39.6% | 53.5% |
| 5415 | Computer systems design and related services | 76.7% | 47.2% |
| 8112 | Electronic and precision equipment repair and maintenance | 1.7% | 9.7% |
| | Overall % Change ICT Jobs | 51.8% | 20.7% |

Location quotients provide another lens through which we can understand the current state of the digital sector in Niagara. As noted earlier, the LQ scores indicate an area's level of specialization in industries. While a score of 1.5 remains the ideal standard of industry-level specialization, a score above 1.0 reveals a sufficient density that points to considerable local competencies. As **Table 4** indicates, relative to other Ontario CMAs, Niagara boasts a comparative strength in audio and video equipment manufacturing (1.27) and computer and peripheral equipment manufacturing (1.03).

Hamilton – Niagara's closest neighbour – showed comparative strength in the communications equipment manufacturing industry and the semiconductor and other electronic component manufacturing industry. Guelph, which shares many similar demographic attributes with Niagara, registered strong competencies in semiconductor and other electronic component manufacturing; manufacturing and reproducing magnetic and optical media; and computer and communications equipment and supplies merchant wholesalers. Windsor, another border region with a local economy grounded in auto-manufacturing, has no demonstrable competencies in any of the digital sector industries. Toronto remains the behemoth of ICT with registered competencies across nearly all the industries in the digital sector except for the software publishers industry which is concentrated in the Waterloo region along with the computer systems design and related services industry.

Table 4: Location Quotients of Six Ontario CMAs' ICT Sector Jobs by Industry

| NAICS | ICT INDUSTRIES | NIAGARA PLQ | HAMILTON PLQ | GUELPH PLQ | WINDSOR PLQ | WATERLOO PLQ | TORONTO PLQ |
|---|---|---|---|---|---|---|---|
| 3341 | Computer and peripheral equipment manufacturing | **1.03** | 0.48 | 0.41 | 0.10 | 1.55 | **1.38** |
| 3342 | Communications equipment manufacturing | 0.26 | **3.72** | 0.31 | 0.10 | 0.60 | **1.09** |
| 3343 | Audio and video equipment manufacturing | **1.27** | 0.73 | 0.00 | 0.00 | 0.92 | **1.27** |
| 3344 | Semiconductor and other electronic component manufacturing | 0.25 | **1.17** | **4.61** | 0.12 | 0.88 | **1.20** |
| 3346 | Manufacturing and reproducing magnetic and optical media | 0.27 | 0.52 | **9.56** | 0.00 | 0.42 | **1.53** |
| 4173 | Computer and communications equipment and supplies merchant wholesalers | 0.16 | 0.57 | **1.06** | 0.42 | 0.33 | **1.33** |
| 5112 | Software publishers | 0.41 | 0.56 | 0.85 | 0.24 | **5.88** | 0.96 |
| 5173 | Wired and wireless telecommunications carriers (except satellite) | 0.32 | 0.89 | 0.26 | 0.50 | 0.76 | **1.35** |
| 5174 | Satellite telecommunications | 0.00 | 0.59 | 0.00 | 0.00 | 0.96 | **0.90** |
| 5179 | Other telecommunications | 0.18 | 0.63 | 0.28 | 0.70 | 0.59 | **1.02** |
| 5182 | Data processing, hosting, and related services | 0.33 | 0.23 | 0.54 | 0.07 | 0.68 | **1.57** |
| 5415 | Computer systems design and related services | 0.34 | 0.54 | 0.42 | 0.32 | 1.28 | **1.39** |
| 8112 | Electronic and precision equipment repair and maintenance | 0.51 | 0.72 | 0.79 | 0.83 | 0.91 | **1.09** |

One final takeaway from Niagara's relatively strong showing in the audio and video equipment industry and the computer and peripheral equipment industry is the need for a deeper examination of how the region might strengthen its core competencies. One of the key features of the tech sector is that regions in Canada and around the world are pursuing smart specialization by investing resources in building the requisite talent pool, research facilities, incubators, accelerators and other support systems that cater to their strengths. For instance, how could Niagara's emerging competencies in these two industries be more closely aligned with Hamilton's strengths in semiconductor and other electronic component manufacturing? In what ways might the pooled competencies of the two neighbouring regions along the "QEW belt" of Toronto raise the profile of a corridor that has been largely overshadowed by the 401 tech belt? **Table 4** offers a panoramic portrait that highlights potential opportunities to explore collaborations across regions sharing similar tech sector strengths but with variation in industry-specific specialization. For a region the size of Niagara, becoming part of a mega-cluster provides strategic opportunities for the region to leverage its assets and partner with the bigger players in order to carve its own niche in a highly competitive global digital landscape.

Another lens through which we can view ICT trends is the distribution of jobs by occupation. The importance of this perspective is that it sheds light on the human and talent dimensions of the ICT sector, providing insights into the nature of skillsets or expertise. This information allows us to make inferences about the region's existing talent pool and its implications for innovation, adaptability and resilience of the digital tech sector.

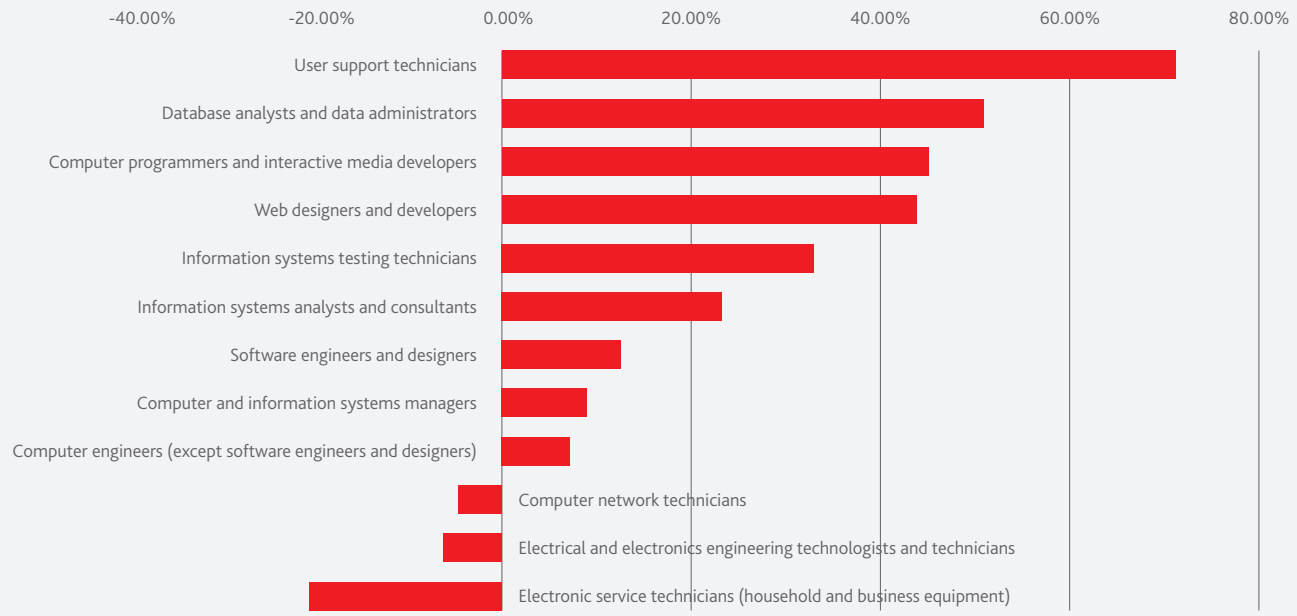
As **Table 5** indicates, information systems analysts and consultants command the greatest number of jobs in Niagara (1,096 jobs), closely followed by user support technicians (947 jobs) and computer programmers and interactive media developers (870 jobs).

But rather than dwelling alone on static scores of skills distribution by occupation, an even more significant indicator of a region's adaptability and resilience is the direction of percentage change in critical occupations and specializations. As **Table 5** and **Figure 1** show, Niagara has seen its largest job growth between 2011 and 2018 in user support technicians (71.63 per cent); database analysts and data administrators (51.91 per cent); computer programmers and interactive media developers (44.85 per cent); web designers and developers (43.47 per cent); and information systems testing technicians (32.65 per cent). In fact, a majority of the occupations in the ICT sector have seen positive trends. Most importantly, the tech sector as a whole has seen a general job increase of nearly 21 per cent. These figures display an increasing stock of skills requisite for high-density creativity and innovation within the tech cluster value chain of activities.

**Table 5: Niagara's Percentage Change (2011 – 2018) in ICT Sector Job by Occupations**

| NOC | ICT OCCUPATIONS | 2011 JOBS | 2018 JOBS | % CHANGE |
|---|---|---|---|---|
| 0213 | Computer and information systems managers | 506 | 560 | 10.8% |
| 2147 | Computer engineers (except software engineers and designers) | 61 | 67 | 8.9% |
| 2171 | Information systems analysts and consultants | 896 | 1,096 | 22.4% |
| 2172 | Database analysts and data administrators | 139 | 211 | 51.9% |
| 2173 | Software engineers and designers | 144 | 162 | 12.2% |
| 2174 | Computer programmers and interactive media developers | 601 | 870 | 44.8% |
| 2175 | Web designers and developers | 176 | 253 | 43.5% |
| 2241 | Electrical and electronics engineering technologists and technicians | 235 | 218 | -7.0% |
| 2242 | Electronic service technicians (household and business equipment) | 721 | 584 | -19.0% |
| 2281 | Computer network technicians | 409 | 390 | -4.7% |
| 2282 | User support technicians | 552 | 947 | 71.6% |
| 2283 | Information systems testing technicians | 25 | 33 | 32.7% |
| | Total ICT Jobs | 4,464 | 5,391 | 20.8% |

FIGURE 1: NIAGARA'S PERCENTAGE CHANGE (2011 - 2018) IN ICT SECTOR JOB BY OCCUPATIONS 2018



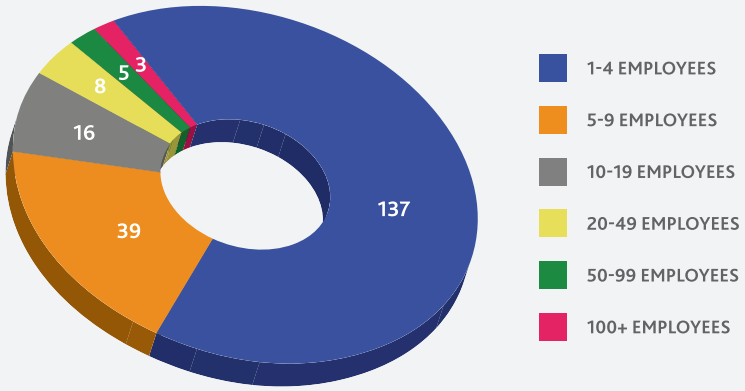

A further lens for determining the vitality of Niagara's ICT sector is the number of enterprises. **Table 6** provides a comparative snapshot of businesses with and without employees as well as the frequency distribution of business counts from small, medium, to large enterprises. As the table shows, among a total of 551 businesses, there are 208 businesses with employees whereas the sum of businesses without employees is much larger at 343 businesses.

**Table 6: Niagara's ICT Sector Business Counts**

| EMPLOYEE COMPOSITION | BUSINESS COUNTS |
|---|---|
| Businesses without Employees | 343 |
| Businesses with Employees | 208 |

Moreover, as Figure 2 indicates, most of the businesses (137 in total) with employees are microenterprises with one to four workers, followed by 39 businesses with somewhere between five and nine workers. There is a total of 16 businesses employing between 10 and 19 workers, eight businesses with 20 to 49 workers and only five businesses employing between 50 and 99 workers Three businesses in Niagara reported employing more than 100 people each. These figures are not entirely surprising for a region relatively new in the digital tech landscape. Moreover, regional innovation systems in general, and digital ecosystems in particular, are notorious for the predominance of business start-ups, which are by nature often small and medium-sized operations. These SMEs also have the advantage of being nimbler and more adaptive than their larger counterparts. Nevertheless, the absence of larger businesses in the sector raises concerns about the lack of anchor firms that generate more jobs, project the global image and deepen the resilience of a region's innovation ecosystem.

FIGURE 2: DISTRIBUTION OF BUSINESSES WITH EMPLOYEES




A final lens for determining the vitality of Niagara's ICT sector is the wage distribution of industries that make up a sector. As indicated in **Table 7**, computer and information systems managers report the highest median wage of $47.45 per hour whereas user support technicians register the lowest median wage of $24.79.

This wage distribution of the sector is cause for concern since it reflects a general pattern in which some of these industries register lower pay scales for residents living in smaller regions compared to their counterparts in larger regions. While these wage differences seem somewhat small, they account for some of the brain drain that plagues the prospects of mid-sized regions. On the positive side, Niagara's relative lower median wages could be pitched as a competitive advantage in the race among regions to attract potential investors. In a similar vein, Niagara's lower median wage within the mosaic of the global technology landscape in a complex network of value chains and trade interdependencies could be leveraged in addition to its industry specializations discussed above. However, suppressed wages in the region's digital sector has ethical and industrial relations implications for employers and employees. Such issues could adversely affect the social trust and functional integrity of an innovation ecosystem. Most importantly, issues of wage distribution and industry specialization should form critical components of the region's smart specialization strategy in any potential mega-tech cluster spanning the Golden Horseshoe.

**Table 7: Niagara's 2018 ICT Sector Median Hourly Wages**

| NOC | OCCUPATIONS | NIAGARA'S 2018 MEDIAN | TORONTO'S 2018 MEDIAN |
|---|---|---|---|
| 0213 | Computer and information systems managers | 47.45 | 52.01 |
| 2147 | Computer engineers (except software engineers and designers) | 46.19 | 41.67 |
| 2171 | Information systems analysts and consultants | 40.06 | 38.81 |
| 2172 | Database analysts and data administrators | 32.15 | 33.30 |
| 2173 | Software engineers and designers | 43.37 | 44.92 |
| 2174 | Computer programmers and interactive media developers | 36.79 | 37.77 |
| 2175 | Web designers and developers | 32.24 | 33.42 |
| 2241 | Electrical and electronics engineering technologists and technicians | 29.65 | 28.43 |
| 2242 | Electronic service technicians (household and business equipment) | 27.11 | 24.47 |
| 2281 | Computer network technicians | 30.19 | 31.87 |
| 2282 | User support technicians | 24.79 | 29.86 |
| 2283 | Information systems testing technicians | 33.01 | 36.00 |

## DISCUSSION AND POLICY IMPLICATIONS

From the data above, it is safe to say that Niagara's pursuit of a digital sector cannot be dismissed as an elusive quest. Neither can one claim that the region is of peripheral importance to Ontario's technology economy and digitized society. The region has a presence in every industry within the ICT sector, and commands considerable competencies in several of them. More importantly, the ICT sector is relatively new but growing, with some industries surpassing the provincial average.

However, enthusiastic claims about recent developments within the region's digital tech sector need to be tempered by some reality checks. The sector has considerable challenges that are partly structural, partly demographic and partly institutional. The analysis reveals industry-specific location quotients that highlight the region's specific strengths relative to other regions of Ontario. Such strengths and specialization are critical for building a cluster niche within a larger digital technology corridor spanning the Niagara and Hamilton regions and deepening linkages with the Kitchener-Waterloo and Toronto regions. In general, the modest advances in the region's ICT firms across a range of industries deserves to be recognized. The vision and effort of a small but highly energized ecosystem of actors should be acknowledged and applauded.

One of the points highlighted earlier is that digital industries should not be considered a standalone sector. Rather, they are a general all-purpose platform that is foundational for every sector of the region's 21st century economy and society. The term "digital" is a generic notion that captures the vision and imperatives of smart industrialization across a range of sectors: manufacturing, transportation and logistics, and agribusiness.

The ICT sector represents a range of activities embedded in cyber-physical systems combining the Internet of Things (IOT), data management, and related services. The digital sector offers platforms that connect embedded system production technologies and smart production processes thereby radically transforming industry and production value chains and business models. Some of the predominant activities with this sector relate to advances in cybersecurity, IOT, augmented reality, cloud computing, system integration, simulation, additive manufacturing, big data, and autonomous robots, to name a few.

In light of all these considerations, there is need for a clearer vision, a concerted approach and more strategic investment to take the region's ICT sector to the next level. Coincidentally, there have been some movements on this front. In 2018, Niagara Economic Development organized a roundtable bringing together representatives from the digital tech sector to identify opportunities, issues and gaps that could inform the economic development strategy. Three broad recommendations emerged, namely that the Region:

> *facilitate an environment of communication and collaboration among industry partners in the technology sector, leading to a centralized communication mechanism, through the creation of a Niagara Leadership Innovation Alliance. The Alliance would involve both the public and private sector; advocate and support building hard infrastructure assets to support the sector, in particular high speed Broadband across the region, SWIFT and 5G network; encourage the alignment between post-secondary institutions and the private sector to ensure jobs in the tech sector for graduates; developing skills for innovation from K-12 upwards and connecting students to businesses.* (Niagara Region 2018).

The above recommendations point to the need for a more strategic physical and institutional infrastructure to support a resilient and adaptive digital innovation ecosystem. While the physical infrastructure needs are self-evident, the institutional and policy platform requires further elaboration. First, Niagara's regional policy environment needs to come up with a comprehensive data management and IP strategy as part of its long-term economic development strategy. Second, there is a need for close attention to the challenges of generating, attracting and retaining talents that will remain in the region and not just use the region's facilities and resources to build a start-up and then pursue scale-up activities elsewhere. Third, while leveraging and nurturing interdependencies with centres like Waterloo and Toronto is an essential part of a viable strategy, should Niagara's digital ecosystem instead pursue a future in which creative content developed locally is leveraged and brought to market within Niagara itself? Addressing that question could make the difference in terms of benefitting locally from the digital economy as evident in actual job creation and spin-offs. Every region needs anchor firms that serve as the base of a viable and sustainable regional technology cluster whose ripple effects will be manifest in growth not only in the sector but in the wider regional economy and the general prosperity of local communities.

Fourth, the region's digital industry groups, incubators, accelerators and post-secondary institutions must develop a more concerted strategy for aligning entrepreneurship training programs with the emerging opportunities. Local organizations like Innovate Niagara, Spark Niagara, Accel North, along with Brock University and Niagara College are deeply invested in the region's digital sector. The next phase in the development of this trend is to coalesce each of these nodes around a collaborative hub that can bring together the many actors such as start-ups, existing SMEs and supporting organizations. Innovate Niagara hosts regular meetings where actors across a range of industries and sectors meet to share ideas and exchange notes. The informal nature of such networking opportunities has its place. However, is there more that can be done to fully leverage competencies across these organizations? Is it time for inter-organizational joint projects to pursue a digital mega-cluster strategy spanning the QEW belt? To what extent is the region strategically leveraging the research capacity and facilities of its post-secondary institutions to advance its goals of economic development?

Universities and colleges in resilient innovation systems perform several critical functions. First, they generate and attract the stock of highly skilled professions and entrepreneurial talent that constitute the critical pool of the local labour market's claim to industrial specialization (Bramwell and Wolfe 2008; Florida 2002). Second, they serve as conduits of formal and informal technical support, leveraging their pool of specialized expertise and facilities to support the routine and innovative ventures of local firms. Third, they serve as conveyor belts for transmitting a global stock of knowledge into the local economy. Universities and colleges serve as intermediary or bridging institutions providing the interactive and iterative platforms for strategic visioning, collaborative governance and firm-level knowledge sharing within a given region.

In closing, the economy of the 21st century is fundamentally different in several respects from the 20th-century production-based economy of manufacturing tangible goods. Most importantly, the new knowledge-driven economy is based on generating, owning and controlling intangible assets, namely intellectual property (IP) and data. The growth of the intangible economy is supported by the ICT sector which fundamentally is about data generation, ownership and management, with a strategic focus on generating, exploiting and mobilizing data assets, facilitating processes of machine learning as part of a system of applying artificial intelligence to wide-scale productions and service-based companies, as well as generating valuable IP assets that are based in the local region.

Against the backdrop of the shifting global economy, Niagara's emerging knowledge-driven economy in general and its digital sector in particular stand at a critical crossroads. For a mid-sized region like Niagara, the critical implication of recent global trends is that they present risks and challenges. First, they represent an uncertain macroeconomic context where change happens at a fast and breakneck pace in a highly competitive landscape where first-movers are poised to gain advantages. Second, these trends are giving rise to more complex and inter-regional supply chains where data/information management capacities will determine a region's place on the national and global economic map. Third, local and regional policy makers, private sector actors, post-secondary institutions and society at large need to better understand the full range of possibilities and benefits which can be achieved from technological enablers of new opportunities.

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