Growing the ICT Industry in Canada: A Knowledge Synthesis Paper

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Overview

Information and communications technology (ICT) industries comprise the backbone of the global digital economy, and constitute one of the key drivers of productivity growth in the knowledge-based global economy. Semiconductors have become such a ubiquitous feature of the modern economy that the control the rhythm at which it runs. A defining characteristic of the ICT sector is the rapid rate of innovation and productivity increases that have occurred, not only in the industries that produce the hardware, software, microelectronic components, content, and services used in ICT applications, but also in the sectors that benefit from the adoption and use of these technologies. Because no other industry or technology sector is more central to the development of globally competitive digital economies than the ICT sector, most countries aim to position their ICT industries to fuel post-recession growth.

The ICT industry in Canada is a critical contributor to national GDP, and although it is weathering the recession better than most, it is not performing as well as it could. Because of its critical importance as a key driver of economic growth and productivity, the ICT sector has been the focus of a great deal of recent policy attention, from the 2007 *Science and Technology Strategy* which identified ICT as one of four national priority sectors, to the current consultation on the development of a national strategy for the digital economy, *Improving Canada's Digital Advantage*. There is mounting concern that the ICT sector is losing ground and needs to 'up its game' if Canada wants to remain a player in the global digital economy. Once a world leader in broadband infrastructure and one of the first countries to develop a strategy for the information economy in the 1990s, Canada has failed to update the strategy in response to dramatic technological and market changes, and "there are currently no bold or significant initiatives underway that will truly accelerate the development of Canada's digital infrastructure" (Canadian Chamber of Commerce 2009, 5; Matthews 2009).[1] Concerted national policy attention is "key to ensuring that when the recession ends we will have advanced our competitive position relative to other countries" (Canadian Chamber of Commerce 2009, 5).

This paper presents an overview of the current state of the ICT industry both globally and in Canada. It draws upon the most recent statistical sources and analytical reports to paint a detailed picture of the current level of development of the sector and emerging technology trends. It situates the state of the ICT industry in Canada, both in manufacturing and services, within this broader comparative context and highlights some of the past accomplishments and current strengths of the sector. It pays particular attention to the importance of local concentrations of ICT firms across the country, or

[1] Both the 2006 report of the Telecommunications Policy Review Panel and the 2007 National Roundtable recommended that Canada re-visit its telecommunications policies and programs and come up with an updated national strategy for Canada's digital economy.

industry clusters, in supporting the overall growth of the sector on a national and regional basis. It highlights some of the critical factors that have contributed to the growth of these clusters and the overall development of the industry. Drawing up a selection of recent submissions to Industry Canada's national consultation on the digital economy and recent presentations by industry leaders, it then goes on to discuss some of the current challenges facing the industry and the obstacles to its future growth. It presents a brief survey of national digital strategies that are being adopted in other leading industrial countries, including some of the key policies to support innovation in the ICT sector and the adoption and diffusion of ICT's in the broader economy. It concludes with a brief discussion of some of the key policy recommendations that have emerged from the consultation on the digital economy and directions for future research.

Canada's ICT Industry in Comparative Perspective

Before the recent economic crisis hit, the ICT sector in both OECD and non-OECD countries had experienced consistent long-term growth since the previous downturn of 2001-2002. However, the impact of the current economic crisis coupled with structural changes in the ICT sector and the emergence of new ICT activities means that the sector continues to undergo significant changes. ICT manufacturing has declined overall, but with the global restructuring of production, ICT goods production has moved to lower-cost locations within the OECD as well as to non-OECD emerging economies in Asia. At the same time, ICT sector activities in OECD countries have shifted towards ICT services which now account for over two-thirds of total ICT sector value-added in these countries. The recession affected both ICT manufacturing and service industries in OECD countries, but hit manufacturing industries particularly hard, and there was a subsequent decline in ICT sector employment and R&D spending. There is cautious optimism however, that signs of recovery are being felt in different ways across OECD and non-OECD countries. Several emerging technologies and new applications of existing technologies, such as mobile broadband, cloud computing, "green ICT" processes, and "smart" systems hold the promise of encouraging future growth in the sector. This section provides an overview of recent changes affecting the sector as well as emerging trends that are likely to affect the sector in the near to medium term.

Prior to the global recession, ICT industries were among the strongest economic performers. In 2007, the top 250 global ICT firms grew by 12 per cent, reaching global revenues of $3.8 trillion. By 2008, the sector represented more than 8 per cent of business value-added activities and employed almost 16 million people (OECD 2008a). During this time, growth in the industry was supported by steady flows of venture capital, as well as access to workers with high-levels of ICT specific skills.[2] ICT skills are a critical driver of innovation-led growth in the industry, and by 2008, the ICT business sector boasted close to 1 million researchers, about half of whom were located in the US (OECD 2008a). R&D has also historically been a key contributor to growth, and the ICT sector spends about two and a half times more than the auto sector and three times more than the pharmaceutical sector on R&D. Overall, spending tends to be strongest in software and services because these areas have expanded most rapidly, but R&D priorities also focus on developing basic technologies for next generation products and services, and new cross-sectoral applications in areas such as climate change and health care. Spending tends to be concentrated in major ICT firms which spent US$ 151 billion in 2006, the top 100 of which spend an average of 7 per cent of revenue on R&D. An increasing share of R&D is also conducted by non-ICT firms in a wide range of sectors including automotive, financial services, and defence, and linked to the growing importance of embedded systems and software in ICT and non-ICT products.[3] Finally, publicly funded research, global research networks, and inter-firm R&D partnerships have also been important drivers of innovation, and R&D partnerships and alliances have been spreading across new geographical and interdisciplinary domains. Though the trend is toward globalized research networks that are concentrated in a few regions in OECD countries, new research hubs in Shanghai, Israel and Bangalore, and to a lesser extent Chinese Taipei, Malaysia and Singapore have begun to grow in importance in recent years.

ICT-related employment is a significant share of total employment with over 11 million people employed in ICT services and over 5 million in ICT manufacturing. From 1995 to 2008, employment in computer and related services and IT services grew more rapidly than business services as a whole, but over the same period, ICT manufacturing employment declined more rapidly than manufacturing employment overall, though employment increases in ICT services tended to outweigh declines in ICT manufacturing in OECD countries. Employment of ICT specialists accounts for approximately 5% of total employment, and ICT intensive-users who carry out ICT tasks or use ICT in other sectors of the economy account for more than 20 per cent of total employment. In the U.S., ICT sector employment accounted for more than 30 per cent of total OECD ICT sector employment in 2008, followed by Japan (19 per cent) and Germany (8 per cent) (OECD 2010). However, even before the recession, Canada and the U.S. experienced steep declines in ICT employment as a result of the shift from manufacturing to services trade and outsourcing with non-OECD countries. Employment tends to be concentrated in large firms, and in

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[2] For example, half of the total US venture capital flows into the ICT sector and tends to focus on software and Web 2.0 applications and ICT-intensive environmental and energy technologies.

[3] The US accounts for 40% of all OECD ICT-related business R&D expenditures, the EU-15 for just under 25 per cent, Japan for 22 per cent, and Korea for 9 per cent.

2009, the top 250 ICT firms employed over 13 million people worldwide, accounting for almost 70 per cent of ICT sector employment in OECD countries. Between 2000 and 2009, employment grew fastest in the top Internet firms (21 per cent a year) followed by IT equipment firms (14 per cent a year) and software firms (8 per cent a year).

The 2008-2009 recession however, ripped through the global economy, though the ICT sector did not collapse to the same extent as it did in 2001-2002, and "remained stronger than OECD economies' performance as a whole" (OECD 2008a, 15). The sector started to show the effects of the downturn by the third quarter of 2008 and declines in the first quarters of 2009 were similar, though not worse, than those felt in 2001-2002, but some industries managed to perform better than others. In general, large ICT firms were stronger in the 1st quarter in 2009 than following the 2001 dot.com bust because they had higher cash to debt ratios, and tended to be better consolidated, but some large hardware manufacturers, such as Japanese electronics producers, were hit particularly hard. There were clear differences in economic impact across ICT industries and, as was the case in 2001-2002, revenues of hardware firms (semiconductors, electronics, communications and IT equipment) were affected more than service firms (IT services, software, Internet-related and telecommunications) due to slumping business and consumer demand. Though service industries experienced a 20 per cent decline in late 2008, they had begun to rebound by mid-2009, but in the semiconductor industry, which tends to act as a bell weather for economic developments in the ICT sector as a whole, production fell sharply at the end of 2008 and world capacity dropped towards 50 per cent in the first quarter of 2009 (OECD 2009a). Despite the downturn however, consumer use of ICT services such as mobile phones and the Internet continued to grow on a global basis.[4]

The negative impact of the recession on employment in the ICT sector resulted in layoffs in both goods and services sectors. Though layoffs were larger in hardware, especially semiconductors and electronics, than in services, and by the end of 2009, employment in ICT goods was holding up better than manufacturing overall and still performed better than during the previous downturn in 2001-2002 in Canada, Sweden, the U.K. and the U.S. Canada, Germany, and the US were hit the hardest, with a decrease of 10 per cent in ICT manufacturing employment. ICT services employment tended to remain flat or slightly decrease in Canada, the U.S. and most European countries, but increased slightly in other countries. At the same time, ICT R&D spending also declined but performed better than employment and much better than production and revenues. Though venture capital

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[4] By the end of 2009, there were an estimated 4.6 billion mobile cellular subscriptions or 67 per 100 people globally and in developed countries, mobile cellular penetration now exceeds 100 per cent. Mobile cellular penetration in developing countries has more than doubled since 2005 and passed the 50 per cent mark to reach 57 out of 100 people (ITU, 2010, 1).

investment slowed across the economy in 2008, about half continued to flow into the ICT sector, and survey data suggest that software, new media, and especially ICT-intensive clean technologies attracted the major share of investment.

The crisis also accelerated the restructuring of global trade and investment which has had major impacts on the ICT sector. Growth in non-OECD economies has increasingly decoupled from growth in OECD countries, and in 2009, OECD countries' share of the world market declined to 76 per cent from 84 per cent in 2003 (OECD 2010). Recent trends include the fact that more of the top 250 global ICT firms are located in non-OECD countries, such as manufacturing firms in Chinese Taipei, IT services in India, and telecommunications service providers from a range of non-OECD economies, non-OECD developing economies in Eastern Europe and Mexico are increasingly important as both producers and growth markets, growth is emerging from the restructuring of global supply chains and reorganization of the international supply of ICT services that benefit non-OECD economies, and China has emerged as "by far" the largest exporter of ICT goods and India "by far" the largest exporter of computer and information services (OECD 2010).

Since then, however, the outlook for ICT production and markets in 2010 and 2011 has improved, especially in comparison to the second half of 2008 and first half of 2009 when ICT growth in OECD countries had declined by over 6 per cent. Previously gloomy projections have been "revised upwards", and "OECD economies are slowly recovering from what in most cases has been the sharpest recession in decades" (OECD 2010, 22). The global economy has recovered faster than expected, and ICT performance has exceeded that of the business sector as a whole. Growth is expected to reach 3 to 4 per cent in 2010 and higher still in 2011, and world ICT spending which fell by 4 per cent in 2009 is expected to grow by 6 per cent in 2010 (OECD 2010). Major emerging economies have experienced rapid recent supply-side growth, and real GDP in these countries is expected to grow by over 8 per cent in 2010 and 2011. China and India have shown strong growth both in goods and services, as well as trade with other emerging economies. This suggests that the emerging economies have decoupled from OECD countries which will help to pull other countries out of recession. The optimism is however, somewhat more cautious for OECD countries, and "although aggregate world output is forecast to grow at over 4% in 2010 and 2011, the recovery is very uneven and remains hesitant and fragile in many OECD countries" (OECD 2010, 22). Hampered by weak macroeconomic conditions and labour markets, coupled with large government deficits and instability in financial markets, growth in OECD countries is expected to remain modest and likely to follow a slower growth path for the foreseeable future. Though recovery of the ICT sector is expected to strengthen in 2010, unemployment in the sector is likely to remain high in the short to medium term largely because employment tends to lag output performance in business cycles (OECD 2010). Sizable government debt due to the recession means that major new investments in ICTs or infrastructure are unlikely in the near future. Likewise the business sector is not making large investment in new equipment and software. Household debt is also high, and the fear of unemployment and tax increases dampens consumer spending on ICT equipment and services.

These somewhat divergent trends between OECD and non-OECD countries are also evident in industry sub-sector developments. The manufacturing and goods production sector began to rebound in mid-2009, and was strongest in emerging Asian economies led by Korea, Chinese Taipei, and China. Declines in manufacturing during the recession were less sharp in Europe, Canada and the US, but the rebound has been sluggish and there are few signs of significant improvement. The slow recovery in manufacturing in OECD countries means that increasing consumption in China and India and other emerging economies will be a major factor shaping future growth in the manufacturing sector. The impact of the economic crisis has been much more muted in ICT services but the sector has still generally underperformed during the recovery in OECD countries.

Telecommunications services have performed the best but all services are expected to improve throughout 2010 and 2011. Since the recovery began, ICT services have experienced a major upsurge in international trade from services exports in India, China, Russia, and smaller countries like Egypt and Viet Nam. In the OECD, Ireland remains the largest exporter of computer and information services followed by the UK, the US, Germany and Canada. In the short to medium term, semiconductors are expected to continue to lead the recovery in manufacturing, followed by PC sales and service which has an expected growth rate of 20 per cent for 2010. Growth in 2010 and beyond could be at a higher level than GDP growth, fueled by new broadband infrastructures and products develop, but financing new ICT investments will continue to be a business and policy challenge (OECD 2008a). Long-term growth prospects depend on business and consumer spending on new ICT goods and services, and on whether non-OECD countries can maintain growth paths that compensate for the slow recovery in OECD economies.[5]

Emerging Trends and Opportunities for Future Growth

Despite recessionary setbacks, long-term prospects for sustained growth in the ICT sector are strong because ICT is increasingly becoming embedded across economic activities and has become "a fundamental part of the economic and social infrastructure" (OECD 2008a, 45). Industry interest in the development of innovative services such as cloud computing,

[5] Non-OECD economies make up over 20 per cent of the global ICT market, and ICT spending in Brazil, China, India, Indonesia and Russia is grew by more than 20 per cent annually from 2003 to 2007. Approximately 50 per cent of ICT goods production now occurs in non-OECD countries and top ICT firms increasingly located in China and India.

mobile broadband and "smart" sensors is increasing, and there is much discussion about how emerging ICT applications can address major global challenges such as climate change, the environment, and ageing populations. Governments provide an important impetus for the development and integration of new technologies and services, and many have policies that directly or indirectly affect ICTs such as deployment of high-speed broadband, health applications or "smart" applications. This section provides a brief overview of some of the emerging trends in the ICT sector in OECD countries.

Mobile Broadband

Broadband is a critical enabling technology because it drives ICT innovation and ICT-enabled innovation in new digital services and makes next generation technologies and applications such as mobile networks and cloud computing possible (Benkler et al. 2010). In this way, broadband and associated technologies contribute to the transformation of economic activity much like other general purpose technologies, such as electricity and the internal combustion engine, did in other industrial eras. Broadband is currently one of fastest globally diffusing technologies for business and domestic use. By 2009, it was estimated that 64 per cent of the developed world has access to the Internet, as opposed to 18 per cent in the developing world (14 cent if China is excluded), for a total of 26 per cent global penetration of fixed broadband services (ITU 2010).[6] Some developed countries are further ahead than others and more than two-thirds of households have access to broadband Internet in Denmark, Finland, Iceland and the Netherlands, and 80 per cent of households have access in Korea. Despite the obvious social benefits of the Internet, it is also a significant driver of economic growth because "broadband access drives online shopping, education, use of government services, playing or downloading digital content and video telephony" (OECD 2008a, 18). In fact, digital content is a key factor driving rapid growth of OECD broadband subscribers and the growing number of users continues to spawn the creation of new digital content, often by the users themselves (OECD 2008a).[7] Digital content is also used in applications in non-media and entertainment industries such as banking, government services, and health. Despite rapid take-up of broadband-enabled Internet applications, diffusion is recent and economic impacts are difficult to disentangle from established ICTs. However, there is a great deal of firm take-up to improve efficiency and productivity, and develop new global value chains and business models, and evidence suggests that broadband access is positively correlated to new firm formation and

[6] More than half of fixed broadband subscribers in developing world are in China which overtook the US as largest fixed broadband market in the world in 2008.

[7] Advertising is the largest online market. Revenues are one sixth of the total for computer and video games, and music, and are growing the fastest for films. User-created content has rapidly expanded through online media such as YouTube, and social networking sites such as Facebook and Twitter.

employment across knowledge-intensive sectors (OECD 2008a). A major challenge, therefore, is to increase global Internet access, most of which is available only through fixed broadband, which currently tends to be limited to Internet users in developed countries that have much stronger broadband infrastructures.

In this context, promising developments are currently taking place in the mobile broadband sector which has important implications for increasing high-speed Internet access and expanding markets to users in the developing world. The technology for mobile broadband is now developed to such an extent that it enables wireless networking technology that allows for speeds that are fast enough for high-value applications, supports mobile devices are fast and powerful, and are affordable for a large segment of the population. The proliferation of new mobile consumer electronics such as smart phones, netbooks, and mobile media devices make it easy for users to access information anywhere, and the number of mobile broadband subscriptions surpassed subscriptions for fixed broadband in 2008 (Andes and Castro 2010; ITU, 2010). The speed of mobile data delivery and the quality of wireless networks has improved rapidly and will advance yet again with the introduction of 4G networks. This "ubiquitous connectivity" is likely to emerge as "one of the defining attributes of the Internet economy over the next quarter century . . . and the result will be an array of new applications, services, and devices" (Andes and Castro 2010, 1). Increased investment, productivity and employment are expected as a result of advances in mobile broadband which offers new opportunities for innovative applications to other sectors such as education, energy, transportation, and health care which could be "transformed by the availability of affordable, high-speed wireless connectivity to the Internet" (Andes and Castro 2010, 4). While the impact of mobile and fixed broadband may increase as the price of ICTs decreases, complementary investments in skills and organizational innovation is required in order to reap benefits of economic growth and job creation. Government broadband policies continue to play an important role in facilitating the development of broadband infrastructure and the development of human capital to drive innovation in this sector (Benkler et al. 2010).

Next Generation Technologies and Applications:
Cloud computing, Green tech, and "smart" systems

In the wake of the 2008-2009 economic crisis firms are looking for ways to improve productivity by consolidating ICT infrastructures and services, some of which have begun to experiment with cloud computing. Cloud computing is one of the most discussed and widely publicized emerging technologies, motivated primarily by its potential to reduce capital expenditures and to deliver scalable IT services at lower variable costs (OECD 2010). Cloud computing also has the potential to lower the barriers to development of ICT-related applications but providers face the challenges from new technologies such as distributed computing, parallel programming, and virtualization, which increase skill requirements for ICT specialists. The U.S. National Institute of Standards and Technology (NIST) defines cloud computing as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance 2009, cited in Castro 2010). A more accessible definition describes it as "using the internet to access someone else's software running on someone else's hardware in someone else's data center while paying for only what you use" (Cunningham 2008 cited in Castro 2010). Typical ICT services that can be delivered through a network 'cloud' include hardware infrastructure (Iaas) which allows users access to virtualized computing resources that can be scaled to firm needs and purchased on an as-needed basis much like any other utility,[8] platforms used for application development (PaaS) which allow users access to a computing platform to develop or host online applications, and software applications (SaaS) used by most consumers to access software remotely form a 'cloud'[9] (Castro 2010; OECD 2010). It is difficult to get a clear picture of current cloud computing activities due to the diversity of firms involved in the sector and a lack of sector specific data. Large cloud computing providers include large Internet firms such as Amazon and Google, software firms such as Microsoft and Oracle, telecommunications firms such as AT&T, and IT equipment and services firms such as IBM, Fujitsu and HP, and services firms from non-OECD countries are also starting to enter the market. For the majority of service providers, however, cloud computing currently contributes only marginally to revenues and employment directly related to cloud computing remains small. Nonetheless, smaller more specialized service firms are starting to enter the market and employment in the industry has increased continuously if not dramatically even throughout the recent crisis (Castro 2010).[10]

Another area for expected future growth in the ICT sector is in "green" ICT industries and sensor technologies that combine improved environmental performance with greater economic efficiency. These areas are emerging as major themes in government policy and business strategy. Governments are promoting the use "smart" applications as part of their green ICT strategies and economic stimulus packages for green growth (see OECD 2009b and 2009c). Sensor and sensor networks show particular promise for addressing environmental challenges in energy, transport, industry, applications, precision agriculture and smart buildings, for example by reducing electricity use and greenhouse gas emissions (see OECD 2010, Chapter 6 for more detail). In spite of the economic crisis, firms continue to invest in green ICTs, and venture capital is flowing

[8] Examples include Rackspace, Cloud and Amazon Simple Storage Service.

[9] Examples include Google Maps, Yahoo Flickr, and Microsoft Hotmail.

[10] Between 2004 and 2009 the number of workers employed by the top 10 cloud computing specialists based in the US increased by 18 per cent a year, but in 2009 employment growth slowed to 5 per cent.

into clean technologies, many of which are ICT intensive, and include the manufacture of energy-efficient semiconductors and semiconductors for photovoltaics and wind power, and services in the area of green ICT consulting, recycling old ICT equipment and the use of virtualization software (see OECD 2010 Chapter 5 for more detail).

Recent Trends in Canada's ICT Sector

According to data from Industry Canada, Canada's ICT industry is a dynamic and globalized economic sector, contributing $59.2 billion in 2008, representing approximately 4.8 per cent of Canada's GDP. It has experienced an average annual growth rate of 4.7 per cent since 2002. By many accounts, the ICT sector in Canada acts as one of the main drivers of economic growth and technological innovation in the Canadian economy. Canada's ICT manufacturing and service firms are world leaders in some sub-sectors and exhibit core strengths in several others. This section provides an overview of Canada's ICT sector including the main industrial activities of Canadian ICT firms, a brief discussion of how the recent recession affected the sector, and a snapshot of the recent economic performance of the sector.

Industry Strengths

Canada's ICT sector exhibits leadership in several ICT industries, and core strengths in several others. Several recent reports identify **wireless technologies and applications** as one of the strongest ICT industry sub-sectors in Canada, where according to Deloitte's Technology Fast 50 program, one quarter of North America's fastest-growing wireless companies are located (Kazam Technologies 2009, Sydor-Estable 2009). As of 2007, the Canadian equipment manufacturing and products industry was comprised of approximately 400 firms, most of which were SMEs, employed approximately 21,000 workers, and generated approximately $18 billion in revenues. In the same time period, the Canadian cellular services industry was comprised of 15 national, regional, and municipal cellular operators that employed approximately 16,000 workers, and generated more than $10 billion in annual revenues, which represents almost 30 per cent of the Canadian telecommunications market. According to International Data Corporation (IDC), the Canadian wireless industry experienced an annual growth rate three times that of any other Canadian telecommunications sector, and forecasts that wireless services will account for the biggest share, 42 per cent or C$16.9 billion, of total Canadian spending on telecom services in 2010 and for one-half, or C$23.7 billion, of telecom service revenue in 2014 (Surtees and Yang, 2010).

Whether measured by the number of Canadian companies active in the industry or international exports, Canada shows particular strength in wireless manufacturing and services including wireless infrastructure such as Wi-Fi and WiMAX wireless networking,[11] data-centric mobile and cellular devices and equipment, and Software Defined Radio (SDR) middleware and applications (Industry Canada 2009). Canada is particularly well-positioned for continued success in the Wi-Fi mesh networking equipment market, and for participation in the emerging WiMAX market. With a significant number of Canadian firms conducting R&D into and commercializing WiMAX products, like Redline Communications, Wavesat, and Vecima Networks, Canada is considered to be a leader in the field (Kazam Technologies 2007). Though they may have been affected by the recent downturn, cellular devices and handsets tend to be another source of industry strength with global leaders like Research in Motion. Canada is also a world leader in the field of satellite communications, and Telesat Canada's ANIK F2 satellite that was developed in partnership with the Communications Research Centre, the Canada Space Agency, EMS Technologies and Com-Dev provides internet access to remote communities in the US and Canada (Sydor-Estable 2006).

Another area of core Canadian strength is in the semiconductor sub-sector. While Canada lacks the presence of a major semiconductor manufacturing facility, it has a highly specialized niche for **fabless semiconductor** firms. A study of the semiconductor industry undertaken for the National Research Council of the U.S. Academies noted that Canada ranked second after the U.S. in 2002 with a concentration of 30 fabless semiconductor firms (Macher, Mowery and Di Minin 2008). The semiconductor and microelectronics components sub-sector is a highly diversified segment that includes component design, some manufacturing capability, as well computer hardware design and applications for defence and private industry. According to the most recent data from Statistics Canada, the semiconductor and electronic component manufacturing sub-sector employed 18,700 workers in 2008 in 646 establishment units. It includes some home grown firms, as well as several leading international companies. There is a strong concentration of employment in the semiconductor segment in the Ottawa region. The vitality of the Ottawa area cluster was strongly bolstered by a federal initiative, the Microelectronics and Systems Development Program launched in 1989 as a five year, $60 million undertaking to support the development of advanced microelectronics and information technology systems. According to an interviewee, a number of key Ottawa area companies, whose sales totaled $50-60 million a year at the start of the program, received funds to invest in R&D. Ten years later the firms, which included Mosaid and Tundra, had grown their total sales to almost ten times that amount.

[11] Mesh networks are emerging to enable wireless networking over a given geographical area. Wi-Fi is a brand name that refers to technology primarily used in wireless routers and is a mature technology. WiMAX is similar to Wi-Fi but is a newer technology that has a much greater range and speed (Sydor-Estable 2009)

Canadian firms are also developing a global reputation for expertise in **digital media and content**, a sector that accounts for $3.5 billion in revenues. Of the 2300 digital media firms in the industry, many are internationally renowned for animation and special effects, video and computer games, education and training products, and corporate applications. For example, Canadian advances in animation and special effects are widely used in contemporary film production and have been involved in the production of many Award-winning films. Canada is also ranked third in the world in video game production after the US and Japan, and Canadian studios such as Electronic Arts, Ubisoft, and BioWare have developed approximately 20 per cent of the top-selling games in North America. Canadian firms also have industry strengths in the areas of mobile content development for wireless handsets, and digital media companies such as CAE, Kuotka Interactive and the NECTAR Foundation are producing cutting edge instructional products for the education, transportation, communications, and manufacturing sectors. Several post-secondary institutions, including the Art Institute of Vancouver's Centre for Digital Imaging and Sound, the Great Northern Way's Centre for Digital Media, the Sheridan Institute of Technology and Advanced Learning in Mississauga, the Digital Media Zone at Ryerson University in Toronto and the National Animation and Design Centre in Montreal, offer many new media programs (HAL 2009; City of Toronto 2010).

The Canadian ICT sector also exhibits strengths in several other industries. Canada has been an early adopter of cutting edge **e-health technology** hardware, software, and services, and Canadian ICT firms have developed a number of e-health technologies including clinical systems management and electronic health records, hospital and physician office resource management systems, long-term and acute care, telemedicine, and home and community care, as well as diagnostic digital imaging tools. Canadian **IT security** industries account for $1.2 billion in revenues, and include firms that provide advanced applications in biometrics, cryptography and encryption, mobile authentication, cyber security, public safety and product certification. Canadian

Sector Performance Indicators

Industry data in Canada is based on the North American Industry Classification System (NAICS). ICT manufacturing includes:

- Computer and peripheral equipment manufacturing
- Communications equipment manufacturing (wired and wireless)
- Audio and video equipment manufacturing
- Semiconductor and Electronic component manufacturing
- Instruments manufacturing (navigational, measuring, medical and control)
- Communication and energy wire and cable manufacturing
- Commercial and service machinery manufacturing

ICT services include:

- Software publishing
- Computer systems design
- Data processing and hosting services
- Telecommunications services (wired, wireless and satellite cable and telecommunications carriers)
- Cable and other program distribution
- ICT wholesaling

ICT companies also generate world-class **ICT professional services** which include **business software and computer services** that are applied in a variety of industries and vertical markets in including business intelligence, enterprise content management, supply chain management, video games, digital media, IT security, e-health, and e-commerce.

ICT Industry Performance

According to data from Industry Canada, Canada's ICT industry is a dynamic and globalized economic sector that has experienced a steady increase in its average annual growth rate since 2002. The share of Canadian GDP attributable to the ICT sector increased by 34 per cent between 2002 and 2008, with an annual growth rate of 5 per cent, and by 2008, output growth in the ICT sector outpaced growth in the Canadian economy as a whole. As of 2008, the ICT industry represented approximately 4.9 per cent of Canada's GDP, and contributed $60.4 billion to the Canadian economy, an increase of 3.3 per cent from 2007. After a significant slump from the third quarter of 2008 to the third quarter of 2009 due to the global economic crisis, real ICT sector output began to increase in late 2009 and showed an increase of 1.3 per cent by the first quarter of 2010, which is similar to the 1.5 per cent increase in output for all Canadian industries, suggesting that the ICT industry has begun to recover from the downturn. The sector is comprised of 31,500 mostly small and medium-sized firms (SMEs), of which 78.6 per cent operate in the software and computer service industries, and 10.6% in the wholesaling industries.[12] The number of large, anchor firms on the sector is relatively small, and in 2008, there were approximately 100 firms with more than 500 employees, which tend to be concentrated in the manufacturing sub-sector (Industry Canada 2010b).

The Branham Group describes 2009 as a "year of opportunity and hardship", and though "turbulent, closed out an extremely successful decade" for the Canadian ICT industry as the top 250 Canadian ICT firms generated $71.32 billion in revenue, down 6 per cent compared to 2008, but up 43 per cent compared to 2003 (Anderson and O'Shea, 2010).[13] The year 2009 was a transitional year in the industry as Nortel Networks declared bankruptcy and underwent aggressive restructuring, while Research in Motion (RIM), which has produced double-digit growth in every year but one in the past decade, took its place as the top ICT company in Canada.[14] In terms of regional distribution, Ontario had the sharpest decline in its share of firms in the top 250, accounting for 57 per cent of firms, whereas Quebec slightly increased its share, and B.C. and Alberta remained the same. Firm

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[12] About 25,800 of these firms, or 82 per cent of the sector, have 10 employees or less.

[13] The Branham Group is an industry analyst and strategic consulting firm based in Ottawa focused on the ICT sector in Canada.

[14] Last year was particularly good for RIM, as it increased revenues from $6.29 billion in 2008 to $11.58 billion in 2009, and increased device sales 89 per cent.

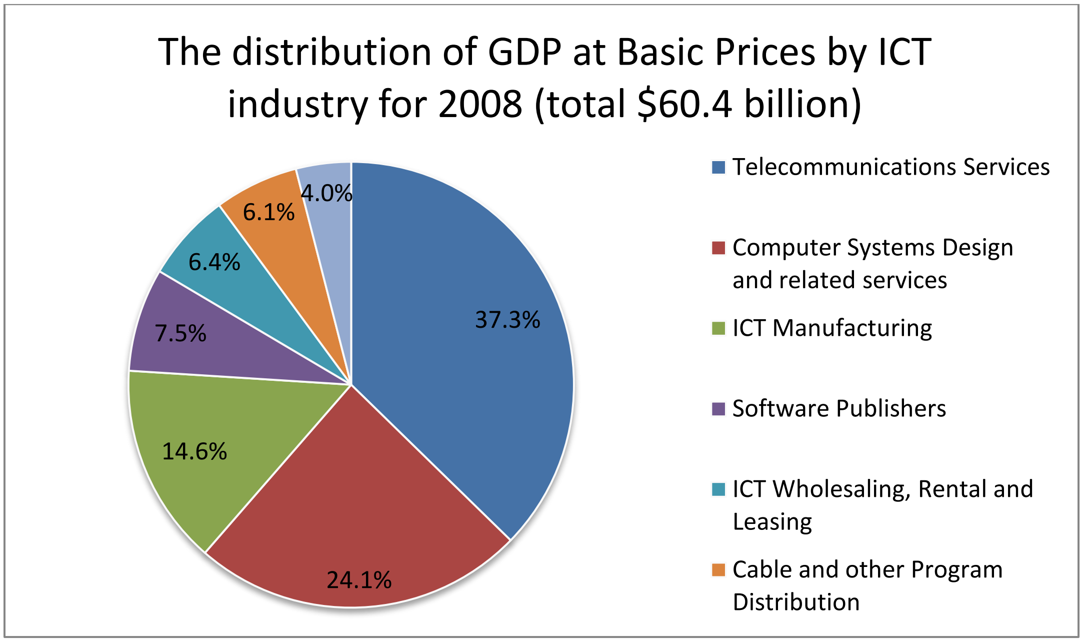
performance by industry category includes firms in the software, ICT professional services, ICT hardware and infrastructure, and service providers. While hardware and infrastructure firms represent almost one quarter of the firms in the top 250, the sub-sector was hit the hardest. It was the only group that experienced a decline in revenues, which fell 21 per cent in 2009, whereas firms in the ICT professional services category that represent almost 30 per cent of the top 250 firms, grew by 21 per cent. The service provider sub-sector was one of the strongest performers, contributing 39 per cent of the top 250 firms' revenues while only accounting for 13 per cent of the top 250 firms. However, overall investment in R&D, sales and marketing, and other core business development activities declined as firms focused on profitability and cash flow issues. One interesting observation is that Toronto, Vancouver and Ottawa have emerged as "hot beds" for ICT start-up activity, and account for 32 per, 24 per cent, and 16 per cent respectively of the 2010 'up and coming' firms.

Output and Exports

Growth in output is evident in both ICT manufacturing and service industries, though ICT services tend to constitute a much larger proportion of GDP than ICT manufacturing. At the same time, GDP changes in ICT services tend to be more moderate and less erratic than in manufacturing. The services sector continued to expand rapidly up to the recent recession, growing by 2.9 per cent in 2008 to reach $47.7 billion. Telecommunications services is the largest single sub-sector within the ICT industry, representing 37 per cent of ICT GDP and 1.8 per cent of total Canadian GDP in 2008, and was the largest contributor to ICT services output growth, increasing by $620 million in 2008. It was followed by computer systems design which increased by $520 million in the same period, reflecting a growth rate of 3.7 per cent for both industry sub-sectors. Like most other ICT sub-sectors, and Canadian industry in general, the services sub-sector felt the impact of the current recession, and post-recession recovery has been slow, increasing by only 0.2 per cent in first quarter of 2010. Output fell slightly in all four key ICT service sub-sectors and since the beginning of 2009, software industry output has seen the largest decline (-4.6 per cent) followed by telecommunications (-2.4 per cent), though the scale of the decline decreased for both software and telecommunications in the first quarter of 2010, suggesting that the downward trend may be slowing (Industry Canada 2010b).[15]

[15] The modest increases in output in ICT services in early 2010 is mainly attributable to the ICT wholesaling industry which increased by 5.5 per cent. Excluding wholesale figures, ICT services output declined from the previous quarter by 0.2 per cent, marking the fourth consecutive decline without the positive effect of the wholesale sub-sector.

Chart 1



The manufacturing sector also experienced steady pre-recession growth, but began to slow before the full effect of the recession was felt. The sector grew by 10.1 per cent in 2007, but slowed to only a 2.5 per cent rate of growth in 2008. By 2008, the total GDP for ICT manufacturing had reached $8.8 billion. The wireless communications equipment industry was the strongest performer, growing by almost 23 per cent in 2008. In contrast, the wired communications equipment sector has continued to decline, shrinking by almost 50% since 2005, and by 11% in 2008 alone. There are indications, however, that the manufacturing sector has started to experience a healthy recovery. It registered a strong rate of growth at 7.5 per cent in the first quarter of 2010, compared with an increase of only 1.9 per cent in the last quarter of 2009, marking the third consecutive quarterly increase for this part of the sector, and bringing it back to pre-2009 levels. This increase is not reflected in other areas of Canadian manufacturing. Manufacturing shipments that experienced declines in 2008 and 2009 also increased sharply in all four key industries by a total of 7.1 per cent in the first quarter of 2010 (Industry Canada 2010b).[16]

Though increases in output have occurred across almost all ICT industry sub-sectors since the end of 2009, exports of ICT goods have dropped sharply, and have declined for the fifth consecutive quarter by 1.4 per cent, reaching the lowest levels in the period analyzed. This drop is attributable to declines in exports of electronic components (-7.1 per cent), instruments (-5.1 per cent) and communications equipment (-4.0 per cent), and

[16] These include 15 per cent in peripheral equipment industry, 8.2 per cent in electronic components, 7.8 per cent in instruments and 4.7 per cent in communications equipment.

exports of computer and peripheral equipment, communications equipment, and electronic components remain at their lowest levels since 2002. Exports to the U.S., which have fallen steadily since 2008, fell by 4.5 per cent in the fourth quarter of 2010, and the U.S. share of Canadian ICT exports now stands at 63 per cent. However, after falling for four consecutive quarters, ICT exports to the Asia Pacific economies and the EU-25 increased slightly (by 2.6 per cent and 4.5 per cent respectively), bringing the share of ICT exports to the EU-25, Asia Pacific and other countries to 13.1 per cent, 12.7 per cent and 11.7 per cent respectively.

Revenues

The latest data available for ICT sector revenues is for 2009, so this overview cannot capture the most recent gains since the economy began to recover, but it does provide another important indicator of overall sector performance (Industry Canada 2010a). Between 2002 and 2008, total revenues for the sector rose from $130.8 to $155.3 billion, a 19 per cent overall increase (or 2.9 per cent annual growth). Revenues grew by 2.8 per cent in 2008, but declined by 0.8 per cent in 2009, the first decrease since 2003. There has been a steady shift way from ICT manufacturing towards ICT services as a total share of the sector. Manufacturing revenues have declined by almost 14 per cent since 2002, and now account for less than 15 per cent of all ICT sector revenues, which in 2009 amounted to $22.9 billion. During the recession of 2008-2009, the sector experienced a significant decline of 9.0 per cent, which was the second year in a row that revenues fell. The largest revenue declines were in the computer equipment industry (-30.7 per cent), followed by electronic components (-23.6 per cent) and wired communications equipment (-14 per cent), whereas other sub-sectors increased somewhat, including wireless communications equipment (11.7 per cent) and audio and video equipment (7.8 per cent).

In contrast, ICT services revenues have steadily grown, registering in increase of 43 per cent since 2002, or an average of annual growth rate of 5.3 per cent, and currently account for over 60 per cent of all ICT sector revenues. Even during the recession, ICT services posted positive revenue growth in both 2008 and 2009. In 2008, ICT services grew by 33.4 per cent, of which the communications services and computer systems design sub-sectors accounted for 81.7 per cent of total sector revenues, and the wireless communications equipment industry had the highest individual rate of growth at 16.6 per cent. Though overall service sector revenues for 2009 increased only slightly (2.9 per cent), all ICT services industries increased revenues by between 2.5 and 4.0 per cent in 2009, except for the software industry which decreased slightly. By the end of 2009, total service sector revenue was $92.8 billion.

Research & Development

ICT industries are the largest private sector performers of R&D in Canada, spending $6.2 billion in 2009, and accounting for 38 per cent of private sector R&D expenditures (Industry Canada 2010a). R&D expenditures have grown constantly and have risen by 17.7 per cent since 2002. Consistent with the trends evident in GDP and revenues, spending on R&D has shifted over time from the manufacturing to the services sector. Overall, expenditures on R&D in ICT manufacturing industries have decreased by 1.3 per cent a year (from 65 per cent in 2002 to 51 per cent in 2009), while R&D spending in the ICT services sector has steadily increased by 7.8 per cent a year (from 32 per cent in 2002 to 46 per cent in 2009). Despite this shift, however, the manufacturing subsector continues to be the largest spender on R&D, accounting for $3.2 billion, or 19 per cent of total private sector expenditures (51 per cent of total sector spending) in 2008, but there have been major decreases in R&D spending on communications equipment and electronics components. ICT services have recently experienced substantial growth in R&D spending and in 2008, accounted for $2.9 billion, or 18 per cent of total private sector R&D (46 per cent of sector spending). The software sub-sector is one of the major performers of R&D, increasing its expenditures by 28 per cent from 2008 to 2009, and 158 per cent since 2002. It is significant that global ICT firms such as Nokia, Ericsson, Alcatel-Lucent have established R&D units in Canada in order to tap into core R&D strengths in wireless technologies and services.

Canada has a well-developed public research infrastructure that supports R&D in the ICT sector. Several key institutions comprise this research infrastructure and provide opportunities for collaborative research. The *National Research Council* is the leading national resource for research, development, and technology-based innovation. It is comprised of twenty institutes and national programs, located in different regions of the country, that span a wide range of scientific disciplines and industry-based research, some of which are directly related to ICT. These include the *Canadian Photonics Fabrication Centre* which provides access to state-of-the-art prototyping equipment to develop leading-edge photonic devices, the *National Institute of Nanotechnology* at the University of Alberta which provides laboratory space and research facilities for multi-disciplinary research in various disciplines including informatics. The *Communications Research Centre Canada (CRC)* is the Government of Canada's primary laboratory for R&D in advanced telecommunications, and the only national laboratory with critical mass and expertise in wireless, broadcasting, satellite and fibre optics, components and systems. *CANARIE Inc.* operates Canada's advanced high-speed network that supports collaboration in science and technology research among Canada's leading public research organizations and universities, and *Precarn* supports market-driven commercialization of R&D between companies and universities in intelligent systems and robotics. The *Networks of Centres of Excellence* foster multi-disciplinary, multi-sectoral partnerships between academia, industry, government and not-for-profit organizations, and supports academic research and the commercialization of research. The program supports several research networks across the country that are directly related to ICT activities, including the Canadian Digital Media Network in Waterloo, the Canadian Institute for Photonic Innovations (CIPI) and the GEOmatics for Informed Decisions Network (GEOIDE) at l'Université Laval, the Graphics Animation and New Media Network (GRAND) and the Mathematics of Information Technology and Complex Systems (MITACS) at the University of British Columbia, and the Intelligent Sensing for Innovative Structures Network (ISIS) at the University of Manitoba. In addition, research networks are supported by various industry consortia including the Network for Emerging Wireless Technologies at TRLabs and the National Optics Institute.

Employment

The ICT sector is a major source of employment in the Canadian economy, and the sector directly employs approximately 600,000 Canadians and another 500,000 IT professionals in other sectors. Employment in the ICT sector is characterized by a highly educated workforce, and 42.1 per cent of workers had a university degree in 2008, compared to a national average of 23.9 per cent. The top three sub-sectors that employ the largest share of educated personnel are software and computing services (51 per cent), communications equipment manufacturing (50 per cent) and computer equipment (43 per cent). Workers in the sector also tend to earn above average wages, and earned an average of $61,971 in 2008, which is 47 per cent higher than the national average of $42,143 (ITAC 2008).

Employment in the ICT industry grew by 4.8 per cent annually between 2002 and 2008, and by 2008, it employed 3.3 per cent of all Canadian workers. After a slight dip in 2007, and a brief recovery in 2008, employment across the ICT sector experienced a contraction in 2009 from which it does not yet appear to have rebounded. Though employment increased in the ICT service industries by 16.2 per cent in 2008, it grew by only 2.9 per cent in 2009. Employment growth in the ICT services sector was driven solely by the computer systems design industry which increased by 3.1 per cent, which was large enough to offset declines in software publishing (-4.3 per cent), data processing (-7.0 per cent), and telecommunications services (-8.6 per cent). Employment declines in the ICT services sector, however, have been modest in comparison to employment declines in the ICT manufacturing sector, which has decreased by 8.8 per cent since 2002. Since 2008, employment has declined across all ICT manufacturing subsectors, but has been felt most severely in computer and peripheral equipment manufacturing (-4.2 per cent) and electronic components (-6.9 per cent), a trend which reflects the overall structural shift from manufacturing to services in the sector. It is notable that while employment declined slightly in manufacturing, and increased slightly in services, some sources report that employment increased substantially in the wireless communications equipment industry which experienced a growth of 50.9 per cent in 2008, reflecting the shift from the use of landline telecommunication devices and services to wireless (ITAC 2008).

There are signs, however, that employment levels in the industry, which have been flat since the start of the recession started to rebound in early 2010. Overall ICT employment grew in the second quarter of 2010 (+0.3 per cent), after falling for five consecutive quarters, similar to employment in the Canadian economy which has also been increasing since mid-2000. Though overall employment in the ICT manufacturing industries was down 0.3 per cent in the second quarter of 2010, employment increased in two of the four key ICT manufacturing industries: employment in the computer and peripheral equipment industry grew by 1.5 per cent; and the instruments industry continued its upward trend for a third consecutive quarter, up 0.4 per cent. Employment in the communications equipment industry and electronic components industry, however, fell by 2.0 per cent and 0.1 per cent, respectively. Overall employment in the ICT services industries, which had trended downwards since the end of 2008, increased 0.4 per cent this quarter, though the decline has been modest in comparison to manufacturing industries, and employment in the Canadian services sector over the recession tended to remain flat. Two out of the three key ICT services industries increased employment this quarter: employment in the software industry and computer systems design industry both increased for a third quarter in a row, by 3.8 per cent and 0.6 per cent, respectively; and employment in the software industry bounced back in the last three quarters (+7.8 per cent) after a large drop in the first three quarters of 2009. On the other hand, employment in the telecommunications services industry is still declining, down 1.6 per cent in the second quarter and 6.5 per cent over the last three quarters (Industry Canada 2010b).

ICT Cluster Dynamics in Canada

It is important to recognize the 'national' ICT industry in Canada is purely the product of statistical aggregation. The underlying dynamics of the industry are rooted in a diverse range of ICT clusters spread across the distinctive regions of the country. While it is clear that a national strategy to support growth and innovation in Canada's ICT industry is necessary in order to be globally competitive, the competitiveness of ICT firms is strongly influenced by the conditions that exist on the ground in the localized setting of the specific ICT clusters in found in different city-regions. While successful ICT firms must compete on a global basis, many of the drivers of innovation – access to capital, R&D and knowledge creation, cross-sectoral knowledge diffusion, and the development of highly skilled personnel – exist in a local context. The early ICT clusters formed in the U.S. primarily around the San Francisco Bay area in Silicon Valley and along Route 128 in Massachusetts during the 1970s. Subsequent more specialized clusters emerged in San Diego, Austin, Texas, Research Triangle Park in North Carolina and Washington, D.C. During the 1980s and 1990s the international clustering of ICT firms in locales as diverse as Bangalore, India Taiwan, Ireland, Israel and Finland became a defining characteristic of the global industry (National Research Council of the National Academies 2009). Observations of these dynamics operating in diverse city-regions have contributed to the increasing policy influence of the theoretical and empirical literature on industrial clusters.

The importance of cluster development has recently been the focus of a great deal of policy attention in the U.S. and Europe. There is a growing recognition in these jurisdictions that the goal of promoting economic development can best be accomplished at the level of the local and regional economy through the lens of strategic clusters. The underlying rationale for this belief is the distinct advantages that clusters afford to firms and the communities that house them. While clusters have long been a source of fascination for economic policy-makers, the evidence behind their direct economic impact was on weaker footing. However recent research in Canada and the U.S. provides strong support for the fact that the concentration of economic resources around clusters of strength generates considerable economic benefits for regions, provinces, and countries (Porter 2003; Spencer, Vinodrai, Gertler, et al. 2010; Delgado, Porter and Stern 2010).

The underlying rationale for this emphasis is the distinct advantages that clusters afford to firms and the communities in which they are located. First, the cluster acts as a magnet drawing talent, and the location of specialized training and educational institutions which can supply new skilled labour to the firms in the cluster. The presence of a 'thick' local labour market act as an attractor for both firms and further skilled workers as the cluster gains a reputation as provider a strong source of employment opportunities for workers and a plentiful supply of needed skills for firms. Second, membership in the cluster makes it easier for firms to source needed parts and components, thereby enhancing the technological and productive capabilities. A third benefit arises from the formation of new firms when larger, anchor firms generate new ideas and research findings that support entrepreneurial spin-offs. Finally, the strength of clusters can provide an important stimulus to public investment in specialized infrastructure, such as communication networks, joint training and research institutions, specialized testing facilities and the expansion of public laboratories or post secondary educational institutions. As the depth and value of such investments increase, so do the economic benefits flowing to firms located in the cluster and their surrounding communities. Indeed, the strength of the cluster and its supporting infrastructure of public investments and collaborative institutions create a self-reinforcing positive feedback loop that benefits the entire region (Wolfe and Gertler 2004).

Detailed research on the dynamics underlying eight ICT clusters in Canada, conducted as part of the Innovation Systems Research Network (ISRN) five-year national study of industrial clusters in Canada, demonstrates the applicability of these general factors to the specific case of the ICT sector.[17] The ISRN research project employed several techniques to investigate cluster dynamics in the individual cases. In addition to the case study methodology described above, project researchers created a statistical database and developed a unique definition of Canadian clusters using four digit level NAICS codes. ICT clusters were grouped into both manufacturing and service clusters (Spencer et al. 2010).[18] Indicators from the ISRN database are used to map the relative size and degree of concentration of the eight clusters, in both ICT manufacturing and ICT service, examined in the ISRN study. Data on levels of employment, the location quotient for the individual clusters, the number of business establishments in the cluster and the average annual full-time employment income for the clusters are presented in the following table.

Table 1: Selected ICT Clusters in Canada

	Cape Breton	New Brunswick	Quebec City	Ottawa-Gatineau	Toronto	Kitchener	Calgary	Vancouver
Employment								
Manufacturing	40	1,415	4,470	15,430	58,695	8,125	8,415	14,845
Services	2,110	12,535	18,410	39,725	148,415	13,570	33,025	63,490
TOTAL	2,150	13,950	22,880	55,155	207,110	21,695	41,440	78,335
Location Quotient								
Manufacturing	0.07	0.31	0.93	2.04	1.76	2.64	1.07	1.07
Services	1.19	0.84	1.18	1.61	1.37	1.35	1.28	1.40
TOTAL	0.93	0.72	1.12	1.71	1.46	1.66	1.23	1.32
Business Establishments								
Manufacturing	10	47	183	325	1,898	155	369	755
Services	27	247	738	2,841	9,750	422	2,199	2,693
TOTAL	37	294	921	3,166	11,648	577	2,568	3,448
Average Annual FT Employment Income								
Manufacturing		$ 50,896	$ 49,712	$ 81,992	$ 70,477	$ 65,668	$ 67,015	$ 68,553
Services	$ 34,298	$ 52,965	$ 57,279	$ 74,887	$ 71,725	$ 63,378	$ 66,797	$ 65,572

Statistics Canada. 2006. Industry - North American Industry Classification System 2002, Sex and Selected Demographic, Cultural, Labour Force, Educational and Income Characteristics, for the Population 15 Years and Over of Canada, Provinces, Territories, Census Metropolitan Areas and Census Agglomerations, 2006 Censuses - 20% Sample Data. Catalog #97-564-XCB2006006. Ottawa, ON: Statistics Canada.

Statistics Canada. 2009. June 2009 Establishment Counts by CA/CMA, Sectors & Employment Size Ranges. Ottawa, ON: Statistics Canada.

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[17] The research was funded under SSHRC Grant No. 412-2000-1002. Each case study used a consistent methodology to examine the geographical co-location of firms, financial services, post-secondary research and training institutions, business and civic associations, and public support organizations, as well as linkages between key actors, and how these interactions contributed to the economic growth of individual firms and the overall cluster. The following sections draw upon the more detailed discussion found in Lucas, Sands and Wolfe 2009.

[1818] The ISRN definition of industrial clusters grouped four digit NAICS codes into clusters based on their tendency to systematically co-locate in CMAs and CAs across the country. More detailed information on the methodology used to define the clusters, as well as the specific four digit NAICS codes included in definition of the ICT manufacturing and service clusters can be in Gertler, Spencer, Vinodrai et al. 2005.

The eight cases studies included ICT sector in Toronto (Britton 2003, 2004; Creutzberg, 2005); telecommunications and photonics in Ottawa (Brouard et al 2005; Chamberlin and de la Mothe 2003); ICT in Waterloo (Nelles, Bramwell and Wolfe 2005; Bramwell and Wolfe 2008; Bramwell and Wolfe 2008); ICT in New Brunswick (Davis and Schaefer 2003; Davis and Sun 2006) and Cape Breton (Johnstone and Haddow 2003); photonics in Quebec City (Kéroack et al. 2004; Ouimet et al. 2007); and wireless in Calgary and Vancouver (Langford and Wood 2005; Langford et al. 2003). The cases differ in longevity, size, firm composition technological focus, and maturity. While the cases studies do not cover all ICT activities in a given region, they serve to highlight the key factors in the formation and growth of ICT clusters, which are summarized below.

Cluster Origins and Development

There is a common theme linking the ICT clusters that were studied; in each case, early commercial success came from exploiting the local knowledge base to commercialize new products and services. Some innovations related to the development of new technologies, such as the development of the CO2 laser in Quebec City and new computer software in Waterloo, while others related to increasing market demands for existing technology, such as the need for wireless communication in Alberta's oil and gas industry and the New Brunswick government's decision to support a provincial broadband network. The early success of cluster firms depended on their ability to exploit both local and global knowledge sources to develop, market, and sell innovations to external customers. Lead anchor firms were able to draw upon existing capital, skilled local labour markets and exploit their existing or new linkages with customers to commercialize their products. Some chose to spin off new firms to develop products or actively promote the growth of new firms through an 'affiliates' program, because the new technologies lay outside their core capabilities. The initial success of an anchor firm or startup often provided a demonstration effect for other potential entrepreneurs in the cluster to emulate their success. The growth of both the lead anchor firms and the gradual birth of additional new firms influenced the organizational structure of the clusters.

The Ottawa case provides a classic illustration of this process. The original decision by Northern Electric in the late 1950s to establish a research facility in the region after a judicial decision in the US cut off its ready access to patents from the Western Electric Co. Its purchase of a substantial tract of land on the outskirts of Ottawa as the future home of Bell Northern Research, largely because of the concentration of federal government laboratories in the nation's capital, created a steady stream of industrial engineers, researchers, and managers moving into the region. Many of the leading entrepreneurs in the Ottawa telecommunications and photonics cluster began their careers as researchers for BNR or its failed subsidiary, Microsystems International Ltd. Both technical and entrepreneurial talent left Nortel over the years to form new firms in the region. The demise of MIL was significant for the cluster in two respects – it attracted a large number of highly skilled IT scientists and engineers to the Ottawa area in the 1970s and its closure released a significant number of skilled workers into the regional economy, many of whom went on to found or work for new firms. More than twenty local startups emerged from the collapse of MIL, including some of the cluster's leading firms, such as Mitel, Mosaid, and Calian (Chamberlin et al. 2003; Harrison et al. 2004).

The initial driving force behind Calgary's wireless cluster was the perceived need for improved communications technology to facilitate exploration and drilling for petroleum and natural gas in the province's diverse geography. A key factor was the creation of NovAtel in 1982, a joint venture of the Alberta Government Telephones (AGT) and Nova Corporation, which developed the first wireless telephone network in North America. Many of the people working at later startups traced their roots back to their formative period as employees of NovAtel (Langford et al. 2003). The Vancouver wireless cluster traces its roots to three firms that emerged in the late 1960s and mid-1970s who were innovators in mobile data technologies: Mobile Data International, Glenayre, and MPR-Teltech. These firms established a critical mass of wireless expertise in the region and spun off most of the firms that now populate the cluster. Their initial success and leading technology made them attractive takeover targets for larger multinationals in the 1990s. The subsequent restructuring resulted in the spinning off of numerous firms that populate the cluster and draw upon the talent pool that remained in Vancouver after the anchor firms' demise (Langford and Wood 2005).

In those cases where a lead anchor firm was absent, such as Quebec and Waterloo, universities and research institutes played a more instrumental role in the cluster's formation. A key event in the formation of the Quebec photonics cluster was the discovery of the CO2 Laser in 1960 at the Defence Research and Development Canada Laboratories which led to the buildup of local expertise in photonics. This expertise was further embedded with the creation of two research institutes based on industry-university-government partnerships in the mid and late 1980s, both the result of. The transition from research to industrial application began in the early 1980s with the creation of many of the photonics cluster's leading firms: Exfo, ABB Bomem, and Gentec (Keroack et al. 2004). The ICT cluster in Waterloo grew out of a strong industrial base in advanced manufacturing, a local university focused on engineering, math and computer science, and a civic culture that supported linkages among firms and between firms and public institutions, particularly universities. Waterloo's first ICT firms were created in the early 1970s when a number of firms began developing software and hardware to support networking and communications applications. Two of the early firms, WATCOM and Dantec Electronic, were both spun-off from the University of Waterloo in 1974. The emergence of these early spinoffs had a strong demonstration effect for subsequent local startups in the 1980s and 1990s, such as Open Text and Research in Motion (Nelles, Bramwell and Wolfe 2005).

The origins of Toronto's ICT cluster reflects the intersection of strategic policies adopted by the federal government, as well as the attractiveness of the GTA as a site for the Canadian operations of large U.S. multinational corporations. Early decisions by the Department of Defence supported the academic ambitions of the University of Toronto to expand in the emerging area of computer technology and laid the basis for the emergence of academic expertise in the field. By the 1970s, the GTA was home to the national offices of leading multinationals, such as Fairchild Semiconductor, Canadian Marconi, Canadian General Electric and Canadian Westinghouse and Control Data Corporation. Federal programs introduced in the 1970s encouraged them to extend their R&D efforts in computer technology, further expanding the technological capabilities of cluster firms. A federal program introduced in the 1980s to support university research centres provided the research expertise at the University of Toronto which supplied the emerging graphics chip firm, ATI Technologies, with some of its first microchip designs, in effect operating as the research arm for what became the GTA's largest semiconductor firm before it was purchased by AMD (Creutzberg 2005).

In each of our cases, the antecedent conditions for cluster formation were laid by the presence of a strong research base, either in the form of lead anchor firms or public sector institutions. The demonstration effect exerted by the success of the lead anchor firms or their role in spinning off new startups to exploit emerging technological niches provided the spark to stimulate further entrepreneurial activity. As the clusters grew, new firms emerged specializing in niche market segments, complementing and supporting the work of other local firms. Conversely, in some case other firms that moved into the region were direct competitors to indigenous firms both for business and employees. Some multinationals enter a cluster to tap into the local resources of knowledge and personnel, as has been the case with Cisco, Google, AMD and other leading U.S. firms. Their presence serves to solidify the cluster's image and facilitates external linkages, particularly if the multinational conducts business with local suppliers and begins working with local customers. Growth in the size of local firms and an expanding market base increases the administrative complexity they face and requires greater managerial expertise to deal with new challenges. The predominance of small and medium-sized firms in many of the clusters means that much of this experience is in limited supply within the cluster, creating a potential barrier to further growth, which has been cited as one of the most critical constraints on the growth of indigenous firms in the ICT clusters in Canada. This issue is discussed in greater detail below.

The Role of Lead Anchor Firms and Organizations

The preceding discussion of the origins and development of Canadian ICT clusters underlines the fact that lead anchor firms and organizations were pivotal in the emergence of clusters in most of the case studies. While the specific anchor organizations differed from cluster to cluster, they played a similar role in focusing resources on exploiting the commercial potential of new knowledge and technology. The types of anchor organizations varied between large private firms (Ottawa, Toronto, Vancouver), a publicly regulated utility (New Brunswick), a joint venture formed by public utilities (Calgary), and public research institutions (Quebec, Waterloo). The crucial assets provided by the anchor firms were in-house capital and market linkages. In many instances, the lead anchor firms played a critical role in incubating and spinning off new firms in emerging technology niches, in providing a training ground for the entrepreneurial talent and skills needed to run the spin off firms and in gaining access for these firms to international markets. The presence of anchor organizations also brought other advantages to their respective regions. First, they provided stable employment for a large number of people and were often the employers of first choice for newcomers to the region. Linked to this was their pivotal role in workforce development and training, providing employees with a range of both technical and managerial experience, and spawning many of their region's future entrepreneurs.

Anchor organizations also acted as reservoirs of talent that were periodically released back into the marketplace, as in the cases of MIL in Ottawa or NovAtel in Calgary. As the clusters matured, the lead anchor firm's role often changed from a mechanism for organizing and focusing resources to releasing those resources into the cluster through the creation of spin-off firms, investments in start-ups, funding specialized training programs, and through an increase in the mobility of its employees. With the increase in the number of firms in the cluster, the anchor firm often played a linking role between the cluster and external markets for emerging SMEs in the cluster. To expand in relatively small local markets, the clusters had to build a strong international outlook in terms of resource flows and markets. Some of the SMEs were linked into international markets through partnerships or supply chain relations with anchor firms, perhaps working on a component of a larger technology that the anchor firm exported. Some of the firms, such as Newbridge Networks in Ottawa, adopted an explicit strategy of spinning off firms that specialized in products which complemented and were integrated into its primary product line. All of the case studies provided evidence that a strong export orientation and international linkages as critical for the current and future success of the local firms in the cluster.

In those clusters where the anchor organization was not a leading firm, the lead organization, whether a university, public research institute or utility, supported the growth of the cluster through spin-off firms. In regions with an established industrial base, such as Waterloo, the cluster benefited from strong links between the emerging industry and the local universities. A critical factor in the growth of the cluster in each instance was the ability to support and encourage early stage spin-off and start-up firms. These firms played a central role in bringing new technologies to the market and helping the cluster to diversify. A critical factor for the success of the cluster was the presence in the local region of the requisite skills and resources needed to grow the emerging firms. A failure to support all stages of firm formation and growth limits the cluster's ability to grow and make it vulnerable to merger and acquisition involving outside competitors.

Talent and Cluster Development

A consistent feature of the ICT cluster case studies was the centrality of skilled labour as the single most important local asset in attracting and holding firms in their respective regions. The presence of a dynamic local labour market emerges from the attraction and retention of highly educated, potentially mobile workers who are drawn to the multiple employment opportunities created by the dense network of local firms. Places with 'thick' labour markets are attractive because they provide skilled workers with the assurance of a range of career options. As Harrison et al. argue, ". . . it is organizations that attract talent to places. 'Magnet organizations' . . . play a crucial role in the development of technology clusters by attracting highly educated and skilled scientists and engineers into a region" (2004, 1066).

Although the incidence of a thick labour market is often associated with the presence of post-secondary institutions in the cluster literature, it was more the exception than the rule in the ICT clusters studied. The role of 'magnet organizations' was played by lead anchor firms such as NovAtel in Calgary or NBTel in New Brunswick, private sector research institutes, such as Bell Northern Research in Ottawa, or public sector research organizations, such as the University of Waterloo or Université Laval in Quebec City. In most instances, firms played the crucial role in developing the strong local supply of skilled labour. The most important early source of talent in Ottawa was Bell Northern Research (BNR), subsequently part of Nortel Networks. The establishment of BNR in Ottawa in the late 1950s drew thousands of industrial engineers, researchers, and managers into the region. This influx provided the critical mass of talent needed to exploit later developments in telecommunications and photonics. Vancouver and Calgary provide additional examples where large private firms created reservoirs of highly skilled labour. In the Calgary case, members of local firms repeatedly referred to the training and network of contacts they had built up at 'NovAtel University' (Langford et al. 2003).

In most of the ICT clusters, the expansion of related research and teaching programs at local universities and colleges lagged, rather than led, the process of cluster formation. Two exceptions were at Laval University in Quebec City where the cluster was stimulated by the training of highly qualified personnel within local research institutes funded by senior levels of government and the University of Waterloo which partnered with local industry to develop a successful cooperative education program from the outset (Bramwell and Wolfe 2008). Close collaboration between the universities and local industry in both these cases fostered the conversion of novel research results into successful commercial products, as well as provided an earlier source of entrepreneurs for the local clusters. I n the other clusters, universities, colleges and other training centres became important sources of talent later in the cluster's life cycle, as the post-secondary institutions became adept at reading market signals regarding the direction of future demand for their graduates. As the number of firms within the cluster grew, there was an increase in the demand for labour, which encouraged firms to collaborate with local universities and colleges to coordinate training programs. Industry representatives remark that focused educational programs such as the coop program at Waterloo and others have been effective at moving students into industry settings, as well as providing an important source of tacit knowledge circulation within the cluster (Wolfe 2009).

The role of labour and talent also changes over the cluster lifecycle, as firms increase and diversify their technological capabilities in order to access new markets. As the cluster grows and firms expand their market reach, they require a wider range of skills, especially management and marketing skills, in order to improve their firm's capabilities. Increasing specialization, which results in anchor firms spinning off non-core activities into new firms, further stimulates the demand for specialized labour. Talent is present in different capacities and at different levels in each of the ICT clusters reflecting their particular stage of development. Waterloo, Quebec, Toronto and Ottawa enjoyed an abundance of highly skilled and experienced labour, much of it engaged in R&D related activities. Calgary and Vancouver, also enjoy a highly skilled labour force across a number of different ICT segments. As noted above, in the later stages of cluster development a key constraint on the ability of firms to grow is often a lack of management and marketing skills. Because many of these skills are acquired through hands-on-learning within the firm, the supply of managers relies heavily on in-house training carried out in large firms. The potential for more successful firms to be bought out by larger competitors, both foreign and domestic, serves as a double-edged sword in facilitating the further growth of the cluster – both by releasing managerial talent into the cluster to facilitate the formation and growth of new firms, but also in reducing the potential for managers to acquire higher level skills through local firms with a global reach. The smaller size of some of the clusters means there are limited opportunities for managers to acquire the hands-on training and experience needed to effectively grow their firms and access export markets. The larger economic centres, with a more diverse mix of industries and broader economic base, are better able to provide the on-the-job management training to meet the needs of cluster firms.

The Role of Research Infrastructure in ICT Clusters

The role of public organizations in cluster development has been the subject of considerable debate, starting with the celebrated case of Silicon Valley. In the case of the Canadian ICT clusters, there are only two clear instances where research universities were instrumental in the formation of the cluster, however, in other instances, the presence of a strong research university helped create the underlying conditions which enhanced the potential for cluster formation and development (Wolfe 2009). In Ottawa and Toronto the federal government contributed initially to the growth of the ICT cluster by investing substantially in public R&D facilities, whereas in Waterloo and Quebec City, increased federal and provincial support for postsecondary education in the 1950s and 1960s, and more direct funding for post-secondary research, especially through various Centres of Excellence programs in the 1980s, provided the stimulus for expanded technology transfer and new firm formation in the local cluster.

Public research infrastructure contributes to cluster development in two additional respects – one as a key source of new ideas for domestic companies, both in terms of spin-offs and knowledge transfer; and second, as a factor contributing to the reputation of the key clusters, thus helping to attract large foreign firms to invest in the local region. Strong universities and research institutes act as attractors of inward investments by leading anchor firms interested in tapping into the knowledge base of the local community, or its local buzz, and as providers of the talent pool that firms in the cluster draw upon, rather than as direct initiators of cluster development. In this respect, universities also act as part of the network linking actors in the local cluster to the global pipelines that are essential to the knowledge flows in the cluster. Successful research universities also attract leading scientists, further reinforcing their linkages to external knowledge flows through the extensive network of contacts they bring to their new location. The case of Cisco in Ottawa as well as Alcatel in Ottawa and Google in Waterloo have all been cited as examples of significant inward investments to the individual ICT clusters. IBM, with one of its Centres for Advanced Studies located in its software laboratories in Markham, north of Toronto, enjoys a strong working relationship with the University of Toronto and has subsequently expanded its presence in the Ottawa cluster and in Victoria through the acquisition of local software companies.

As clusters mature, their technological trajectories become more predictable. This enables cluster organizations and individual firms to better anticipate and therefore plan for future requirements for skills and knowledge. With the growth of the cluster's relative economic importance within a region, local research and training institutions have a greater incentive to collaborate on R&D and organize courses of study around cluster priorities. Cluster development provides new opportunities for partnerships between research and educational institutions and firms. This confluence of factors results in the gradual entrenchment of the educational infrastructure in a region that supports the continued growth of the cluster. This was evident in the organization of wireless and photonics programs at local universities in Calgary and Ottawa and in the establishment of collaborative research institutes in Quebec and New Brunswick.

Thus a strong network of educational institutions is an important condition for successful ICT clusters. The presence of a research university is a necessary, but not sufficient, condition for cluster development; not every region with a strong research university generates a dynamic ICT cluster. The role of the university in the cluster also changes over time. Universities are not only sources of research and innovation and the generators of human capital; as clusters mature, they also contribute to the incremental innovation that keeps firms competitive. Tangible links between the university and industry, in the form of both large-scale and more informal research collaborations, consulting by university faculty, and the movement of students back and forth to industry through coop placements, as well as permanent hiring upon graduation, all serve as conduits of knowledge that keep firms at the leading edge of innovation and keep universities relevant to local industry (Wolfe 2009).

Global/local Linkages and Knowledge Flows

A common strand in the cluster literature is the centrality of local linkages and knowledge flows in defining the geographic basis of a cluster. According to Porter, clusters consist of "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (1998, 199). Key features of clusters are internal networking, linkages, and formal and informal interactions. This conception of the cluster incorporates key aspects of the Porter diamond, by assuming that firms co-located in the cluster tend to be rivals in the same product markets or part of a locally-based supply chain, and that close monitoring of competitors or tight buyer-supplier interaction are essential for the competitive dynamics of the cluster. The evidence from the case studies of Canadian ICT clusters suggests that these characteristics do not apply universally to all clusters – especially those in transformative technologies with global research networks, at an earlier stage of development, or in smaller, open national economies.

The essential feature regarding linkages in the case of ICT clusters in Canada is their non-local dimension. A strong export orientation is essential to the future viability of Canadian ICT clusters where growth depends on the ability of firms to identify and exploit international markets. Accessing international customers and suppliers and monitoring international competitors requires numerous skills and resources. A prominent export profile also contributes to the international reputation and branding that clusters such as Waterloo and Ottawa currently enjoy. Not only does this increase the reputation of regions, it helps attract new firms and labour (especially inward bound several multinational firms locating to the region as a result of the critical mass of companies and talent), thus contributing to the overall agglomeration effect.

If Porter's conditions do not hold in all instances, this opens up the question of the relationship between the global and the local, and complicates the issue of whether local concentrations of firms in related sectors rely primarily on local sources of knowledge? A growing body of research recognizes that relatively few clusters are self-sufficient in terms of the knowledge base from which they draw. The knowledge flows that feed innovation in a cluster are often both local and global. Successful clusters are effective at building and managing a variety of channels for accessing relevant knowledge from around the globe. A key finding from the case studies of Canadian ICT clusters is the early and continuing role of external linkages in their development. The amount of inter-firm collaboration in the form of local customer or supplier relationships is relatively low in most cases. For the majority of firms, the focus of their economic activity – key customers, sources of supply, competitors, important strategic partnerships, and the resulting knowledge flows – occurs at the global level (Bramwell, Nelles and Wolfe 2008).

As firms expand into more competitive markets they need to expand their networks in order to identify and access the knowledge needed to continue innovating. If the knowledge base is global, as is the case with ICT, firms are required to monitor and assess international developments. This is done partly through local research collaborations and partly by partnering with external research organizations. While the existence of 'knowledge pipelines' between local firms and external knowledge sources are critical to sustaining regional competitive advantage, these pipelines often work in tandem with a strong local knowledge base. Most of the ICT clusters exhibit strong external linkages, some through the reach of multinational firms and others through research partnerships with local and non-local universities which typically maintain international research collaborations.

Some of the clusters display higher levels of internal networking (Calgary, Ottawa and Waterloo), information interactions and linkages, but these tend to occur through informal and interpersonal contacts. Linkages are also found to exist between firms in related industries, such as photonics and telecom in Ottawa. Some firms in individual clusters rely upon a local supply base for certain inputs, but the vast majority draw components and knowledge inputs from a diverse array of geographic sources. The most important linkages, however, are to markets, particularly international markets, as many of the firms were geared to supply continental and international markets from their inception. A core theme that emerges from the case studies is the fluid nature of relations between customers, suppliers and competitors in the cluster; firms that may have viewed each other as competitors at a particular stage of technology development may end up as collaborators or in a buyer-supplier relationship in the next stage of their products' development. Geographically proximity in the local cluster facilitates their awareness of each other's technical capabilities and thus the potential for partnering and collaboration.

Financing ICT Clusters

High levels of R&D, and the potential for innovation and commercialization that accompanies it, often attract a ready supply of investment money and venture capital funding. The Ottawa case (and to a lesser extent Quebec City) experienced significant growth in the amount of venture capital funding flowing into the region in the later 1990s and early 2000s, with Ottawa actually being one of the leading destinations for the inflow of venture capital in the first two years of the decade. Venture capital funding, however, can also bring certain disadvantages. In Ottawa, venture capital is described as a double-edged sword where some firms benefited significantly, while other SMEs cited the lack of funding as a deterrent to growth. For those who did receive venture funding, there was increasing pressure to provide investors with a lucrative exit strategy, which often forced firms to engage in M&A activity, with negative impacts on their ability to grow organically. While the Ottawa cluster has been home to Canada's most active venture capital community in ICT, the post-2001 collapse of the telecom sector resulted in a significant reduction in the levels of this activity.

Some of the clusters, such as Ottawa and Waterloo, developed effective networks of angel investors at an early stage of their development, who used the experience they had gained to help launch successive rounds of startups. In Toronto, Ottawa and Waterloo some successful entrepreneurs went on to launch their own local venture funds. Many, however, experienced subsequent problems obtaining financing to support firm growth. This was the case in Calgary, Quebec, and New Brunswick. In addition to private sources of financing, several federal and provincial government programs were mentioned as important sources of firm financing – particularly the federal SR&ED tax incentive (and its provincial counterparts) and the grants available through the National Research Council's Industrial Research Assistance Program (IRAP). While most of the clusters relied primarily on private sources of finance, the Cape Breton case was the exception with its heavy reliance on government financing.

The Role of Cluster Organizations

The growth of clusters often leads to the formation of local civic associations that provide the member firms with a collective voice and an important means to agitate for supportive public policies. As Feldman et al. have noted the recognition of the collective challenges facing a cluster leads the entrepreneurial founders of its firms to form the organizations needed to sustain their own activities and encourage new entrepreneurs to launch their own firms. These organizations also constitute an important mechanism for sharing hard earned entrepreneurial and business skills and in the more effective associations, this mechanism is institutionalized through peer to peer knowledge sharing and mentoring relations. The establishment of these organizations raises the profile of the cluster in both the local economy and more distant ones and helps generate the kind of buzz that attracts new entrants and talent to the region (2005). Cluster organizations typically play a central role in the transition of the cluster to a more mature phase of development.

The emergence of dynamic local civic associations supports the growth of civic capital as a key contributor to the process of cluster development. Civic capital consists of interpersonal networks and solidarity within a community based on a shared identity, expectations or goals and tied to a specific region or locality. Many of the Canadian ICT clusters have witnessed the emergence of exactly this form of local civic association over the past two decades – WinBC in Vancouver, Calgary Technologies, Inc. in Calgary, Communitech in Waterloo, Technicity in Toronto, the Ottawa Centre for Research and Innovation and the Quebec Optics and Photonics Association. In New Brunswick, the National Research Council attempted to fill the role of cluster mediator through initiatives linked to its research institute in Fredericton. These intermediary organizations often anchor the cluster, facilitating linkages among cluster firms and providing a portal for knowledge flows. This is clearly the case in the larger, more successful clusters among the cases. Overall, the presence of local civic associations provided an important indicator of cluster dynamism and maturity (Wolfe and Nelles 2008).

Success Factors in Cluster Development

Based on this survey of the ISRN case studies of Canadian ICT clusters, several factors that contribute to the growth of the clusters can be summarized. First, commercial success came from the ability of firms to draw on the local knowledge base – source of R&D support – for industrial innovation process. Second, anchor firms or organizations were pivotal in the emergence of ICT clusters – played a key role in creating spin-off firms, investing in start-ups, funding specialized training programs for employees, and building linkages to global markets. Third, skilled labour emerged as the most important local asset that attracts and retains ICT firms to a region. A 'thick' labour market attracts and retains educated and mobile workers who are drawn to multiple employment opportunities, but it also attracts the ICT firms that employ them. This underscores the pivotal role of universities and community colleges in training and educating the highly skilled workforce required by ICT firms. Fourth, local civic associations provide member firms with a collective voice to address local industry concerns and to advocate for supportive public policies, as well as a means of sharing entrepreneurial and 'how-to' business skills crucial to managing SMEs in a global market and developing, marketing, and selling products and services to external customers.

Current Challenges for the ICT Industry in Canada

Because of its critical position as a key driver of economic growth, there are mounting concerns that the ICT sector in Canada is facing critical challenges on a national scale. As the CATA Alliance stated, "The world is still changing rapidly, and our advantage [in digital industries] is quickly slipping away in today's globalized technology and business environment." (Wesley Clover 2008). In light of this concern, four themes are evident in recent discussions about how to strengthen Canada's digital economy in general, and its ICT sector in particular. First, there is a need to reestablish the leadership of Canadian ICT manufacturing and services industries to make them more competitive in the global ICT sector. Second, ICT is not just a stand-alone industry, but functions as an enabler that increases multi-factor productivity growth in other sectors of the economy, such as finance, health care, manufacturing, and transportation (OECD 2003; Industry Canada 2009a). Available evidence suggests that Canadian firms in other sectors have lagged competitors in the U.S. and elsewhere in the pace at which they have adopted and implemented ICTs as an integral part of their firm processes. This lag has impeded the rate of productivity growth in Canada and the global competitiveness of Canadian firms. Third, evidence from the U.S. suggests that ICT is one of the sectors that have recovered most quickly from the recent recession which increases the likelihood that it will be a leading sector for employment growth as the recovery takes hold (Mandel 2010). This accentuates the strategic significance of the sector for future economic growth in Canada. A fourth theme concerns the fact that technology and management skills are as important to the growth of the sector as innovation and access to capital, but the sector faces alarming declines in post-secondary enrolment, especially female enrolment coupled with mismatches in the ICT labour market where unemployed ICT professionals lack the specific skills required by employers (Canadian Coalition of Tomorrow's ICT Skills 2010, 5; ICTC 2008a).

"Hollowing-Out" of the ICT Industry: Not Enough Flagship Firms

The most pressing issue confronting the ICT industry in Canada is the relatively small size of the many firms which populate the sector. As noted above, there are currently 31,500 ICT companies in the ICT sector in Canada. However, the vast majority of these companies are primarily single operator companies or small businesses that provide professional services to their local clients. According to the most recent Branham 300 list, an annual survey of the top tech companies in Canada, there were only 10 ICT companies headquartered in Canada which reported revenues of $1 billion or more in 2009. Of these

10 firms, only five – RIM, Celestica, CGI, MDA and Softchoice – could truly be considered multinational ICT firms. Nortel which was on the list for 2009 no longer exists and BCE, Rogers, Telus and Shaw are primarily domestic telecom providers who do not compete in the international marketplace (Anderson and O'Shea 2010). In addition, the Branham 300 notes that there are 217 additional firms with revenues in excess of $10 million a year. The majority of the ICT firms in this second tier are export oriented and R&D intensive firms. The future growth of the ICT sector in Canada depends to a large extent on the economic success of this tier of firms. However, as international competition intensifies in the global ICT market, the challenge faced by this group of firms has become all the greater. Furthermore, the growth prospects for these firms are handicapped by the relative dearth of large internationally competitive flagship ICT firms in Canada which can both act as their guides into the international marketplace and also serve as incubators and training grounds for the managerial talent needed to take these firms to the next level of international competition (ITAC 2010).

The relative absence of globally competitive, multinational firms headquartered in Canada speaks directly to the current debate about the 'hollowing out' of the ICT sector. While the sector retains a strong export orientation, the relative predominance of small and medium-sized firms is very much a function of both the collapse and the takeover of some of the large, high profile indigenous firms in over the course of the past decade. The principal firm in this instance is Nortel Networks, which prior to its dismantling in 2009 was the largest R&D performer in the country and the largest ICT firm in terms of sales. However, Nortel is far from the only indigenous firm that has been lost over the past decade: Newbridge Networks was sold to Alcatel, JDS Fitel was merged with Uniphase and in the wake of the dot.com bust in 2001 subsequently saw the bulk of its activities moved to California and the majority of its employees let go, Cognos was sold to IBM and ATI, the leading Canadian semiconductor firm was sold to AMD and subsequently downsized as part of a broader corporate restructuring. The Cognos acquisition stands as the major exception to this rule; the integration of Cognos into the IBM software lab in Ottawa has resulted in the IBM Canada Software Lab, anchored both in the GTA and Ottawa, as IBM's largest development centre outside the U.S. and the largest software enterprise in Canada.

The loss of this considerable number of 'flagship' firms is widely viewed within the industry as a substantial blow to its overall growth prospects. While the negative effects of this trend are devastating for the industry as whole, its impact on the dynamic local clusters which act as the breeding ground for high technology firms has been even more apparent. A paper prepared by the investment firm Wesley Clover on behalf of the Canadian Advanced Technology Alliance (CATA) in 2008 documented some of the consequences for the Ottawa cluster since 2001, which in the previous decade had ambitiously been dubbed Silicon Valley North. The transfer of most of JDS Uniphase's activity to California resulted in the effective loss of 15,000 jobs; Tropic Networks was sold to Alcatel; Ubiquity Software was sold to Avaya and its management functions were transferred to the U.S.; Meriton Networks was sold to a Texas based company; Atreus Systems was sold to Sonus, based outside of Boston; while Dell Computers closed a technical support call centre and Volex Canada, a U.K. company, closed its Ottawa plant. Combined with the subsequent sale of the remaining units of Nortel, these developments resulted in a serious downsizing of both employment and sales from the Ottawa-based ICT cluster of firms (Wesley Clover 2008). While the employment effects of the downsizing and takeovers have been partially offset by the rapid rate of new firm formation in the region, it will take years before any of the new startups can grow to the scale of the firms that have been lost. And many informed observers are skeptical as to whether they will ever reach that scale.

A succession of speakers at the Seventh Annual Re$earch Money Conference held in collaboration with ITAC in 2008 noted the long term consequences of this downsizing of the sector's leading firms. David MacDonald, the President and CEO of Softchoice Corporation and the Chairman of ITAC at the time said the problem of the absence of large global leader in the Canadian ICT industry was getting worse, not better. He said the presence of these firms with global reach is crucial to the sector as most technology entrepreneurs get their training while working as employees for the larger firms in the industry. It is difficult to breed entrepreneurs with the requisite skills and experience in an industrial environment which lacks these large firms with global reach. He noted that a growing concern was that the talent pool in the ICT sector in Canada was not deep enough to train sufficient numbers of mangers to run Canadian firms with a global reach. "Hollowing out" is an issue. "We are looking at alarming shortages of skilled workers in all stages of our business. Nowhere is that shortage so acute as in the C-suite." He concluded that there are far too few people who can manage a company to breakthrough to the billion dollar level. He concluded that companies grow because their people grow, but the current environment for the ICT industry in Canada did not favour growth. Kevin Francis, the CEO of CentreBeam reinforced this point in a talk aptly entitled "Canada: Scale or Surrender?" He said the overwhelming experience of the ICT sector in Canada was the presence of many small firms, some of which managed to grow, but were usually acquired once they had done so. He asked whether Canada as a country aspired to building the kind of innovation ecosystem in the ICT sector that would allow the country to develop a substantial international presence. The Canadian industry has three of the ingredients essential to achieve this goal: access to capital, the necessary brain power, and excellent educational institutions. What it seems to lack is the willingness to start from the premise that successful firms have to go global and the managerial experience to achieve this goal (Fripp 2008).

Even the large Canadian firms which currently populate the ICT industry tend to be small relative to global industry standards, with only one or two ranking consistently among the top global firms. The relative absence of global scale companies in the Canadian ICT sector has been noted by many observers. A recent ranking of the 100 largest technology intensive companies in 2009 by *Canadian Business* magazine noted that RIM stood out at the top of the list with a market value of $46 billion, while the second ranked firm, CGI was less than 1/14 of RIM's size. To underline the relative weakness of the sector, the total market value of the 2nd through 100th companies added up to less than half of RIM's market value. RIM also was ranked as the 6th largest R&D spender in the country. With the implosion of Nortel and the loss of many the other leading ICT firms noted above, there are concerns that Canada now has too few large R&D performers that are well-positioned to develop new technologies and products for emerging global markets. It is difficult to grow the small R&D intensive start-ups that predominate in the sector into large global anchor firms to replace the ones that have failed, before they are sold to foreign investors, taking the IP with them (Maich 2010).

The relatively weak standing of Canadian ICT firms has underlined by their position in the OECD's comparative ranking of the 250 top ICT firms. In 2009, Canada had just seven firms on the list with total revenues of $62 million, which was a slight increase from $56 million in revenues in 2000. Finland with just one firm included in the list had total revenues of $56 million in 2009. The United States was the undisputed leader with 75 firms, while Japan was second with 52 and Taiwan was third with 18 firms (OECD 2010). It must be remembered that this list includes revenues for Nortel and that the subsequent collapse and sale of Nortel may have reduced Canada's standing on the list to an even greater degree. Overcoming the relative weakness of Canadian ICT firms on a global scale is one of the key challenges repeatedly identified by industry leaders to growing the ICT industry in Canada. Responding to this challenge involves supporting the growth of SMEs into large anchor firms to replace the ones that have imploded or been taken over. It also requires significant increases in firm R&D activity, export orientation and access to investment capital. This involves the encouragement of cross-sectoral knowledge transfer among firms operating in different ICT sub-sectors, such as intermodal collaboration between wireless, cable TV operators and traditional wireline communications, or linking digital content and services activities (Deloitte 2009; MacLean 2007). The CATA Alliance has recently highlighted the importance of growing larger scale ICT firms in Canada by establishing the target of growing ten flagship domestic firms with revenues greater than $5 billion by 2020 as a key goal of its Innovation Nation campaign (Matthews 2009).

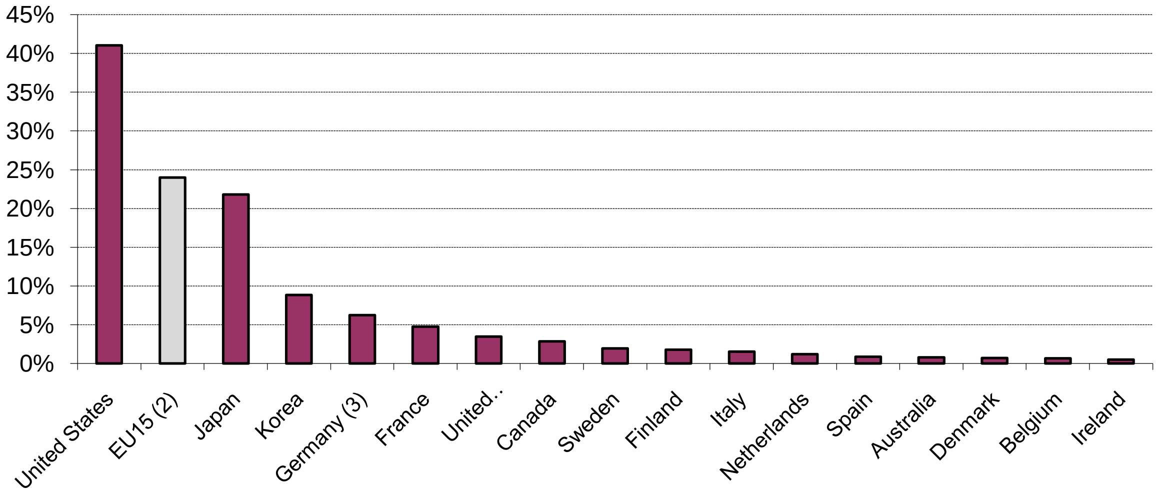
Lagging Innovation: Underperforming on R&D

The relative lack of global Canadian ICT firms has critical ramifications for other aspects of the economy's performance. Particularly noteworthy in this respect is Canada's relatively low level of business performed R&D. Not only do Canadian firms not spend enough to adopt ICT technologies, ICT firms themselves are not spending enough on the R&D that drives innovation. Given that the ICT sector, comprised of computer and electronic products, information and cultural industries and computer systems design and related services, is the top performing R&D sector, its relative weakness is a key factor in explaining the weak state of our overall performance on R&D. Although the ICT sector produces just 5 per cent of total GDP in Canada, it accounts for the largest share of business expenditures on R&D, spending $6.2 billion on R&D in 2008 which represented 38 per cent of total private sector R&D spending in that year (Industry Canada 2009b; Council of Canadian Academies 2009). However, Nortel alone still spent $1.67 billion on R&D in 2008, a remarkable 15 per cent of its total sales. While it is too early to assess the full impact of Nortel's disappearance on R&D spending in the sector, it is likely that overall spending in Canada by the firms that purchased Nortel's remaining assets will amount to much less.

Yet despite the apparently high level of spending on R&D by firms in the sector, Canada ranks relatively low in international comparisons. According to the *State of the Nation 2008* report from the Science, Technology and Innovation Council, Canada's overall business expenditures on R&D remain relatively low by international standards. In 2006, Canada ranked 15th in the OECD and business R&D intensity has been falling since 2002. Canadian firms invested 1.06 per cent of GDP in research and development, compared to the 1.8 per cent of GDP invested by U.S. firms (STIC 2009). The latest international data available from the OECD indicate that Canada ranked 10th in R&D spending in the ICT manufacturing sector in 2005 at .22 per cent of GDP, while R&D spending in the ICT services sector was somewhat lower at .15 per cent of GDP, but Canada ranked 7th overall among the OECD countries. The most recent version of the OECD's *Information Technology Outlook* indicates that no Canadian firms were included among the top 20 global R&D spenders in 2009, although RIM did have the second fastest rate of growth in R&D spending after Google (OECD 2010, 172-73).

However, as Chart 2 indicates, Canada accounted for slightly less than 2.9 per cent of total R&D spending in the ICT sector by OECD countries compared to the 40 per cent of R&D spending accounted for by the U.S. Thus, spending by Canadian ICT firms on R&D constituted less than 10 per cent of the amount accounted for by U.S. firms. Given that Canada's economy is close to 10 per cent of the U.S. both in terms of population and GDP, the comparison in R&D spending is telling. Given that some of the fastest growing countries in the ICT industries, such as China, India, Taiwan and Israel, are missing from this list, it is clear that Canadian firms will have to dramatically increase their spending on R&D to remain competitive.

Chart 2
Share of Selected OECD Countries in Total OECD Area R&D Expenditures in ICT 2005



Source: OECD, Information Technology Outlook 2008

Further light can be shed on Canada's R&D performance in the ICT sector from the results of Statistics Canada 2003 Survey of Innovation. The 2003 Survey was the first to cover innovation in the ICT service industries as well as innovation in ICT manufacturing. In the ICT sector, 78.2 per cent of establishments were innovative, although they were far more likely to develop product innovations that process innovations. The sources of innovative products and services was quite varied and included internal research and development, training, market introductions of innovations and the acquisition of machinery and equipment. The most revealing aspect of the survey, however, is the obstacles to innovation. The most frequently cited obstacles to innovation by firms in the ICT sector were economic factors, which includes both the costs of innovating and the risks associated with the potential for market failure of the innovation. A set of related factors was the inability to devote staff time to the innovation because of production requirements, as well as the lack of required information on potential markets and the shortage of qualified personnel to develop and implement the innovations (Lonmo 2005). While the factors that influence innovative performance are not necessarily identical to those that determine levels of spending on R&D, it is reasonable to assume that the some of the same concerns, such as lack of market information, the cost and risks associated with developing new products and processes and access to highly qualified personnel are all important.

Lagging Productivity: Canada as a "Middling Performer" in ICT Adoption

As noted above, there is a growing consensus among economists that investments in information and communications technology have been one of the principal drivers of productivity growth across the industrial countries, especially in the U.S., since the mid-

1990s. The productivity increases have come from two interrelated sources: greater productivity in the production of ICTs themselves, especially hardware and software, has been one important source of the increase; while the widespread diffusion of ICTs across a range of other industrial sectors, especially service industries such as logistics, wholesaling, retailing and financial services has been the second important source. However, Canada is widely seen to have missed out on much of the potential increase in productivity derived from the ICT sector. In terms of global productivity performance, Canada is described as a 'middling performer', both because the ICT sector occupies a much smaller proportion of the Canadian economy relative to other countries such as the U.S. and because Canadian firms tend to under-invest in machinery, equipment and technology (Council of Canadian Academies 2009).

Although investment in ICT has increasingly been recognized as the key driver of productivity increases, Canadian firms invest less than their peers in many other leading countries. In particular, there has been a consistent gap in the amount that Canadian firms invest in ICT relative to what their U.S. counterparts invest according to the most recent data available from a number of different sources. The Council of Canadian Academies suggests that the current gap amounts to almost $16 billion annually or 1.3 per cent of GDP. This stands in sharp contrast to other capital investments in machinery and equipment which have been approximately even over the past 20 years (Council of Canadian Academies 2010). A similar point was made in a recent report by the Institute for Competitiveness and Prosperity. According to the ICP, investments in ICT equipment and software accounts for roughly one third of total investments in machinery and equipment, but accounts for virtually all the gap in machinery and equipment investments between Canada and the U.S. Calculated on a per worker basis, the gap between Canadian and U.S. investments in ICT was $1,506.00 or 37 per cent in 2009. The cumulative effect of a persistent underinvestment in machinery and equipment by Canadian firms over the past 20 years was that the stock of machinery and equipment in Canada is currently only half the level of that in the U.S. (Institute for Competitiveness and Prosperity 2010, 39-40).

When the Canada-U.S. gap in ICT capital stock per worker is decomposed on an industry by industry basis, an interesting pattern emerges. The ICT investment gap is widespread and relatively consistent across a broad cross-section of Canadian industries, with two notable exceptions – utilities, as well as finance and insurance. The average across the business sector as a whole is 50 per cent, while it is even lower in the manufacturing sector at less than 40 per cent of the U.S. level (Council of Canadian Academies 2009, 69). A number of studies have attempted to analyze the underlying factors that account for this substantial difference in the level of ICT investment per worker. Studies conducted by Andrew Sharpe of the Centre for the Study of Living Standards found that the underlying structure of the Canadian economy accounts for part of the difference. Canada has a smaller share of its economy concentrated in ICT industries, as well as a higher proportion of small and medium-sized enterprises which tend to invest less in ICTs. The slower rate of ICT adoption by Canadian SMEs compared to their U.S. counterparts has been partially explained by differences in managerial attitudes in the two countries (Sharpe 2005; Sharpe and Arsenault 2008). Further research by the Information Technology Association of Canada has shed some light on this divergence. Their research suggests that business managers do not need to be convinced of the benefits associated with greater investments in ICT equipment and software, yet they seem to be more comfortable with investing in increased labour and non-ICT related machinery and equipment to achieve their business objectives. One possible explanation for this anomalous behaviour is that a large number of small and medium-sized enterprises lack access to the expertise that is required to advise them on how to make more effective use of ICTs in their business. In fact, many SMEs employ no ICT staff whatsoever, while approximately 50 per cent employ two or less ICT staff. This lack of the in-house expertise needed to advise business managers on the relevant ICT investments represents a serious obstacle to increasing the pace of ICT adoption by Canadian business (ITAC 2010, 4).

Funding the ICT Sector

Some observers argue that the inability to grow and maintain a sufficient number of large-scale anchor firms in the ICT sector is partly a product of the lack of adequate financing for these firms at different stages of their development. From this perspective, there is a need to increase the number of technology-based start-ups and support entrepreneurial behavior at the early stages of firm development. Industry observers believe that limitations in the tax treatment of R&D, combined with the relative lack of both foreign and domestic sources of venture capital, represents a major obstacle to the ability to grow small start-ups into large anchor firms in Canada. According to the brief prepared for the Science, Technology and Innovation Council on behalf of CATA, there is a serious gap in the levels of new venture funding available to firms in the U.S. compared to those in Canada. New venture funding in the U.S. was $34.7 billion in 2007 compared to only $1.2 billion in Canada, far less than the usual 10:1 ratio that characterizes differences between the two economies. The brief also identified a number of key irritants from the perspective of the industry in the tax treatment of venture capital investments, especially from the U.S., including the infamous Section 116 of the Income Tax Act that . . . and other issues. (Wesley Clover 2008).

Although the federal government dealt with some of these issues in the 2010 budget, the long-term trend in declining levels of venture investment in has persisted. According to more recent data from Thomson Reuters, the total amount of venture capital funds invested in 2009 was $1.0 billion, the lowest level since the mid-1990s. Both the number of new startups that received venture capital funding and the number of new deals has been declining in recent years. The total number of new firms financed was 331, which was 15 per cent lower than the number financed the previous year. The analysis compiled by Thomson Reuters also indicates that the average size of deals over the past six years has been $3.7 million, which is about one third the average size of deals in the U.S. over the same period (Thomson Reuters 2009). Earlier analysis undertaken for the Canadian Venture Capital Association noted that the returns on venture capital investments in Canada for the ten year period ending in mid-2006 average 2.5 per cent compared to average returns of 20.7 per cent in the U.S. for the same period (Durufflé 2006).

Not surprisingly, a survey conducted by Deloitte for the global venture capital industry reported that 66 per cent of the survey respondents in Canada expected the number of venture firms to decrease between now and 2015, while venture capitalists in Brazil, India and China all expect to add more venture firms in their countries during the same period. The outlook for the value of venture capital investments expected over the course of the next five years was similarly pessimistic, with half of the survey respondents in Canada expecting to see a decline or no change in the value of such investments. The low expectations for the future growth of the venture capital industry is also creating a negative climate in the country with 61 per cent of the survey respondents suggesting that the lack of a critical mass of venture capital firms in Canada is creating unfavourable climate for the venture industry in this country (Deloitte Canada 2010).

Government initiatives at both the federal and provincial levels to establish publicly supported venture capital funds and 'funds of funds' have provided some support for the industry in recent years, but are insufficient to offset the decline in amount being invested in private funds or to compensate for the low level of returns achieved in the industry. Overall both the total number of deals done in Canada and the U.S. as well as the size of the deals has been trending downwards as the tightening of the equity markets has made it more difficult for venture capitalists to achieve successful exits from their investments. The most recent 10 year returns on venture capital posted in the U.S. (reflecting the first full 10 year period since the collapse of the dot.com bubble) are negative for the first time, leading a growing number of commentators both in the U.S. and other countries to question the future viability of the venture capital model for financing innovative startup firms. This raises even more serious questions about where the future sources of funding for the Canadian ICT sector will come from.

Despite the low level of returns experienced in the Canadian venture capital industry and the declining expectations for the future growth of the industry, several interesting innovations have emerged in recent years for financing startup firms. While these are still relatively small scale initiatives, they have attracted a fair amount of attention due to the relatively high degree of success they have enjoyed. One of most noteworthy of these innovations is the combination of incubator and equity financing provided by Extreme Venture Partners for a number of the startup software firms it has invested in. The company was founded in 2007 and has invested in 14 software firms to date, most of which are housed in an office building in downtown Toronto. The firm focuses on software applications for mobile devices and has targeted four high growth areas for investment: local advertising, health care applications, tools to alleviate network congestion and mobile cell-phone based money transfers. It has expanded from 25 employees to 250 in three years. The largest firm in its current portfolio is Extreme Labs which designs apps for smartphones, including the Blackberry, and houses. One of the most widely recognized of its investments is Bumptop, which grew out of a Master's thesis by a University of Toronto computer science student and was subsequently acquired by Google for $35 million. Extreme also hosts Extreme University which runs 12 week training programs for budding entrepreneurs. Extreme provides each team of participants with $5,000 in seed funding and receives ownership of a share of the project for their investment. The students in turn get the opportunity to work with experienced entrepreneurs to develop and promote their idea. Extreme Labs draws employees from the University of Toronto and Waterloo and is part of a broader ecosystem of research institutions, incubators and investors in downtown Toronto that includes Ryerson's new Digital Media Zone, OCAD University's new incubator and the much larger facility at MaRS (Onstad 2010; Lorinc, Tossell and el Akkad 2010). While the burgeoning field of investments in software development for mobile devices is far from sufficient to replace Canada's former preeminence in hardware development for wireline equipment, it does represent one bright spot in the current ICT field.

Shortages of Highly Skilled Workers

There is little disagreement that in order to sustain its high wage economy, Canada needs to sustain a highly skilled and highly productive workforce, and that its comparative advantage will increasingly depend on the skills and knowledge embedded in its workforce. Due to its position as a key driver of growth and innovation in Canada's economy, the importance of a highly skilled labour force is particularly crucial for the ICT sector. As outlined in the consultation paper, Improving Canada's Digital Advantage, there are persuasive arguments that 'talent' or skilled human capital is "one of the main sources of available leverage for improving digital advantage" (CCTICTS 2010, 5), and that if Canada wants to build on this advantage, it needs to have a more concerted approach to the development of its ICT workforce.

There is a great deal of employment data available on Canada's ICT sector from sources such as the Statistics Canada Labour Force Survey, which affords policymakers a detailed overview of employment trends in the sector. Prior to the current recession, there was strong growth in the IT labour force particularly between 2005 and 2007, the industry's third major growth spurt since 2000, by which point it reached an historic high of 640,000 workers.[19] The profile of the IT labour force has been relatively consistent over time and workers in the sector tend to be comparatively young (47 per cent of workers are less than 35), predominantly male (75 per cent of the IT workforce), highly educated (75 per cent have a post-secondary degree), Ontario and Quebec have the largest share (75 per cent), jobs are predominantly full-time (95 per cent) and predominantly permanent (92 per cent), and job tenure appears to be more secure as people are staying in their jobs longer (Wolfson 2008).

More Canadians now work in the ICT sector than in agriculture, forestry, fishing, mining, oil and gas, utilities and transportation industry (including the auto industry) combined (CCTITCS 2010). A more recent report indicates that employment in the ICT sector weathered the recent recession better than most other sectors. The ICT labour market experienced half the unemployment rate (4.5 per cent) compared to the national average of 8.5 per cent for December 2009, and employment actually increased by 44,500 workers in the sector for a total of approximately 684,500 by the end of 2009. Interestingly, the greatest percentage of growth in the ICT labour market was in the Atlantic Region (16.1 per cent), the Prairies (13.8 per cent) and Quebec (10.6 per cent). Other notable trends include: significant variation in the size of provincial ICT labour markets where Ontario has ten times the ICT workforce (326, 603) than the Atlantic provinces (32, 044); the highest rate of growth was in the professional, scientific and technical services occupations, but ICT-intensive jobs in other sectors such as transportation and logistics, arts and entertainment, and business services also increased; and there are signs of increasing employment for young ICT workers and secondary school and college-educated as opposed to university-educated workers. It is significant, however, that there appeared to be a slight but noticeable decline in the employment of workers with graduate degrees (ICTC 2009).

This relatively positive snapshot of the current ICT labour force, however, obscures the fact that the ICT sector potentially faces some serious potential challenges in the supply and demand for ICT skills in the near future (Prism Economics 2008). Labour markets function smoothly when the supply and demand for skills are in balance. Shifting demand due to technological innovation is one the main drivers of change in the ICT industry because technology is the principal determinant of the skills that are need in ICT occupations. Emerging technology trends in areas such as Web 2.0, Internet security, virtualization, wireless technologies and cloud computing are expected to affect skills requirements up to 2015. However, it is less the demand and more the supply of skills that

[19] This report covers only IT occupations associated with software as the Software Sector Council, which has since been renamed to the ICT Sector Council to reflect the broader sectoral composition of manufacturing and services, was working on definitions of hardware occupations at the time to be included in future labour force studies.

will create future challenges for the ICT industry. Skill mismatches in the ICT labour force fall into two main categories. Skills shortages occur when employers receive enough applicants with formal qualifications but cannot recruit workers with the right sets of industry-specific skills required; for example, applicants may have technology skills but lack business and project management experience. Labour shortages occur when there is a shortage of applicants with general ICT skills and qualifications.

Recent labour market data suggests that the future supply of ICT skills in Canada may be affected by several factors (Prism Economics 2008). First, the sector faces some demographic challenges. Even though workers in the ICT sector tend to be younger than the national average, the ICT sector is facing retirements in certain occupations such as electrical and electronic engineers. More problematic however, is the fact that only 25 per cent of workers in core ICT specialist occupations are female (CCTICTS 2010). Second, post-secondary enrolment and graduation trends suggest that Canada may not be educating and training enough people in the ICT occupations and there is evidence of decreasing university enrolment in ICT-related programs.[20] For example, according to the CCTICTS (2010), between 2001 and 2007, undergraduate IT enrolment in Canadian universities dropped by 45 per cent, resulting in a 35 per cent decline in graduates by 2007, and enrolment in graduate programs declined by 21 per cent since 2003, leading to a 16 per cent drop in graduates by 2007. Finally, the integration of internationally educated professionals (IEPs) into the sector has not been as smooth as it could be, and there is an oversupply of IEPs in some regions and an under-supply in others (Prism Economics 2008).

Projected skills and labour shortages may not, however, be as critical as some analysts suggest and the balance of supply and demand for ICT skills depends on the rate of growth in the sector. Forecasts of supply and demand suggest that 50 to 70 per cent of future hiring requirements could be met by domestic graduates, that approximately 50 per cent of workers will require university training whereas 30 per cent will require college training, and that IEPs will account for 30 per cent of annual new entries into the labour market. In a high growth scenario labour shortages are possible, but in slow and moderate growth scenarios, “there is little likelihood of widespread labour shortages of ICT labour on a national basis” (Prism Economics 2008, 5). The picture shifts somewhat, however, in relation to specific occupations, where skills shortages are expected in all regions for specific occupations. The demand for information systems analysts, the fastest growing ICT core occupation, is expected to increase by 26 to 28 per cent between 2008 and 2015,

[20] This assertion appears somewhat contradictory and may require more detailed analysis. While the Prism Economics (2008) report suggests that post-secondary enrolment for ICT professions is likely sufficient, at least for a slow to moderate growth scenario, the Canadian Coalition for Tomorrow’s ICT Skills cites another ICTC study that reports an “alarming decline [of 20-30%] in ICT-related post-secondary enrolments”, (ICTC 2008 cited in CCTICT 2010, 7).

as is the demand for software engineers, computer engineers and electronic engineers, shortages of which could jeopardize the growth of ICT clusters outside of large labour markets. In addition, highly specialized 'hybrid technologists' who have a deep expertise in an ICT discipline or combine two or more technical disciplines such as bio-informatics, game design, media, smart power, or analytics are expected to be in high demand because of their highly specialized skill sets, as well as business technology managers who have both ICT and business expertise areas.[21]

Lagging Digital Infrastructure

There is a general consensus among OECD countries that the availability of broadband is a key driver of innovation, growth, and jobs in the ICT sector and in the economy as a whole (OECD 2008a). The role of broadband as a communication and content distribution platform has evolved significantly in a very short period due to technological developments, such as more widespread broadband, wireless access, increased affordability and speed, and the emergence of new technologies, such as portable media devices and equipment. As a result, new broadband applications and digital content creation are expected to be some of the strongest future growth areas in the digital economy. Not only has the increased availability of broadband encouraged the development of new Internet activities and demand for new content and applications, there is greater consumer willingness to pay for Internet access and Internet content, and broadband now reaches larger populations (OECD 2008b).[22] In order to reach its full impact, however, broadband must reach a critical mass of potential users.

Because of its position as a key driver of growth in the digital economy, broadband infrastructure and content development has attracted a great deal of policy attention in OCED countries in recent years. The purpose of the Seoul Declaration for the Future of the Internet Economy is to "promote the Internet economy by providing policy directions and guidance aimed at facilitating convergence, stimulating creativity, strengthening confidence and expanding the opportunities for global economic, social and cultural development" (OECD 2008a, 3). The declaration outlines three basic recommendations. First, broadband should be diffused as widely as possible to ensure high quality services at competitive prices. Second, national policies should promote innovation in broadband networks, applications and services by supporting R&D and policy coordination among public and private sectors, especially in vitally important areas such as health, education, the environment, and transportation (OECD 2008c). Finally, national policies should

[21] See CCTICTS (2010) for a more detailed discussion of policy recommendations of how to address the challenges.

[22] Broadband subscribers in OECD countries increased from 68 million in June 2003 to 251 million in June 2008 (OECD 2008a).

facilitate the development of affordable and universally accessible high-speed fixed and mobile broadband networks in order to address 'digital divides' between those who have easy access to the Internet and those who do not, either because they live in rural and remote areas, or are economically and socially disadvantaged.

In this context, countries tend to pay a great deal of attention to international rankings of broadband and ICT sector development, especially those of the International Telecommunications Union and the OECD (Correa 2007). Canada was initially lauded for its leadership and forward-thinking in the area of broadband infrastructure and penetration and held up as a model for how broadband infrastructure should be developed (Frieden 2005). Canada was a very early adopter of broadband and cable, and DSL services have been available in at least some parts of the country since 1996, when SaskTel became one of the world's first telecommunications carriers to offer DSL, and Rogers Communications premiered the first high-speed cable Internet service in the world. Government policy was not far behind, and in 2001 the National Broadband Task Force was created by the Minister of Industry to establish a policy on Canadian broadband services, with the ambitious mandate to ensure that broadband services were universally available to all Canadian businesses and households by 2004 (Benkler et al. 2010).

Since then, however, concerns have been mounting that despite its early leadership position, Canada has begun to lag other developed nations and has become "a poor performer on price and speed and a declining performer in penetration" (Benkler et al. 2010, 247). Canada's position on the Information Technology Union's international ICT Development Index (IDI), in which broadband penetration is a major indicator, dropped from 18th in 2007 to 21st in 2008. The Canadian media has recently picked up the charge and has reported findings about Canada's broadband position from other comparative international benchmarking studies. For example in 2008, the Globe and Mail reported that Canada's position in OECD broadband subscription rankings had slipped from 2nd behind South Korea in 2002, to 9th in 2007, and 10th by mid-2008. Specific issues of concern include download limitations placed on subscribers, lower speeds of connectivity, the absence of regulations that allow smaller Internet service providers (ISPs) to access larger networks (a practice known as 'local-loop unbundling'), and government inaction on rural broadband rollout. In addition, the article expressed concern that Canada would lag further behind because several countries were taking the lead in next generation broadband and had begun to deploy superfast fibre networks whereas Canada has not yet begun to rollout fibre networks (Globe and Mail, May 20, 2008). In 2009, CBC News reported on the findings from the second annual international innovation rankings from Oxford's Said Business School, which placed Canada 25th out of 34 countries, just ahead of Australia and the US, and that Canada "squeaked into qualifying for adequate broadband" coverage.[23] In 2010, the Globe and Mail reported on Harvard University's Berkman Center study on global broadband practices and policy which ranked Canada 19th worldwide in overall Internet access. According to the Berkman Center study, Canada faces an enduring urban-rural coverage gap, and ISPs have tended to focus on fixed broadband and have been slow to deploy wireless and fibre technologies so 3G wireless penetration is substantially weaker (Benkler et al 2010). The article echoed concerns expressed throughout the country that

> in the economic race among nations, widespread Internet access and its fast, reliable and cheap provision to the most people, is a prerequisite for success. And Canada is falling behind. If we are to compete, it will take new policies, new vision from corporations, the federal government and its regulators, and a national collective will to compete" (Globe and Mail, 2010).

There are however, divergent perspectives which argue that Canada's digital infrastructure is not as weak as these comparative analyses would suggest. The multiplicity of variables and indicators used to measure national ICT sectors in general and broadband penetration in particular, leave these findings open to interpretation. For example, a recent report on Canada's broadband infrastructure argues that examining a wider range of indicators of broadband penetration, speeds, and prices from sources other than the OECD indicates that "Canada's situation is far from dire" because "Canada places within the top 10 of most rankings" and that in fact, given its geographic and demographic challenges, and the fact that the ICT sector is comprised mostly of SMEs, "Canada has done remarkably well" (Goldberg 2009, 44).[24] Furthermore, the report expresses concern that calls to improve Canada's broadband infrastructure have become increasingly political and tend to overlook the fact that the available data and methodologies used to describe Canada's progress require deeper scrutiny.

Regardless of these debates, the fact remains that the Internet economy and the technologies and services involved in its development and diffusion continue to change rapidly, driving major changes in digital infrastructure requirements in the coming decade (Industry Canada 2009a). Recent innovations underlying the changes in the industry include: fibre optic technologies that are being deployed in different ways to overcome the limitations of traditional telephone networks and improve the performance of cable

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[23] The study measured internet download and upload speeds, and the amount of time it takes data to reach users (or latency).

[24] For example, Goldberg (2009) argues that according to the International Telecommunications Union, Canadians have access to among the most affordable entry-level services, and that when measured as a percentage of households rather than by the OECD's per 100 metric, the portrayal of Canada's relative performance is more accurate, and Canada is surpassed by South Korea, Iceland, the Netherlands and Denmark largely because these countries have higher population density.

systems; new wireless technologies such as 3G and WiMAX which provide high-speed access to mobile users and are currently being deployed and even faster technologies are being developed that provide higher speeds and greater capacity; the development of Next Generation Networks (NGNs) which combine interactive multi-media capabilities of the Internet with the quality and security of traditional telecom networks; and initiatives such as the US GENI and the EU Future Internet projects that are in the process of re-designing the Internet to improve quality of service and security (Industry Canada 2009a).

It is not entirely clear where Canada stands in relation to its competitors. There is evidence to suggest that it is an industry leader in emerging wireless technologies such as WiMAX, but there is also evidence to suggest that it maybe lagging its peers in terms of broadband infrastructure. Another recent industry study suggests that a national digital strategy needs to address infrastructure shortcomings in the four major areas of access to broadband services, access to digital television services, innovation in digital media in the form of technology, content creation, and services, and securing sources of financing to encourage infrastructure and content development (Nordicity 2009). Either way, the discussion of national digital strategies in other OECD countries in the next section suggests that a digital strategy for Canada that does not address issues of broadband infrastructure and access will be missing a key policy piece of the ICT innovation agenda.

Canada in Comparative Perspective: National Digital Economy Strategies

Despite numerous strengths and core capacities, there is mounting concern that Canada's ICT industry is "not at the front of the pack", and not keeping pace with its global competitors (Industry Canada 2009a, 3). The World Economic Forum *Networked Readiness Index* ranks Canada 10th out of 134 economies, up from 13th in 2007-08, but The Economist's 2007 *e-Readiness Index* ranks Canada 13th out of 69 economies down from 6th in 2006, and according to International Telecommunications Union, Canada is ranked 21st on the ICT Development Index down from 18th in 2007. Many of the countries that rank ahead or at the same level as Canada have comprehensive national digital economy strategies that they regularly update in response to changing market conditions. For example, in the E.U., broad 'Information Society' policies are often complemented by national strategies, especially in Nordic countries, but Britain has also recently developed its 'Digital Britain' Strategy. China and India have digital economy strategies in place that focus on issues particular to growth in ICT manufacturing, software, and services sectors. Other countries have undertaken extensive expenditures in digital infrastructure to act as an economic stimulus in the current recession. The Obama administration earmarked $4.5 billion to the Smart Grid project and $19 billion to health-related IT. The Rudd administration in Australia is spending A$ 43 billion (US$30.6 billion) to create a nationwide high speed broadband network. Government policy priorities are also reflected in the creation of new administrative structures to oversee growth in their ICT sectors, and Australia, for example, has created a Ministry for Broadband, Communications and the Digital Economy. In this context, calls to develop a national digital strategy have become increasingly insistent. Luckily, there is a strong belief that with the right strategies and supports in place, Canada is "not too far behind to overtake the leaders" (Industry Canada 2009a, 3; Matthews 2009).

This section provides a comparative overview of national policy approaches to ICT innovation and strategies for the digital economy, and identifies policy approaches and recommendations most relevant to Canada's policy efforts. A brief discussion of recent developments and shifts in national digital strategies and ICT policies is followed by a more detailed discussion of key policy priorities in the four main areas of digital infrastructure, digital content, digital skills, and digital innovation, as well as a fifth area of ICTs and the environment. The discussion includes with a comparative examination of the national digital strategies of the UK, Australia, New Zealand, Germany, and France in relation to this framework, and isolates the broad themes and policy lessons most relevant to Canada's efforts.[25]

The Recent Evolution of ICT Policies

Prior to the recent recession, the policy trend in OECD governments was to integrate ICT policies into broad national strategies to encourage growth, employment, and wider socio-economic objectives, as well as to address global issues such as climate change, energy efficiency and global health, and to encourage the use of e-government to make service delivery more efficient (OECD 2008a, 2009a). Because ICTs are increasingly being applied in "areas as diverse as education, healthcare, climate change, and energy efficiency", governments saw "a greater need for a coordinated, horizontal…approach" and approximately one-third of OECD countries attempted to centralize the formation and co-ordination of ICT-related policies to facilitate growth in the ICT sector as well as in ICT applications (OECD 2008a, 20). In 2008, the top 10 policy priorities of OECD countries were a mixture of traditional targets such as expanding e-government applications and encouraging R&D in ICT R&D, and newer development areas such as expanding digital content and access to public sector information. As will be evident in some of the case studies outlined below, some governments introduced broadband policies to expand broadband infrastructure, improve online trust and IT security and to promote social inclusion (Britain, France, New Zealand) , and others focused on the development of next generation "smart" applications in urban systems, transport systems, health care, and energy distribution (Germany, Australia).

[25] The US was not included because its National Broadband Plan only addresses broadband rather than larger digital strategy issues.

The recession, however, appears to have motivated a re-evaluation of this integrated approach, and as a result, national approaches to ICT policy and digital strategy have shifted. Policymakers are aware of the strong but complex interaction effect between policy and economic outcomes. As the OECD observes, ICT policies "have helped shape the economic recovery but they have also been shaped by the recession and the hesitant recovery" (OECD 2010, p. 258). Weak macroeconomic conditions and labour markets, coupled with large government deficits, means that policies are coming under much more scrutiny for their efficiency and their impact on growth, productivity, and employment. Because governments have limited resources, they need to isolate key policies and programs with the best chance to shape positive outcomes in the ICT sector. Governments need both generic national strategies that affect the national economy as a whole, as well as sector-specific policies that encourage growth and innovation in the production of ICT manufacturing and services. Recent policy initiatives have emphasized areas that most directly contribute to short and long-term growth and typically include measures to address ICT employment, broadband infrastructure, R&D and venture financing, and the development of 'smart' ICT applications for environmental issues (OECD 2010). Even before the recession, however, the distinction between generic and sector-specific policies had begun to blur, and there has been a trend toward cross-cutting digital strategies that seek to address all of these issues in a comprehensive national policy framework. Based on the core underlying assumption that "the Internet has become a fundamental infrastructure for economic modernization and structural change," the cornerstone of many of these national policies is the expansion of broadband infrastructure for business and household use (OECD 2010, 258).

Current Policy Priorities

Current policy priorities to broad digital economy strategies, as well as sector-specific policies to encourage innovation in ICTs, fall under five main categories: digital infrastructure, digital content, digital skills, ICTs and the environment, and innovation policy for the ICT industry. In most cases, the first three areas, and on occasion the fourth, tend to be addressed within national digital strategies, whereas the last area, ICT innovation, is often (but not always) addressed separately under national science and technology policy frameworks. The first four priority areas are discussed in this section, along with an overview of national digital strategies, while the fifth is considered in the next section.

Digital Infrastructure

As outlined in the Seoul Declaration… the availability of broadband is seen to be a key driver of innovation, growth, and jobs in the ICT sector and the economy as a whole, but in order to achieve its full impact, it must reach a critical mass of potential users (OECD 2008b). Because many OECD countries had begun to focus on supporting the development of national broadband infrastructure and providing government services online before the recession hit, many of them now have higher levels of broadband penetration, and where competition exists, speeds tend to be higher and prices for end-users tend to be lower (OECD 2009d; ITU 2010). Individual country broadband policies typically differ on provisions relating to network access for Internet service providers (ISPs) which involve questions of open access to DSL and fibre infrastructures, as well as whether to develop high-speed broadband infrastructure in areas that are already served, or to link up underserved regions.[26] The continued roll out of fixed and mobile broadband infrastructure to firms and households remains an important priority, not just for purposes of economic growth, but also because of the importance of the Internet for economic, social, and political use. As a result, many broadband policies also focus on connecting unserved and underserved populations, such as the elderly and others who cannot afford it, and people in rural and remote areas. Other policy activities tend to focus on increasing and improving the digital delivery of government services, as well as encouraging uptake of these services (OECD 2010).

Digital Content

Growing consumer and business demand for digital content drives the growing impact of the Internet on economic growth. Most countries have digital content programs in place that focus on developing domestic content-based ICT services that use the Internet to reach global markets, and on encouraging commercial use of public sector information and data. Digital content development policies tend to focus on encouraging the development of content in areas such as education, media, entertainment and interactive software development. For example, Australia's Digital Education Revolution program seeks to encourage the development of educational digital content; Canada provides funds for media (CMF), interactive content (CIF), periodicals and books (CBF) to promote the creation of digital and interactive content in each of these areas; the University of Texas Austin's Portugal Program focuses on digital content development with direct links to the creative and culture-oriented industries. This area has become less of a focus since the recession, however, as governments have more urgent priorities linked to economic recovery, and have sought to promote the use of digital content through broadband development rather than its production. Nonetheless, policies to encourage digital content creation remain in the top 10 policy priorities and will likely gain importance in the future as the use of the Internet and digital services increase (OECD 2010).

[26] See OECD 2010 for an overview of broadband policies and public investments in selected OECD countries.

Digital Skills

Due to the fact that unemployment is expected to remain high for some time in OECD countries, ICT skills and employment are seen as key policy priorities. Policymakers recognize that there is a strong correlation between ICT skills and economic growth. Roughly 5 per cent of total ICT employment is comprised of ICT specialist occupations, whereas roughly 20 to 25 per cent are ICT-intensive occupations in other sectors. However, many Western industrialized countries face shortages of workers with ICT specialist and ICT generic skills and are attempting to attract more people into these careers. As a result, many national strategies include policies to develop a highly skilled ICT specialist workforce to drive innovation and growth in domestic ICT manufacturing and services production. In addition, because generic ICT skills are necessary for many non-ICT occupations due to increased used of embedded systems throughout the economy, a lack of qualified professionals may also have negative impacts on economic restructuring in other sectors. Many national strategies also include policies to strengthen ICT skills sets that help diffuse ICT into other sectors of the economy including health, transportation, business services, and advanced manufacturing. Finally, basic skills are required in order to access electronic services provided by government and businesses, so many policies also focus on developing digital literacy in the population as a whole to enable a broad cross-section of the population to benefit from the digital economy. ICT skills and employment policies include a range of measures such as promoting ICT in post-secondary education;[27] vocational training programs that target a wide range of unemployed workers, from ICT specialists whose skills and expertise are outdated, to workers with limited ICT skills who need to find better jobs, or the unemployed who require ICT skills in order to find jobs; targeted policies to increase the participation of specific groups in ICT specialist occupations such as women and foreign-trained professionals; and increasing awareness and digital literacy in primary and secondary school students.

ICTs and the Environment

As concerns about environmental issues and climate change increase, governments have begun to turn their attention to the potential role of ICTs in addressing these issues. Over half of the countries that responded to the recent OECD survey indicated increased

[27] These include for example, ICT education components in graduate programs, the promotion of knowledge exchange between universities and industry through co-op and research internship programs, and funding for upgrading of ICT infrastructure in post-secondary institutions. These programs, however, tend to focus on science and technology programs rather than graduate programs in the social sciences and humanities, a shortcoming that could be short-sighted in light of the increasing importance of the social impact of the digital economy, and of arts and culture in providing digital content.

attention to policies for ICTs and the environment, such as the sustainable use of ICTs (minimizing energy use and reducing and recycling electronic waste), the use of ICTs to reduce environmental footprints in other industry sectors (the use of "smart sensors" in electricity grids, transport systems, and buildings), and encouraging behavioural changes in individuals and organizations. In general, there is a correlation between countries that give medium or high priority to these issues and national levels of ICT development, measured by broadband coverage and uptake, such as Japan, Korea, the Netherlands, Norway, the US, Australia and Spain. Austria and Canada do not prioritize green ICT policies in the survey, but do have measures to address the role of ICTs in the environment.

National Digital Economy Strategies

The federal government has come under increasing pressure to develop a national digital economy strategy for Canada. In this context, it is useful to review how other countries have approached this complex policy area. A detailed examination of national digital strategies in OECD countries is beyond the scope of this paper, but this section highlights the most salient aspects of each strategy. It offers a brief description of the national digital strategies of the UK, France, Germany, Australia and New Zealand in relation to the framework outlined above, and isolates similarities that may be relevant to Canada's efforts.[28]

Digital Britain

The Digital Britain strategy was launched in June 2009 by the Minister for Communications, Technology and Broadcasting. The strategy focuses on how Britain can develop and sustain its position in the global digital economy and integrates creative industry, technological innovation, and digital communications policies.[29] Core elements of the strategy include skills development, broadband, and digital content creation measures. The strategy outlines several measures in the areas of ***digital skills***, including the allocation of £8.5 million for the establishment of a National Skills Academy for Information Technology that will train 10,000 ICT professionals in its first three years, the allocation of £11 million for training programs for under- and unemployed workers under the Train to Gain scheme, the introduction of programs at the primary and secondary school level to increase ICT literacy, and a three year National Plan for Digital Participation that makes use of social networking to improve digital awareness and literacy in the broader public

[28] This overview does not discuss the US National Broadband Plan because it is confined to broadband policy alone and does not reflect a larger, more comprehensive national digital strategy.

[29] The creative industries represent more than 8% of Britain's GDP, whereas Canada's cultural industries generate less than half that amount (Nordicity 2009).

(Nordicity 2009).[30] The strategy's approach to ***digital content*** includes a number of measures that focus on encouraging the creation of cultural content, funding for digital cultural activities, and the protection of copyright and intellectual property. It also includes long-term secure funding for the BBC, coordinating industry and government approaches to copyright infringement and digital piracy, and expanding tax credits to producers of television, film, and video games (Nordicity 2009). The predominant focus, however, appears to be on ***digital infrastructure*** and broadcasting policies and includes a plan to implement universal access to broadband by 2012, allocate funding for next generation broadband, digitalize television by 2012 and national radio by 2015, liberalize and expand the 3G spectrum, and allocate £300 million to low income families to increase home broadband access.[31]

Australia's Digital Economy: Future Directions

As in the U.K., Australia has a separate government ministry, the Department of Broadband, Communications and the Digital Economy, to deal with digital economy issues and the ICT sector. Rather than creating a comprehensive national digital strategy, Australia's policy document, *Australia's Digital Economy: Future Directions*, outlines the Australian government's existing commitments that are related to the digital economy but delivered under different industries and policy frameworks. The only major new program announcements are the National Broadband Plan and the establishment of a company to build the National Broadband Network, as well as an initiative to convert all television services to digital.[32] The paper aligns with other policy initiatives focused on innovation and infrastructure, and complements the *Powering Ideas* report which outlines the government's innovation agenda for the 21st Century. In the area of ***digital infrastructure*** the policy paper announces the National Broadband Plan under which a new company will be established to invest up to A$43 billion over eight years to build and operate a National Broadband Network to deliver superfast broadband. The Plan also addresses inadequate access to broadband infrastructure in regional and rural areas through the Rural and Regional National Broadband Network Initiative and the Digital Regions Initiative, which

[30] The Digital Britain strategy is a very broad plan that includes a large number of measures aimed at meeting digital strategy goals. For more detail see the Digital Britain final report, available at http://www.official-documents.gov.uk/document/cm76/7650/7650.pdf.

[31] From the information available at the time of writing, it appears that the new U.K. government is maintaining the key elements of this strategy.

[32] For more detail see *Australia's Digital Economy: Future Directions* for an overview of all policies and programs related to the digital economy but captured under various Ministries and policy frameworks available at http://www.dbcde.gov.au/digital_economy/future_directions_of_the_digital_economy/australias_digital_economy_future_directions

will co-fund digital enablement projects with state, territory and local governments to improve the delivery of education, health and emergency services in regional, rural and remote communities. The other major initiative outlined is a key spectrum initiative that facilitates the conversion to digital television. Similar to the Digital Britain report, the government foresees that this conversion will potentially allow other spectrum freed up from the switchover, or the 'digital dividend', to be used by industry to develop a range of new communications services including high speed wireless broadband. The Australian government is also consulting on the re-allocation and/or renewal of the 15 spectrum licenses for various spectrum bands that are used to provide mobile phone and mobile broadband services.

The document appears to have few programs related to ***digital content*** beyond the Australian Government's Creative Industries Innovation Centre which provides business advisory services to SMEs in the creative industries sector, such as music, visual and performing arts, graphic design, games and interactive media. Again, there appear to be few initiatives in ***digital skills***, but there is a substantial A$2 billion commitment over five years to the Digital Education Revolution to build digital media literacy programs in primary and secondary schools. A pre-existing and separate innovation policy framework outlined in Australia's *Innovation Agenda* addresses ***ICT innovation and application*** policy and programs, one of the most interesting of which is the announcement of A$100 million investment in 2009–10, under the National Energy Efficiency Initiative ("Smart Grid, Smart City") to construct an integrated, commercial scale, smart grid in one Australian city, town or region. This 'smart grid' will see the electricity transmission and distribution network equipped with digital sensors and remote controls and will integrate renewable energy sources such as solar and wind and smart meters that communicate information to and from individual households. ***Internet security*** measures were introduced including A$125.8 million over four years for a Cyber–Safety Plan to combat online risks and help parents and educators protect children from inappropriate material.

The Digital Strategy 2.0 (New Zealand)

Like Australia, New Zealand's *Digital Strategy 2.0* announced several new programs but also reports on many ongoing programs, some of which received additional funding to implement new policy directions for the digital economy strategy. Again, the primary emphasis of the strategy is on the expansion of ***digital infrastructure***. Under the strategy, the New Zealand government announced the investment of at least $500 million into broadband infrastructure over the next five years, $340 million of which was announced as the first stage of the Broadband Investment Fund (BIF) which will co-invest in urban and rural broadband and will help deliver additional international cable. In addition to the BIF investment, $160 million will be invested in broadband across the health and education sectors over the next five years. Under the plan, fibre-to-the-premise connections will be implemented to businesses and public institutions such as secondary schools, universities and research institutes, hospitals and libraries in major centres, as well as significantly increased bandwidth connections throughout the entire country, and allocate additional spectrum for wireless broadband access. In the area of ***digital content***, the strategy announced the development of a New Zealand Digital Content Innovation Cluster intended to encourage collaboration and networking, to support specific projects from leading firms, researchers and educational institutes, and to boost local production of broadband applications in areas such as e-learning, e-health and online gaming. Government support was also allocated for the production, distribution and archiving of content across new digital platforms, as well as support for digital broadcasting and the visibility of New Zealand culture online. Funding of $53.75m was allocated for a Screen Production Incentive Fund for the increased production of medium- and larger scale New Zealand cultural screen content. Other areas of focus include accelerating the implementation of the New Zealand Geospatial Strategy, funding of $4.2m to implement the e-research program to improve the ability of researchers to access New Zealand's publicly funded research, and the completion of a National Digital Heritage Archive to collect, preserve, store and enable access to New Zealand-published born-digital content.

The strategy's approach to ***digital skills*** focuses both on improving digital literacy and on increasing the supply of skilled labour for the ICT sector. The plan addresses digital literacy in small businesses through the launch of the Connected New Zealand program to support small and medium enterprises to invest in and use digital technologies. Under the Foundations for Discovery and the e-learning Action Plan for Schools, $65.3 million was allocated to schools for ICT investment to ensure that all students leave school digitally literate, through appropriate early childhood, primary and secondary curricula and teaching. In terms of increasing the supply of skilled labour for the sector, the government plans to work with the New Zealand Computer Society to implement a framework of professional standards and qualification equivalency, and promote digital careers and skills though the National ICT Skills Collaboration Initiative. The pre-existing New Zealand Skills Strategy includes ongoing work to address skills issues, including in the ICT sector, and the need to better use and develop ICT skills in the workplace. Fewer measures were targeted in the area of ***ICT innovation and application*** beyond the commitment of $24 million over four years for the New Economy Research Fund to commercialize research in the areas of high-tech manufacturing, ICT, new materials and sophisticated engineering.

France Numérique 2012

As has been noted elsewhere in this paper, OECD countries pay a great deal of attention to international rankings and where they stack up in comparison to their peers. Like the

German strategy, the *France Numérique 2012* plan underscores the fact that France invests half of what the U.S. does, and one third of what the Scandinavian countries, Japan and Korea invest in digital economy activities, and announces the intention to reduce the gap between France and its international competitors by doubling investments in the digital economy. The plan established a new Minister of State for Development of the Digital Economy to oversee the implementation of digital economy policies in conjunction with the existing National Digital Council (Conseil National du Numerique) that has been operating for the past 10 years. It consists of 154 measures intended to meet the three core policy objectives of ensuring that all citizens have universal access to broadband Internet, ensuring that France switches over to all-digital in the audiovisual sector before 30 November 2011, and reducing the digital divide. There is a strong emphasis on ***digital infrastructure*** and one of the primary objectives of the strategy is to guarantee universal access to high speed Internet for the entire French population by 2012.

The other primary objective of the strategy is to facilitate the complete transition to digital television, including 18 free public access channels, by the end of 2011. Like several other countries, France plans to release a number of frequencies to facilitate the changeover to all-digital television, including high-definition television and personal mobile television, and expects that the frequencies resulting from the end of analog television will be allocated to covering the territory with new-generation networks of fixed and mobile super-broadband. Ensuring universal broadband access involves not only supplying as many households as possible with computers and broadband, but supplying them with ***digital content*** as well. Measures outlined in the strategy include the creation of a national directory of protected digital works, a public research body (observatoire) of content marking technologies, reducing the time to market for audiovisual content, copyright protection for web 2.0 players, and a reform of the private copy commission to make the issue more transparent, as well as doubling the number of investigators for cyber-crime. Primary objectives are targeted at improving ***digital skills*** and literacy for primary and secondary students as well as improving the digital literacy of small businesses.

iD2010: Information Society Germany 2010

The iD2010 plan, delivered by the Ministry of Economics and Technology in 2006, is one of the earliest national approaches to a digital economy strategy, but tends to provide an overview of existing programs rather than announcing new ones. Germany observes that the ICT investments of German firms are considerably lower than in the US, the Scandinavian countries, or Japan. ICT is one of the priority areas of the German government's integrated innovation policy, and in a departure from other national strategies, the German plan focuses more on ICT innovation and applications than on broadband and other digital infrastructure. The 2006 program builds on the previous plan outlined in 2003 and groups together the Federal Government's various initiatives in the fields of ICT and new media. In terms of ***digital infrastructure***, the strategy outlines the goal to increase broadband coverage to 98 per cent of all households by 2008 and to achieve broadband usage rate of 50 per cent of households before 2010, as well as to promote digitization of transmission paths and foster convergence of broadcasting services and new media including mobile telecommunication, and to promote digital interoperability and ICT standardization through research and knowledge-sharing on open standards and next generation networks. There is little mention of ***digital content*** creation beyond improving the commercial exploitation of public information such as government-funded research, geodata and meta-information systems, and creating a National Geographic Database (NGDB). Germany is one of the few countries that mentions concerns about shortages of ICT professionals, and the ***digital skills*** component of the strategy refers to programs aimed at improving the IT training system to make it easier to obtain credential recognition for skills acquired "on the job", significantly increasing number of graduates (particularly female) from post-secondary ICT programs, and improving digital literacy in primary and secondary schools.

Consistent with the government's policy emphasis on the ICT sector, the primary focus of the German digital strategy appears to be on ***ICT innovation and applications.*** Several programs to facilitate the application of ICTs are outlined in relative detail. In the area of transport telematics, the plan outlines programs to develop and introduce new technologies such as driver-assistance systems and traffic management systems, integrate innovative information technologies into logistics processes, promote innovative positioning methods which use GSM networks, W-LAN or GALILEO, and support development and implementation of intermodal telematics strategies in public transport. The strategy also emphasizes the expansion of the telematics infrastructure in the healthcare sector by implementing the use of electronic health cards and establishing an inter-sectoral and interoperable communication platform for all stakeholders in the healthcare delivery process. To promote the development of multimedia technologies, the plan outlines programs to develop, test and use multimedia technologies, especially in networked intelligent systems, web-based simulation, and robotics, encourage the use of mobile technologies in SMEs and public authorities, use RFID for electronic passports and electronic ID cards, and to create solutions to serve as examples of on-line intelligence in energy systems.

Finally, rather than simply improving national Internet security measures, the German plan outlines the intention to support the development of the IT security industry by ensuring medium-term and long-term IT security at federal level of government and in critical infrastructures, supporting German exports IT security products, solutions and services, establishing broad, producer- and product-neutral platform aimed at promoting

ICT security for citizens and SMEs, developing and piloting biometric applications as well as standards for conformity assessments of biometric documents and scanners. In order to support innovation in these emerging industries, the strategy outlines the government's ongoing efforts to develop a long-term strategy for ICT research in the form of the new "ICT 2020" research support program (that was to be presented in 2007) that includes support for research and innovation clusters, and to ensure the coordination of German and European ICT research activities.

Summary

The framework outlined in this section analyzed national digital strategies according to the four areas of digital infrastructure: digital content, digital skills, and ICT innovation and applications. This brief overview of national digital strategies in the UK, Australia, New Zealand, France and Germany indicates that these strategies vary a great deal in scope and focus, but share some distinct similarities. In the area of ***digital infrastructure***, all five strategies emphasized the expansion of digital infrastructure to provide universal or near universal Internet access in the short-term, but rarely outlined whether the focus would be on fixed or mobile broadband. In addition, Britain, Australia, and France announced their intention to convert all television to digital in the short-term. Strategies varied a fair bit in the area of ***digital content***. While all strategies referred to the creation of digital content in some form, most referred to the protection and promotion of cultural heritage, or the expansion of geographic mapping systems. Only Britain, Australia, and New Zealand referred to support for the creation of digital content in ICT growth producing areas such as entertainment and education.

In the area of ***digital skills***, the promotion of digital literacy, primarily for school age children, and to a lesser extent for small business, was a consistent focus in all strategies. Some countries, such as Australia, earmarked substantial funding for these activities. However, it is rather surprising that increasing the supply of skilled workers for the ICT sector was rarely mentioned as an explicit focus. Few countries, except for Britain and Germany, explicitly expressed concern about future shortages of skilled ICT workers.[33] Furthermore, the *Digital Britain* plan was the only strategy to outline an innovative approach to ICT skills development with the announcement of the establishment of a National Skills Academy for Information Technology, and the allocation of £ 8.5 million seems a rather small sum for the sustainability of such an ambitious program. In addition, only Germany made brief mention of increasing the enrolment of women in ICT education and training programs. Policymakers know that a highly skilled workforce is one of the key

[33] It is possible that these issues are dealt with under policy frameworks in other ministries, but given the broad strategic approach to ICT and the digital economy in these plans, it would be expected that pre-existing relevant digital skills programs would be mentioned in these documents.

drivers of innovation in the ICT sector. This report has identified the need to develop Canada's skilled labour force in ICT specialist, research, and hybrid professions as a key competitive advantage as an area that deserves concerted policy attention.

Innovation Policy for the ICT Industry

There is widespread recognition that government support has been a critical factor in stimulating the emergence and continued growth of the ICT industry. Nowhere is this truer than in the U.S. Government funding in support of computer research from both the Defense Advanced Projects Research Agency (DARPA), the National Science Foundation, the Office of Naval Research and the National Aeronautics and Space Administration (NASA) in the U.S. lead to major breakthroughs in critical ICT related technologies, including relational databases, the Internet, artificial intelligence and virtual reality, among others (National Research Council of the National Academies 1999). Most interestingly, "the government role co-evolved with IT industries: its organization and emphasis changes to focus on capabilities not ready for commercialization and on new needs that emerged as commercial capabilities grew, both moving targets" (National Research Council of the National Academies 2003, 9). The key characteristic of U.S. government support for IT-related research was its breadth of scope, both in terms of the long time horizon that it adopted and the focus on a pre-commercial range of research activities.

In addition to its funding of the areas of basic research that laid the basis for some of the most important pieces of the ICT industry, direct government support was also critical in building the academic discipline of computer science and many of the university departments, without which the software code upon which the entire digital economy runs would not have been written (Mowery and Langlois 1996). Public funding played a less central role in the major breakthroughs in the early development of integrated circuits and semiconductor technologies that laid the basis for the digital revolution. Rather, public procurement provided the initial market that allowed the industry to grow and develop in the 1960s. Although many of the initial discoveries occurred in private laboratories with the support of private funding, the subsequent development of these new technologies was strongly stimulated by the defence and space establishment as purchasers of the new products. The lure of potential procurement contracts drove much of the R&D effort in this sector during the 1950s and 1960s and fed the growth of the emerging ICT cluster in Silicon Valley. Particularly influential were the decisions by the U.S. Air Force to employ semiconductors in the guidance system of the Minuteman missile and NASA decision to deploy integrated circuits in the Apollo spacecraft. The acceleration of the Minuteman program in the early 1960s led to the consumption of one fifth of the total output of integrated circuits by itself. In effect, defence and space procurement helped lower the barriers to entry in the industry and allowed a number of smaller firms to play an aggressive role in the development of the new technology (Ferguson and Morris 1993; Leslie 2000).

The subsequent expansion of the semiconductor industry through the 1960s and 1970s paved the way for the emergence of the digital economy in the next two decades. However, the success of the ICT sector in the U.S. sparked a host of government programs in Europe, Japan, Taiwan and Korea that were designed to support the growth of their own domestic industries (Wessner 2003; Rowen 2007). The success of these programs prompted greater efforts on the part of both the U.S. semiconductor industry and the federal government to revive the competitive status of the industry in the 1980s. These efforts were marked by the introduction of a host of federal programs and joint government-industry initiatives designed to enhance the innovative capacity of the U.S. semiconductor manufacturers and increase their ability to compete with the increasing number of producers in Europe and Asia. Among the measures introduced in the 1980s were the creation of the Semiconductor Research Corporation, jointly with the industry association, passage of the National Cooperative Research Act which removed legal impediments to the formation of industry research consortia, funding for SEMATECH, an industry research consortium founded by 14 leading U.S. semiconductor manufacturers and the launching of a Semiconductor Roadmap process as a joint undertaking by industry, government and university researchers. While all of these initiatives are deemed to have had a positive impact on the competitiveness of the industry, SEMATECH is widely seen as a critical factor in ensuring the long term viability of semiconductor design and manufacturing by U.S. firms (Wessner 2003).

Another area of concentration in high technology research and development that emerged at the turn of the century is the area of nanotechnology. The U.S. government has been a leader in investing in research and development in nanotechnology since 2001 through the National Nanotechnology Initiative (NNI). The interim report on the first five years of the National Nanotechnology Initiative submitted by the National Nanotechnology Advisory Panel in May, 2005 reported that the federal government spent over $4 billion on nanotechnology research between fiscal year 2001 and the end of fiscal year 2005. The report stated that United States led in the number of startup companies based on nanotechnology and in research output as measured by patents and publications. It noted that state and local initiatives provide a vehicle for additional R&D funding that helped stimulate commercialization and local economic development activity. In 2004, U. S. state and local governments invested more than $400 million into nanotechnology research facilities, and business incubation programs (President's Council of Advisors on Science and Technology 2005). One notable beneficiary of these state-led initiatives to support nanotechnology is the cluster that has emerged over the past decade in upstate New York around Albany NanoTech, a research centre with $5.5 billion of facilities and equipment that employs 2,500 researchers, engineers and academics. In addition to federal funding, the cluster has enjoyed strong support from the state government and key private sector partners, such as IBM. Since 2002, it has attracted a growing portion of SEMATECH's activities to relocate from Austin, Texas to Albany.

The NNI was extended after 2005 and currently operates under the NNI Strategic Plan, the framework that guides the nanotechnology work of the federal government. Its goal is to realize the NNI vision by providing guidance for agency leaders, program managers, and researchers with respect to the implementation of nanotechnology R&D investments and activities. The NNI does not fund research directly; rather, it influences the Federal budget and planning processes through its member agencies. The NNI currently subsumes the individual nanotechnology-related activities of 25 Federal agencies with a range of research and regulatory roles and responsibilities. Thirteen of the participating agencies have R&D budgets that relate to nanotechnology. Annual funding under the NNI amounts to approximately $1.7 billion, while an additional $500 million was allocated to it under the American Recovery and Reinvestment Act of 2009. The program is currently undergoing a major consultation on the draft Strategic Plan on the NNI to chart its future direction.

Another important federal program that supports innovation in the ICT sector is the U.S. Networking and Information Technology Research Program (NITRD) which is supported by 13 member agencies of the U.S. government and had research funding of $3 billion in 2008. Legislation to reauthorize the America Competes Act which was passed by the House of Representatives in June 2010, but is still awaiting passage in the U.S. Senate, calls for NITRD to develop a five year strategic plan focusing on how ICTs can support large-scale research in a wide variety of areas considered to be of strategic importance for the national interest. Proponents of this legislation view it as essential for the U.S. to keep pace with increases in funding for ICT R&D in other jurisdictions, particularly the E.U. (Ezell and Andes 2010).

U.S. research and program support for the ICT industry has continued to be emulated in other leading industrial countries through the 1990s and 2000s, especially in Europe. According to the OECD, two specific sets of policies rank high among government efforts to promote greater innovation in ICTs – ICT research and development programs and ICT innovation support programs. Many of the leading OECD countries, including the U.S., Finland, Norway, Germany and Japan, have large ICT related research programs in place. In the European Union the 7th Framework Program will increase the annual level of funding by 50 per cent between 2010 and 2013, an increase of $7 billion over this period. This funding is in addition to the national levels of funding already provided by individual member states – such as the $520 million annually made available through Germany's ICT 2020 – Research for Innovation program and Finland' $110 million in annual funding. A number of countries have agencies solely dedicated to supporting research for the ICT industry, such as National ICT Australia (NICTA), while ICT R&D support is more frequently part of the larger mandate of science and technology promotion agencies, such as Finland's TEKES or the National Science Foundation in the U.S. (Ezell and Andes 2010, OECD 2008a, 2010).

A recent study of European national and regional policies to support the ICT sector identified a number of common policy approaches pursued across a wide range of E.U. member countries, including direct subsidies and public procurement. A majority of the initiatives to support the direct production of ICTs tend to concentrate on innovation activities, including funding for R&D, technology transfer activities and dedicated programs to support partnerships and networking, principally between industry and universities. The survey noted that the overwhelming bulk of national strategies to support the ICT sector among European nations were focused on technology development and transfer. There was also a large degree of support for incubators and ICT clusters, which reflects the preoccupation with promoting the growth and development of SMEs within the ICT sector (Friedewald, Hawkins et al. 2005).

Several of the smaller Nordic economies – including Finland – are noteworthy for the targeted and highly effective support they have provided to promote the growth of their respective ICT industries in recent years. Tekes is the Finnish technology program whose main objective is to promote the competitiveness of Finnish industry. It does this by financing national programs which focus on areas with a strong level of R&D investment is important for national priorities. In the first half of the 2000s, there were seven Tekes programs, out of a total of 34, which supported ICT related research. These programs had a total investment of €600 million, of which Tekes provided half. The programs typically vary in length from three to five years. Tekes tends to support programs that promote cooperation among several companies or cooperation between companies and research institutes or universities. The Tekes programs in ICT are considered as a critical factor in fostering the development of the Finnish ICT industry since the crisis of the early 1990s. The Tekes funding has served to strengthen the Finnish ICT cluster and develop a strong knowledge infrastructure, as well as promoting the growth of firms, such as Nokia, that were able to reap the significant benefits of first mover advantages. "It is widely understood that the success of the Finnish ICT cluster depends heavily on the success of a handful of firms, . . . These positive network externalities have resulted in the take-off of the whole Finnish ICT sector" (Friedewald, Hawkins et al. 2005. 42).

Cluster Strategies and Cluster Policies

As the preceding accounts of national policies for the ICT industry make clear, programs that provide support for local industrial concentrations of firms and supporting institutions remain a critical part of most strategies for growing the ICT sector. Most respondents to the OECD's annual *Information Technology Outlook* survey identify the establishment of clusters of firms and innovation networks as a critical mechanism for supporting innovation in ICTs. A number of OECD member countries fund a specific set of policies and institutions to support ICT innovation, including Finland's Strategic Centre for Science, Technology and Innovation in the Field of ICT, Germany's Networks of Competence, a network of 13 regional high technology clusters and Korea's RFID/USN clusters to promote sensor-based technologies. Most other OECD countries include their support for ICT clusters under a broader range of cluster support policies, including Denmark's cross-sector innovation networks, France's Pôles de compétivité and Sweden's Vinnova, the innovation promotion agency (OECD 2010, 2007).

Recent policy documents from the European Commission identify clusters as a critical policy tool for streamlining the delivery of a range of different policy focused on the goal of stimulating innovation in regional economies. The European Commission documents the ways to implement regional policy for smart growth specific in a number of key policy areas in order to gain the maximum benefit from existing local and regional clusters. These include support for the internationalization of cluster firms, the commercialization of research results, specialized programs and training institutes for the local labour force, joint branding and marketing programs for cluster firms and policies to help cluster firms take better advantage of the trend towards open innovation in the R&D strategies of large multinationals. Existing cluster organizations can also provide a convenient mechanism for delivering specialized business and innovation support programs to cluster firms and developing collective strategies to promote the growth of local clusters (European Commission 2010).

Cluster initiatives afford policy-makers a lens or focusing device through which they can address a wide range of business needs in a collective fashion and ensuring a cost effective means of delivering their programs to a critical mass of recipients in a manner that has been designed through a joint public-private decision-making process (Landabaso and Rosenfeld 2009). Clusters are effective as a policy instrument because they can help promote linkages between firms, universities and research institutes and provide a basis for firms to take better advantage of market opportunities. They also afford the opportunity for small and medium-sized firms to establish connections with larger partners and multinational firms. Several Canadian cities are well advanced in their efforts to support the growth of their own industrial clusters. Ottawa has long provided support for the development of its ICT cluster through the actions of the City, the Ottawa Partnership and the Ottawa Centre for Research and Innovation. The Montreal Metropolitan Community began implementation of an integrated innovation and economic development strategy focused on the promotion of fifteen industrial clusters, including the ICT cluster, in 2005 (CMM 2005). Waterloo Region through the combined efforts of the local civic association, Communitech, the municipalities in the region and strong support from the universities and several leading ICT firms has adopted a series of initiatives to support the cluster, mostly recently the Corridor for Advancing Canada`s Digital Media. The City of Toronto launched a detailed cluster development strategy process for the ICT cluster in 2006 (The Impact Group 2006). The strategy has supported a diverse range of activities by a variety of not-for-profit organizations across the city and recently has begun to coalesce around a new organization, Technicity (City of Toronto 2010).

However, a critical challenge for federal systems of government in the effective implementation of cluster policies concerns the issue of policy alignment. The recent OECD report on national policy approaches to cluster development notes that national governments of federal countries have limited options in promoting policy coherence across multiple levels of government. They lack the authority to dictate policy goals to subnational governments, although direct funding can be used to induce those governments to adopt a desired course of policy action. With respect to cluster development, however, the report identifies the lack of policy coordination across different levels of government as leading to a number of 'missed opportunities'. The first arises from federal or provincial funding for research centers or centre of excellence programs. These policies typically develop from a research policy focus based in ministries of higher education with responsibility for university funding. The centers funded under these initiatives serve to support the development of regional specialization, but without formulating direct linkages to cluster policies and strategies, regions and urban areas are less effective at capturing the benefits of that research. The second arises from the lack of integration of science and industrial parks with cluster programs. Programs to promote science and industrial parks often originate at the local level and are therefore not explicitly aligned with cluster policies and programs originating at the national or provincial level. The third arises from the lack of coordination of regional with national innovation systems that leaves the regional systems isolated from the greater resources available under the national programs (OECD 2007, 122). A coordinated approach to cluster development in general and clusters in the ICT sector in particular, requires that national policies to support the sector be integrated at the 'governance' level, across existing program boundaries, as well as levels of government, leading to a more effective degree of 'policy alignment'.[34]

Policy Recommendations and the Need for Further Research

This synthesis paper has provided an overview of the current state of research and understanding on the extent of the ICT industry in Canada from a comparative perspective. It has survey some of the factors that are currently driving growth in various sub-sectors of

[34] A more comprehensive review of the key lessons derived from the ISRN study of Canadian clusters for cluster strategies and cluster policies can be found in Wolfe 2008.

the industry and where Canada enjoys the greatest competitive advantage and opportunities for future growth. It has also analyzed the critical role played by local concentrations of firms and supporting institutions in supporting the growth of ICT firms and suggested that recognition of existing concentrations of strength in ICT clusters should be a central part of a national strategy to promote the digital economy in Canada. It has surveyed some of the current strategies employed in a cross-section of OECD countries, indicating the incredible scope and variety that currently can be found in the array of policy instruments being deployed by the E.U. and leading industrial countries.

The detailed prescription of a comprehensive set of policies to promote the further growth of the ICT industry in Canada lies beyond the scope of this paper. However, several submissions to Industry Canada`s consultation on the Digital Economy contain policy recommendations that are worthy of note. In its submission, the Information Technology Association of Canada makes a number of recommendations with respect to growing the ICT industry, increasing the adoption and use of ICTs in other sectors of the Canadian economy, and expanding the conception of broadband by developing a truly digital definition of infrastructure. Among the relevant recommendations are: increased collaboration across existing support mechanisms and levels of government, setting targets for the growth of ICT firms in Canada – such as 20 firms above $1 billion by 2017, addressing the gap in venture funding for ICT startups through new mechanisms, such as flow through shares, address the administrative and other issues in the SR&ED that are hindering the growth of ICT firms, and providing increased support for innovation programs, such as IRAP with a proven track record, but insufficient funding to respond to current demand. With respect to the adoption and diffusion of ICTs, it calls for the expansion and wider application of FedDev Ontario's 'SMART' program to encourage the use of ICTs, green and lean technologies among Ontario`s manufacturers (ITAC 2010).

In its submission, the ICT Consortium, which includes The Toronto Region Research Alliance, CATA, and a number of Canadian and multinational ICT companies, suggests that the most important factor influencing the growth of ICT industry is the adoption and use of ICTs in Canadian industry. The single most effective way to influence this is having governments act as model users of ICT productivity tools in areas such as digital environmental monitoring, electronic health records,'smart' energy monitoring and control, and e-skills development. It calls for the federal government to partner with Canadian branches of international ICT companies, whether domestic or foreign owned, in subsidizing the costs incurred for the execution of global mandates, such as skills development, design, engineering and business development. It also recommends the provision of tax expenditures or direct subsidies for companies increasing their adoption of ICT productivity tools, funding a core of ICT productivity specialists to work with SMEs to increase their adoption of ICT productivity tools, consideration of accelerated depreciation for ICT equipment purchased to offer a service and ensuring that government procurement mechanisms support companies able to deliver services to government'on-line'. Most importantly, it urges the federal government to adopt a grand strategy to kick start the digital economy. Its preferred option is building smart communities across the country, which would include smart grids and other interconnected intelligent systems, such as water, traffic management, emergency services, land-use planning and zoning. "Smart Communities will create a demand-side imperative for companies to invest in productivity tools and innovative services in order to compete in the digital economy in local, national and international smart communities" (The ICT Consortium 2010).

The Council of Canadian Academies expands on the idea of providing expert support for SMEs in the adoption of ICTs in the form of a proposal to create a Digital Transformation Assistance Program (DTAP) modeled on the National Research Council`s IRAP. DTAP would establish a cadre of expert advisors to work with business across the country to enhance awareness of the opportunities for implementing ICTs and reduce the risk. It could leverage its advisory services with financial incentives that could be used for the purchase of key inputs and services from the private sector. It could also facilitate the cost of acquiring needed ICT skills by providing temporary wage subsidies for student interns and new graduates. Over time, the field staff of DTAP could become a reservoir of knowledge and insights into the reasons why Canadian SMEs are slow to invest in digital technologies. A key objective for the organization would be to distil these insights and ensure their broad dissemination to potential users of ICTs and policy-makers. The submission also makes recommendations about the importance of government procurement to stimulate the uptake of ICTs and the need for complementary investments in ICT skills and digital infrastructure (Council of Canadian Academies 2010).

Not surprising, there is a substantial amount of overlap between some of these recommendations. The implementation of a selection of them would go a long way towards addressing the current challenges facing the ICT industry in Canada. There is no shortage of further research that could be undertaken to support this broad policy agenda. Included among the many topics addressed in this paper that need further research and understanding are the factors influencing the adoption and use of ICTs by Canadian firms. This has been clearly identified by virtually all studies and reports as a major obstacle to growing the ICT industry in Canada. A related issue concerns the factors influencing the performance of venture capital markets in Canada and the potential implications of the rise of alternative funding mechanisms, such as the role of super angels. Farther up the growth ladder, there is a need for research on how the broader capital markets in Canada affect the potential to grow Canadian ICT firms to global scale. There is a need to support research on the kind of management skills required by Canadian ICT firms to allow them to compete effectively in international markets. Finally, we need further research on how industrial clusters can support the growth of firms in the ICT industry across the country and how to align federal and provincial policies most effectively in support of cluster strategies.

References

Anderson, D. and O'Shea, C. 2010. "Branham 300 2010 – Top Canadian Tech Companies," *Backbone Magazine*. April 1.

Andes, S. and Castro, D. 2010. *Opportunities and Innovations in the Mobile Broadband Economy*. The Information Technology & Innovation Foundation. Washington, D.C.

Benkler, Y., Faris, R., Gasser, U., Miyakawa, L., and Schultze, S. 2010. *Next Generation Connectivity: A Review of Broadband Internet Transitions and Policy from Around the World*. Berkman Center for Internet & Society, Harvard University. Cambridge, Mass.

Bramwell, A. and Wolfe, D. 2008. "Universities and Regional Economic Development: The Entrepreneurial University of Waterloo," *Research Policy* 37(8): 1175-1187.

Bramwell, A., Nelles, J. and Wolfe, D. 2008. "Knowledge, Innovation and Institutions: Global and Local Dimensions of the ICT Cluster in Waterloo Canada", *Regional Studies*. 42(1): 101-116.

Britton, J. 2004. "High Technology Localization and Extra-Regional Networks," *Entrepreneurship and Regional Development* 16(5): 369-390.

Britton, J. 2003. "Network Structure of an Industrial Cluster: Electronics in Toronto," *Environment and Planning A* 35: 983-1006.

Brouard, F., Chamerlin, T., Doutriaux, J., and de la Mothe, J. 2005. "Firm demographics in Silicon Valley North », in L.V. Shavinina, Ed. *Silicon Valley North : A High-Tech Cluster of Innovation and Entrepreneurship*. London : Elsevier.

Canadian Chamber of Commerce. 2009. *Mapping the Future of the Digital Economy: Key To Canada's Economic Success*.

Canadian Coalition for Tomorrow's ICT Skills. 2010. *Canada: The Go-To Country for Brainpower Resources in the Global Digital Economy*. Submission to the consultation paper on a Digital Economy Strategy for Canada, *Improving Canada's Digital Advantage: Strategies for Sustainable Prosperity*.

Castro, D. 2010. *Cloud Computing Requires National Policy Leadership*. The Information Technology & Innovation Foundation. Washington, D.C.

City of Toronto. 2010. *Toronto: Canada`s High Tech Hub*. Toronto.

Chamberlin, T. and de la Mothe, J. 2003. "Northern Light: Ottawa's Technology Cluster," in Wolfe, D.A. (Ed.), *Clusters Old and New: The Transition to a Knowledge Economy in Canada's Regions*. Kingston: McGill-Queen's University Press, pp. 213-234.

Communauté metropolitan de Montréal. 2005. *Charting our International Future: A competitive metropolitan Montreal region*. Montreal.

Correa, D. 2007. *Assessing Broadband in America: OECD and ITIF Broadband Rankings*. Washington, D.C.: The Information Technology and Innovation Foundation.

Council of Canadian Academies. 2009. *Innovation and Business Strategy: Why Canada Falls Short*. Report of the Expert Panel on Business Innovation. Ottawa.

Council of Canadian Academies. 2010. "Catalyzing Canada's Digital Economy," A Response to the Public Consultation on a Digital Economy Strategy for Canada by the Expert Panel on Digital Technologies and Innovation. Ottawa.

Creutzberg, T. 2005. "Scalar dimensions and non-market governance in knowledge economies: The microelectronics industry in the greater Toronto region". Paper presented to the Annual Meeting of the Canadian Political Science Association, University of Western Ontario, London, ON, June 2-4.

Cunningham, L. 2008. "Cloud Computing Defined," November 21, 2008, http://it.toolbox.com/blogs/oracle-guide/cloud-computing-defined-28433

Davis, C. and Sun, E. 2006. "Business Development Capabilities in Information Technology SMEs in a Regional Economy," *Journal of Technology Transfer.* 31(1): 145-161.

Davis, C. and Schaefer, N.V. 2003. "Development Dynamics of a Startup Innovation Cluster: the ICT Sector in New Brunswick," in Wolfe, D. (Ed.), *Clusters Old and New: the Transition to a Knowledge Economy in Canada's Regions*. Montreal: McGill-Queen's University Press, pp.121-160.

Delgado, M., M. E. Porter, and S. Stern. 2010. "Clusters, Convergence and Economic Performance." Institute for Strategy and Competitiveness, Harvard Business School. Cambridge, Mass. Http://www.isc.hbs.edu/econ-clusters.htm.

Deloitte Canada. 2010. *2010 The Global Trends in Venture Capital: Outlook for the Future Survey*. http://www.deloitte.com/print/en_CA.

Deloitte Center for the Edge. 2009. *The 2009 Shift Index: industry Metrics and Perspectives*.

Durufflé, G. 2006. "Drivers of Canadian VC Performance." Report to the Annual Meeting of the Canadian Venture Capital Association. Vancouver.

European Commission. 2010. *Document accompanying the Commission Communication on Regional policy contributing to smart growth in Europe 2020*. COM (2010) 553 Final. Commission Staff Working Document. Brussels: European Commission.

Ezell, S. and Andes, S. 2010. "ICT R&D Policies: An International Perspective," *IEEE Internet Computing* (July/August): 76-80.

Feldman, M. P. Francis, J. and Bercovitz. J. 2005. "Creating a Cluster While Building a Firm: Entrepreneurs and the Formation of Industrial Clusters." *Regional Studies* 39: 129–41.

Ferguson, C. H., and Morris, C.R. 1993. *Computer Wars: How the West Can Win in a Post-IBM World*. New York: Times Books.

Freiden, R. 2005. "Lessons from Broadband Development in Canada, Japan, Korea and the United States," *Telecommunications Policy* 29(8): 595-613.

Friedewald, M., Hawkins, R.W., Chatrie, I. Kimpeler, S., Lengrand, L., Poel, M. and Rachidy, J. 2005. *Benchmarking national and regional policies in support of the ICT sector in the EU*. Report for the Directorate General for Enterprise and Industry, European Commission. Stuttgart: Fraunhofer IRB Verlag.

Fripp, R. 2008. *Proceedings of the Seventh Annual Re$earch Money Conference, "From Entrepreneur to Titan: Can Canadian Entrepreneurs Grow Start-ups into Domestic Multinationals*." Eaton Centre Marriott, Toronto, May 21.

Gertler, M., Spencer G., Vinodrai, T. and Wolfe, D. 2004. "Analytical Measures to Assess and Evaluate Clusters," Presentation to the Joint ONRIS/MEDT Fall Workshop, Toronto. http://www.utoronto.ca/onris/research_review/Presentations/index.html.

Globe and Mail. 2010. "Canada's broadband lag," February 21. www.globeandmail.com.

Goldberg, M. 2009. *Lagging or Leading: The State of Canada's Broadband Infrastructure*. Report prepared by Mark H. Goldberg and Associates and Giganomics Consulting.

Government of Canada. 2010. *Improving Canada's Digital Advantage: Strategies for Sustainable Prosperity*. Consultation paper on a Digital Economy Strategy for Canada.

Harrison, R. T., Cooper, S. Y. and Mason, C. M. 2004. "Entrepreneurial Activity and the Dynamics of Technology-Based Cluster Development: The Case of Ottawa." *Urban Studies* 41(5/6 May): 1045–70.

ICT Consortium. 2010. *Smart Communities – The Grant Challenge Project to Launch the Digital Economy*. Submission to Industry Canada`s Digital Economy Strategy Consultation. Toronto.

Impact Group. 2006. *ICT Toronto: An Information and Communication Technology (ICT) Cluster Development Strategy for the Toronto Region*. Toronto.

Hickling Arthurs Low. 2009. *Canada's Entertainment Software Industry: The Opportunities and Challenges of a Growing Industry*. Report Prepared for the Entertainment Software Association of Canada. Ottawa.

Industry Canada. 2009a. *Canada's Digital Economy: Moving Forward*. Background paper for the Forum on the Digital Economy, Ottawa, June 22.

Industry Canada. 2009b. *ICT Statistical Overview and Canadian ICT Sector Overview*. Ottawa.

Industry Canada. 2010a. *Canadian ICT Statistical Overview (ICTSO): Key Indicators by Industry*. Innovation, Science and Technology Branch. Ottawa.

Industry Canada. 2010b. *Quarterly Monitor of the Canadian ICT Sector*. Information and Communications Technology Branch. Ottawa.

Information and Communications Technology Council. 2008a. *Outlook for Human Resources in the Information and Communications Technology Labour Market, 2008 to 2015*. Summary Report. Ottawa.

Information and Communications Technology Council. 2008b. *IT Enrolments and Retention: Situation Report*. Ottawa.

Information and Communications Technology Council. 2009. *2009 Trends Special Report*.

Information Technology Association of Canada (ITAC). 2008. Submission for consultation paper on "Sharpening Canada's Competitive Edge," to the Competition Review Panel. Ottawa.

Information Technology Association of Canada (ITAC). 2010. *ITAC's Response to the Consultation Paper on a Digital Economy Strategy for Canada*. Ottawa.

Institute for Competitiveness and Prosperity. 2010. *Beyond the Recovery*. Report on Canada 7. Toronto.

International Telecommunications Union. 2010. *Measuring the Information Society 2010. Market Information and Statistics Division*. Geneva.

Johnstone, H. and Haddow, R. 2003. "Industrial decline and high-technology renewal in Cape Breton: Exploring the limits of the possible," in D.A. Wolfe, ed. *Clusters Old and New*. Montreal and Kingston: McGill-Queen's University Press.

Kazam Technologies. 2007. *The Canadian Wireless Industry - Analysis, Positioning and Capabilities: 2006-2009*.

Kéroack, M., Ouimet, M. and Landry, R. 2004, "Networking and Innovation in the Quebec Optics/Photonics Cluster," in Wolfe, D. and Lucas, M. (Eds.). *Clusters in a Cold Climate: Innovation Dynamics in a Diverse Economy*. Montreal and Kingston: McGill-Queen's University Press, pp. 113-137.

Landabaso, M., and Rosenfeld, S. 2009. "Public policies for industrial districts and clusters," in G. Becattini, M. Bellandi, and L. De Propris, eds, *A Handbook of Industrial Districts*. Nottingham: Edward Elgar.

Langford, C., Wood, J. and Ross, T. 2003. "The Origins and Structure of the Calgary Wireless Cluster," in D.A. Wolfe, ed., *Clusters Old and New: The Transition to a Knowledge Economy in Canada's Regions*. Montreal: McGill-Queen's University Press, pp. 161-185.

Langford, C. and Wood, J. 2005. "The Evolution and Structure of the Vancouver Wireless Cluster: Growth and Loss of Core Firms," in Wolfe, D. and Lucas, M. (Eds), *Global Networks and Local Linkages: the Paradox of Cluster Development in an Open Economy.* Kingston: McGill-Queen's University Press, pp. 207-226.

Leslie, S. W. 2000. "The Biggest 'Angel' of Them All: The Military and the Making of Silicon Valley." In *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*, ed. Martin Kenney. Stanford, Calif.: Stanford University Press.

Lonmo, C. 2003. "Innovation in Information and Communication Technology (ICT) Sector service Industries: Results from the Survey of Innovation 2003." Working paper. Statistics Canada. Science, Innovation and Electronic Information Division. Cat. No. 88F0006XIE No. 12. Ottawa.

Lorinc, J., Tossell, I. and el Akkad, O. 2010. "The Age of the App." *The Globe and Mail*. March 25.

Lucas, M., Sands, A., and Wolfe, D. 2009. "Regional Clusters in a Global Industry: ICT Clusters in Canada," *European Planning Studies*. 17(2): 189-209.

Macher, J.T., Mowery, D., and Di Minin. 2008. "Semiconductors," in J.T. Macher and D. Mowery, eds, *Innovation in Global Industries: U.S. Firms Competing in a New World*. Washington, D.C.: National Academies Press.

Maclean, D. 2007. "Fuelling Creativity: Innovation, Participation, and Entrepreneurship", Paper prepared for the Canada Roundtable on the Future of the Internet Economy.

Maich, Steve. 2010. "Editor's letter: Why Canada needs RIM to win," *Canadian Business*. February 15.

Mandel, M. 2010. "The Coming Communications Boom? Jobs, Innovation, and Countercyclical Regulatory Policy". Policy Memo for the Progressive Policy Institute.

Matthews, T. 2009. "Canada's ICT Sector: Enabler to the Digital Economy," Keynote Speech to the Industry Canada Roundtable for "Canada's Digital Economy: Moving Forward". Ottawa. June 22.

Mell, P. and Grance, T. 2009. "NIST Definition of Cloud Computing, Version 15." National Institute of Standards and Technology. Washington, D.C. www.csrc.nist.gov.

Mowery, D.C. and Langlois, R. 1996. "Spinning Off and Spinning On (?): The Federal Government Role in the Development of the U.S. Computer Software Industry," *Research Policy* 25: 947-966.

National Research Council of the National Academies. 1999. *Funding a Revolution: Government Support for Computing Research*. Computer Science and Telecommunications Board. Washington, D.C.: National Academies Press.

National Research Council of the National Academies. 2003. *Innovation in Information Technology*. Computer Science and Telecommunications Board. Washington, D.C.: National Academies Press.

National Research Council of the National Academies. 2009. *Assessing the Impacts of Changes in the Information Technology R&D Ecosystem: Retaining Leadership in an Increasingly Global Environment*. Computer Science and Telecommunications Board. Washington, D.C.: National Academies Press.

Nelles, J., Bramwell, A. and Wolfe, D. 2005. "History, Culture and Path Dependency: Origins of the Waterloo ICT Cluster," in D. Wolfe and M. Lucas, eds, *Global Networks and Local Linkages: the Paradox of Cluster Development in an Open Economy.* Kingston: McGill-Queen's University Press, pp. 227-252.

Nordicity. 2009. *Towards A National Digital Strategy*. Issues discussion paper prepared by Nordicity. Toronto.

OECD. 2003. *ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2007. *Competitive Regional Clusters: National Policy Approaches.* OECD Reviews of Regional Innovation. Paris: Organisation for Economic Co-operation and Development.

OECD. 2008a. *OECD Information Technology Outlook 2008*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2008b. "Shaping Policies for the Future of the Internet Economy," *OECD Digital Economy Papers* No. 148. Paris: Organisation for Economic Co-operation and Development.

OECD. 2008c. *Broadband Growth and Policies in OECD Countries*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2009a. *The Impact of the Crisis on ICT and ICT-related Employment*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2009b. *Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2009c. *Smart Sensor Networks: Technologies and Applications for Green Growth*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2009b. *OECD Communications Outlook 2009*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2010. *Information Technology Outlook 2010*. Organisation for Economic Co-operation and Development. Paris.

Ouimet, M. and Amara, N. and Landry, R. 2007. "Network positions and efforts to innovate in a small Canadian optics and photonics clusters," *International Journal of Entrepreneurship and Innovation Management* 7(2-5): 139-159.

Onstad, K. 2010. "Download My App." *Toronto Life*. November, pp. 42-48.

Porter, M. E. 1998. "Clusters and Competition: New Agendas for Companies, governments, and institutions", in M.E. Porter, ed. *On Competition*. Cambridge, MA: Harvard Business Review Books.

Porter, M. E. 2003. "The Economic Performance of Regions." *Regional Studies* 37(6&7): 549–78.

President's Council of Advisors on Science and Technology. 2005. *The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Board*. Washington, D.C.: National Science and Technology Council.

Prism Economics. 2008. *Outlook for Human Resources in the Information and Communications Technology Labour Market, 2008 to 2015*. Report prepared for the Information and Communications Technology Council. Toronto.

Rowen, H. S. 2007. "How Governments Shaped their IT Industries," in H.S. Rowen, M.G. Hancock and W.F. Miller, eds, *Making IT: The Rise of Asia in High Tech*. Stanford, CA: Stanford University Press.

Science, Technology and Innovation Council. 2009. *State of the Nation 2008: Canada's Science, Technology and Innovation System*. Ottawa.

Sharpe, A. 2005. "What explains the Canada-US ICT investment intensity gap?" *International Productivity Monitor* 11 (Fall): 21-28.

Sharpe, A. and Arsenault, J.-F. 2008. *The Canada-US ICT investment gap: An Update*. CSLS Research Report No. 2008-1. Ottawa: Centre for the Study of Living Standards.

Spencer, G., T. Vinodrai, M. S. Gertler, and D. A. Wolfe. 2010. "Do clusters make a difference? Defining and assessing their economic performance." *Regional Studies* 44(6), July: 697–715.

Surtees, L. and Yang, S. 2010. *Canadian Wireless Services 2010-2014 Forecast and Analysis: Wireless Wars 7*. Framingham, MA: International Data Group.

Sydor-Estable, N. 2006. *Key Wireless Technologies and Developing Trends*. Information and Communications Technology Branch, Industry Canada. Ottawa.

Thomson Reuters. 2009. *Canada`s Venture Capital Industry in 2009*. Toronto. http://www.cvca.ca/resources/statistics/.

Wesley Clover. 2008. "The Challenge of Survival for Canada's ICT Sector," notes prepared on behalf of the Canadian Advanced Technology Alliance for the Science, Technology and Innovation Council. Ottawa.

Wessner, C. W., ed. 2003. *Securing the Future: Regional and National Programs to Support the Semiconductor Industry*. Board on Science, Technology and Economic Policy, National Research Council of the National Academies. Washington, D.C.: National Academies Press.

Wolfe, D.A. 2008. *Cluster Strategies and Cluster Policies: Lessons from the ISRN National Study*. Toronto: Munk Centre for International Studies.

Wolfe, D.A. 2009. "Universities and Knowledge Transfer: Powering Local Economic and Cluster Development," in G.B. Doern and C. Stoney, eds, *Research and Innovation Policy: Changing Federal Government-University Relations*. Toronto: University of Toronto Press.

Wolfe, D.A. and Gertler, M.S. 2004. "Clusters from the Inside and Out: Local Dynamics and Global Linkages", *Urban Studies*, 41(5-6): 1071-1093.

Wolfe, D. A. and Nelles, J. 2008. "The Role of Civic Capital and Civic Associations in Cluster Policies," In Charlie Karlsson, ed., *Handbook of Research on Innovations and Clusters: Cases and Policies*. Cheltenham, UK: Edward Elgar.

Wolfson, W. 2008. *Analysis of Labour Force Survey Data for the Information Technology Occupations: 2000-2007*. Report prepared for the Software Sector Council. Toronto.