Growing Innovation Ecosystems: University-Industry Knowledge Transfer and Regional Economic Development in Canada

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Executive Summary

More than ever, governments in Canada and other leading countries are focused on leveraging public investments in higher education research and development to stimulate innovation, enhance competitiveness and bolster economic growth. To realize these goals, initiatives to strengthen existing knowledge flows between universities and firms must be developed, and policies to encourage new university-industry linkages must be implemented. Because of the iterative and personalized nature of the innovation process, knowledge exchange often occurs on a local basis between firms and institutions located in proximity to each another. Hence it is critical for national and subnational governments to work together to encourage publicly and privately-driven policies, programs and initiatives that support the development of local and regional university-industry linkages, and ultimately reflect an advanced understanding of the significance of geographical proximity for the knowledge transfer process. As such, this paper underscores the value of adopting a localized view of university-industry knowledge flows.

Many universities are engaged key players embedded in the knowledge transfer process underpinning successful regional innovation systems. This report discusses the critical role these institutions play in harnessing the full innovation potential of their local economies. Universities promote the economic growth of their local surroundings through the production of basic and applied research, the generation of tacit and codified knowledge, and the development of highly qualified and skilled personnel. Universities also attract talent to their local communities and collaborate with industry, which cumulatively intensifies the flow of knowledge between academic institutions and firms and facilitates technology transfer and commercialization. Local firms are advantaged with access to new ideas and fresh perspectives on challenging and complex problems through a variety of knowledge transfer mechanisms including but not limited to consultation, sponsored research projects and the recruitment of R&D graduates. Furthermore, many firms engage with local universities to obtain access to the university's facilities, customized training courses, and research results.

A number of factors support the development of networks and other mechanisms that facilitate linkages between universities and industry in Canada. This knowledge synthesis paper outlines several institutional factors and policies that build the Canadian university's capacity to respond to the continually changing R&D and knowledge requirements of local firms, build the absorptive capacity of local firms to make use of this knowledge, and build the human capital, finance capital and intellectual property that underpins local knowledge flows. The paper also discusses the range of challenges universities and firms face, which pose significant barriers to the university-industry knowledge transfer process. The list of barriers that complicate university-industry collaboration is organized into two broad categories: orientation-related barriers refer to differences in the primary missions of universities and industry, and transaction-related barriers refer to conflicts over intellectual property and university policies and regulations.

The specific geographic environment and historical context in which a university is situated also substantively influences the institution's capacity to advance knowledge transfer and technology commercialization. Hence, there is a great deal of variation in the kinds of university-industry partnerships that emerge across different sectors and jurisdictions; the degree of variation ranges from the type of knowledge transfer activities that occur between universities and local firms, to the role the university assumes in technology commercialization. The paper provides an overview of international policies and programs designed to facilitate university-industry knowledge transfer and commercialization at a national and subnational level in Canada and competitor nations and regions in Europe, Asia, Australia and the USA. A spectrum of public policies, institutional policies and managerial practices that can yield new insights for reforming existing policies and creating new mechanisms for supporting academic entrepreneurship are reviewed. However, while policy lessons can be drawn from the experiences of other countries and regions, Canada and its provinces should not adopt or attempt to emulate models that have worked in other jurisdictions without first critically analyzing how a variety of factors influence university-industry collaborations differently across different sectors and regions, and identifying policies and institutions that fit with its own national and regional contexts.

Many national and subnational governments have embraced policy experimentation and creativity in order to intensify efforts at supporting and leveraging the unfettered flow of knowledge throughout their economies. To this end, several leading economies have adopted the innovation ecosystems approach. This approach is a sophisticated way of seeing the innovation system as a whole that enables policy makers to pay close attention to the collaborative, interdependent nature of the innovation process and identify the best means of stimulating productive networks and relationships within and across disciplines and sectors of comparative advantage. The paper discusses the advantages of adopting an innovation ecosystem approach, the means for building a healthy and sustainable innovation ecosystem, the role of the university in advancing knowledge flows within an innovation ecosystem and the pervasiveness of innovation ecosystems around the world.

Universities across the globe are becoming increasingly entrepreneurial in their approach to knowledge and technology transfer activities, actively seeking to build direct connections with industry to pursue both individual and joint commercialization opportunities; a number of emerging best practices employed by universities to build linkages with industry are reviewed in this paper. However, universities cannot expect to optimize regional knowledge transfer without the continued strong support of government, industry and other actors within the innovation ecosystem. As such, academic and civic leaders, industry partners and policy makers from multiple levels of government must collaboratively advance a localized view of university-industry knowledge flows and encourage the development of new and existing local/regional institutional arrangements and capabilities that will cultivate more robust linkages between local universities and firms.

Introduction

Growing concerns about Canada's poor track record on the transfer of technology from universities to industry and the commercialization of academic research indicates that knowledge and new ideas may not be diffused as easily as might be assumed. There is a general lack of understanding about how the university-industry technology transfer process actually unfolds in Canada, hence a careful examination of the existing research on university–industry knowledge transfer in Canada and elsewhere, as well as research gaps and opportunities, is overdue. Guided by the three key themes of creating collaborative networks between university researchers and industry, mechanisms that facilitate knowledge transfer from universities to industry and the role of government-funded and private sector intermediaries in supporting the knowledge receptor capacity of industry, the purpose of this paper is to synthesize the literature on university-industry knowledge transfer and regional economic growth. In this knowledge synthesis, we adopt a *localized* view of university-industry knowledge flows, focusing on the process of building linkages between universities and industry on a regional basis to encourage and facilitate the knowledge transfer and commercialization process. From this perspective, knowledge transfers between universities and firms are iterative, highly personalized and, as a consequence, often occur on a local basis, which underscores the significance of geographical proximity for the knowledge transfer process. The paper consists of three main sections: the first provides a synthesis of the existing literature on dynamics that support successful *local* university-industry linkages followed by a brief discussion of the challenges to the university-industry technology transfer process in Canada; the second contains a detailed overview of programs implemented elsewhere to provide ideas and insights that can inform Canada's policy efforts; finally the third section discusses the role of universities in emerging approaches to building 'innovation ecosystems' to facilitate knowledge transfer and regional economic growth. The paper concludes with a discussion of regional best practices in Canada and elsewhere.

Part I - Knowledge Transfer and Regional Economic Growth: University-Industry Linkages in Regional Innovation Systems

The literature on knowledge diffusion and economic performance has exploded in recent years, and Stern, Porter and Fulham (2002) distinguishes between *the cluster-based theory* of national competitive advantage, *the knowledge-driven endogenous theory*, and the literature on *national* and *regional innovation systems.* While cluster-based theories emphasize the microeconomic underpinnings of innovation in country-specific industrial clusters, such as local supporting industries, universities and the nature of local competitiveness, endogenous models of knowledge-driven growth emphasize the knowledge accumulation and the level of R&D effort allocated towards creation of new knowledge in private firms and public research, and the literature on national innovation systems analyzes the role of the national policy environment, universities and the educational sector, as well as a range of other institutions that affect the innovation process (Loof and Brostrom 2005). Nieminen and Kaukonen (2001: 5) broadly describe the *national innovation system* - and its regional counterpart - as "the system of organisations and actors whose interaction shapes the innovativeness of the national economy and society." It is through this last theoretical lens that this paper approaches this synthesis of the literature on knowledge transfer between universities and industry in Canada and elsewhere.

Recognition of the networked and interdependent nature of the innovation process led evolutionary economists to develop the innovation systems approach, with an initial focus on the national level. The approach emphasizes the role of various institutional structures and social forces in determining innovative capacities; its key insight lies in the emphasis placed on the systemic nature of the relationships. Systems are defined as a set of interrelated components which share a common boundary and work towards a common purpose. An innovation system is thus comprised of the relationships among a set of components that interact in the production, diffusion and adoption of new and commercially valuable knowledge (Lundvall 1992). The systems of innovation approach stresses the social nature of the innovation process wherein innovation results from the interaction among the specific components of invention, research, technical change, and learning that comprise the system. The advantage of applying the innovation systems approach is that it analyzes failures or shortcomings in innovative performance in terms of deficits in the interaction among or between the various agents who comprise the system, and the resulting failures are viewed as a result of system failures or blockages rather than the shortcomings of individual agents or actors.

In tandem with the early work on national systems of innovation, a parallel stream developed in the late 1980s, which identified the constellation of institutions at the regional level that contribute to the innovation process as the *regional innovation system*. The focus on the regional level of analysis was linked to a growing recognition of the importance of network relations among various actors and the tendency for those networks to be spatially grounded. The networked form of organization is characterized by transactions among interrelated groups of firms linked by both cooperative and competitive relations that engage in reciprocal and mutually supportive actions (Powell 1990). Initially developed and implemented in Finland and Sweden, the regional innovation systems approach has gained increasing momentum across OECD countries, which are adapting several core constructs in nationally and regionally specific ways.[1] Though there is substantial variation in the form that these systems take in different national and regional contexts, regional innovation policies typically emphasize the following:

- The development of spatial agglomerations of firms and knowledge bases and linkages to global knowledge networks in a system of open innovation;
- Spatial and organizational proximity between the process of knowledge exploration and exploitation;

[1] In Finland, the regional innovation systems approach was originally pioneered by the Science and Technology Policy Council, now renamed the Research and Innovation Council, and by TEKES, and in Sweden, by VINNOVA, the Swedish Governmental Agency for Innovation Systems (Asheim 2012).

- global excellence in basic research and knowledge exploration and
- the crucial role of institutions in promoting emerging industries (Asheim 2012)

In the context of the ‘policy push’ to support and facilitate the innovation process, universities play a crucial role in regional innovation systems, and facilitating knowledge transfer has become a ‘third mission’ after teaching and research. Feldman and Kogler (2008: 446) argue that we should take a more expansive view of university contributions, not reducing universities “to a simple factor of production” but instead recognizing them as a multifaceted “creative force in the economy.” Famously exemplified by Stanford and MIT, ‘entrepreneurial universities’ fulfil a range of functions in regional innovation systems, spinning-out high-tech firms, consulting to local industry, delivering policy advice and informing general public debates, providing highly trained and educated graduates for regional and national labour markets, licensing new technologies, bringing global state-of-the-art science and technology and researchers into the region, and forming networks and stimulating social interaction and learning, thereby developing regional innovative capacity and supporting regional economic growth (Salter and Martin 2001; Lockett et al. 2005; Breznitz and Feldman 2010).

Research-intensive universities play an important role in promoting the economic growth of city-regions through the production of basic and applied research, the generation of tacit and codified knowledge, and the development of highly qualified and skilled personnel. For firms, linkages with universities have measurable impact on their bottom line. For example, Loof and Brostrom (2005) find that income from the new product sales is considerably greater for firms that have joint research projects with universities than for non-collaborating firms. In addition to access to new ideas and fresh perspectives on challenging and complex problems, a recent survey of firms in the U.K. reveals that the primary reasons that firms engage with U.K. universities is to obtain access to facilities, enhance workforce training, augment technological capability, diversify through the development of new products, and recruit graduates (Her Majesty’s Government 2009). Firms with particularly robust ties to universities regularly recruit qualified R&D personnel, participate in joint research projects such as doctoral dissertations, have access to customized training courses, research results, R&D infrastructure and university patents and licenses, improve their corporate image through cooperation with PSE institutions, gain indirect access to competitors’ know-how’, and to public funding conditional upon collaborative ties with a university (Arvanitis et al., 2005).

Yet the perceived role of the university as an engine of regional economic development and a driver of technological innovation has led to misguided and inflated expectations regarding the contribution these institutions should make in advancing economic growth in their local city-regions (Florida, 1999; Florida and Cohen, 1999; Florida, 2006). Consequently, universities should more accurately be seen as “catalysts” of technological innovation, stimulating and increasing the production and flow of knowledge which is an integral part of the innovation process (Doutriaux 2003). This more nuanced understanding of the university’s role in the innovation process and efforts at regional economic development “emphasizes the interactive and social nature of the knowledge transfer process and the importance of tacit dimensions of knowledge" (Bramwell and Wolfe 2008: 1176). In this respect, universities are "agents" of economic growth because of the important role they play in producing knowledge through basic and applied research; generating, attracting and leveraging research and creative talent; and advancing critical mechanisms of knowledge transfer for uptake and innovative application by firms, which in turn creates economic value within the city-region (Douglass 2005; Ghafele 2011; Apax Partners 2011). Ryan and Ghafele (2007) assert that "[u]niversities are much more than the depositories of various knowledge islands" and embody the "'know how' and 'know why' institutions in any healthy knowledge economy", a core competency that is difficult for firms to replicate. Furthermore, although "it is not the primary purpose of the university to generate commercially relevant knowledge, but to provide novel perspectives on established views", Ghafele (2012) argues that university-generated knowledge managed through deliberate knowledge transfer mechanisms is "the ultimate source of competitive advantage in the marketplace".

Universities and Regional Innovation Systems

Though the mechanisms of knowledge transfer are similar across regional economies, individual universities differ in the way they contribute to the regional innovation systems in which they are located. Active participation in the local economy is, in many ways, a matter of the individual policies pursued by different institutions. Based on a study of university contributions to local innovation in 22 different locations in six countries, Lester (2005: 3) argues that

> the 'one-size-fits-all' approach to economic development pursued by so many universities, with its focus on patenting, licensing, and new business formation, should be replaced with a more comprehensive, more differentiated view of the university role. Universities need a stronger awareness of the pathways along which local industries are developing and the innovation processes that are associated with those pathways.

Focusing on the regional knowledge impact of universities[2], Uyarra (2008) identifies a typology of universities in relation to their impact on regional innovation systems, highlighting how these different roles are influenced by different economic, structural, organizational, institutional, and political factors and manifested in multiple mechanisms and scales of engagement.

- For the university as *Knowledge factory*, the main role of the institution is to produce scientific knowledge, the primary unit of performance assessment is innovation outputs, institutional engagement with industry tends to be implicitly unidirectional, and the key factors influencing impact are research intensity and outputs, geographical proximity and industry sector.
- For *the Relational university*, the main role of the institution is the exchange of knowledge, the primary unit of analysis is linkages, institutional engagement with

[2] As opposed to the 'expenditure' impacts of universities through employment and purchasing of good and services.

industry tends to be implicitly bi-directional, and key factors influencing impact are the size, maturity, R&D intensity and openness of participating firms, the overlap between technical field and industrial sector, and the level of scientists' research excellence and experience.

- For the *Systemic University*, the institution's main role is boundary-spanning, the primary unit of analysis is systems and networks, the directionality of institutional engagement is the "triple-helix" between university, industry and government, and key factors influencing its impact include regional system configuration, regional policy, and the institutional capacity of universities.
- In contrast, the *Entrepreneurial University's* primary role is explicitly focused on active commercialization, the primary unit of analysis is intermediaries such as industry liaison offices and technology transfer offices, institutional engagement is explicitly bi-directional, and key factors influencing institutional impact are organizational structures, managerial practices, and faculty behavior and incentives.
- For the *Engaged University*, the primary focus of the institution is on its developmental role, that main unit of analysis is the spaces of governance in which the university participates, the directionality of engagement is responsive, and key factors influencing impact are the number and synergies between universities, university leadership, and joined up policies and institutional and policy incentives.

Needless to say, these categories represent something of an ideal type and are not necessarily mutually exclusive. It may be possible to find examples of different universities that combine elements of more than one typology or to find some variation within a specific institution in terms of how its various units interact with the regional and local economy.

The subsequent discussion focuses on 'entrepreneurial' and 'engaged' types of universities as they are the most explicitly engaged in bi-directional and relational forms of knowledge transfer activities, and therefore most directly relevant to this discussion of university-industry knowledge transfer. The 'entrepreneurial' or 'engaged' university is becoming a key descriptor of universities focused on commercialization through the establishment of spin-offs, patent generation, and the licensing of technology (Etzkowitz, Webster, Gebhardt, et al. 2000). These types of universities focus their knowledge creation and transfer capabilities to enable conversion to commercial and industrial utilization, and aid firms in the region by consulting and conducting applied (often contract) research and by providing laboratory facilities and expertise for firms looking to augment their own capabilities (Friedman and Silberman 2003). Perceived as critical enablers or 'animateurs' of regional development, engaged and entrepreneurial universities embed a stronger regional focus in their missions which are delivered in conjunction with broad-based coalitions of state and non-state actors. For these embedded universities, there is a greater focus on adaptive responses to regional needs, which also implies a greater alignment between the different functions of the university and trajectories of regional development. This regional focus of engaged universities is "embedded in all the key functions: promoting social inclusion and mobility, providing a base for skill development and stimulating innovation through basic science research" (Charles 2006: 14). Rather than being 'bounded' by the region in which they are located, however, engaged universities are seen as complex organizations, nested within national policy frameworks, and trying to link processes occurring at different levels and to integrate the teaching, research and community elements of university regional engagement (Charles 2006).

The University of Waterloo is an exemplary entrepreneurial university in Canada, highly committed to advancing its region's innovation agenda and contributing to local economic development. This institution has been described as "a critical catalyst" in advancing the region's innovation efforts "through its ability to generate and attract the talent that underpins academic and applied excellence in science, math and engineering, support for local firm-based R&D, and its explicit institutional support for entrepreneurial activity at the local level" (Bramwell and Wolfe 2008: 1176). The university's success in the production of new ideas, the flow of knowledge and technology transfer is attributed to the robust linkages it has established with local and non-local firms in areas of exceptional growth potential like ICT, environment and energy, health informatics, and software engineering. Its capacity for generating and attracting talent to the region is leveraged by a strong Cooperative Education Program that provides students and firms with an ideal interface for developing new ideas, sharing knowledge, skills development and training, facilitating entrepreneurial activities and engaging in social learning. Overall, the Co-op program underscores the importance and impact of "the reciprocal nature of student-embodied knowledge transfer" in advancing the Waterloo region's innovation agenda (ibid.: 1182). In addition, the university's innovative Intellectual Property policy, which grants full ownership of IP to the creator, encourages faculty researchers and/or students to commercialize their ideas.[3] According to Bramwell and Wolfe (2008), this IP policy initiative and the university's Co-op program have driven the establishment of a large number of high profile start-ups and spin-offs in the region – developments that contribute directly to growth and innovation in the local and regional economy.

Knowledge Transfer Mechanisms

A multi-dimensional conception of the knowledge transfer process is consistent with the view of universities as engaged key players embedded in that process underpinning successful regional innovation systems. A brief overview of the different activities, services and incentives that advance the university-industry knowledge transfer process provides an informative backdrop to the more detailed discussion of international policy and practice that follows. There is a wide range of mechanisms that facilitate knowledge transfer between universities and industry.

Geiger (2010: 11) provides a helpful table that summarizes the range of corporate-university research relationships:

[3] University of Waterloo, "UW IP Policy #73", Established October 28th, 1997, University of Waterloo Secretariat, Waterloo, Ontario.

Individual Projects	**Institutional Links**	**Personnel**
Contract research, deliverables	Collaborative Research in Consortia	Internships for students
		Programs to support faculty
Unrestricted grants	Participation in Federal Centers	Graduate student support
Straight licensing	Partnerships or Alliances	
Sponsored research projects	Satellite Laboratories	
Faculty consulting		
Material transfer agreements		

However, new firm formation in the form of spin-out and start-up companies, licensing, contract research between firms and university researchers, and researcher mobility between academia and industry are the most common mechanisms for knowledge transfer.

Spin-outs and start-ups are the university-industry knowledge transfer mechanisms that have attracted the most policy attention. Because new technologies may not be easily patented and universities may not be able to capture the full value of their technology through licensing agreements, universities and individual researchers often seek more direct involvement in the commercialization process by spinning-out a company. However, considerable debate surrounds the effectiveness of spin-out strategies. Breznitz and Feldman (2010: 8) argue that the proximity of university spinoffs to their university of origin increases the contribution of the spinoff to the local economy and therefore that the creation of local spinoff companies is "the most direct way for universities to contribute to economic development" (see also Holly 2012; Holly et al. 2011). Spin-offs stimulate local economic growth by producing innovative products that satisfy customer demand, generating jobs, particularly for high educated people, and attracting investment in the development of university technology.[4] In contrast, Lockett et al. (2005) argue that most university spin-outs do not generate significant wealth and those that do often have little impact on the regional economy because they tend to be focused at national and international levels. Nonetheless, while start-up companies may not provide the university with large financial returns, Lockett et al. (2005) concede that they still generate high skilled employment opportunities, and that high profile spin-outs encourage entrepreneurial activity by other academics.

[4] According to the Association of University Technology Managers, or AUTM, annual survey, between 70 percent and 80 percent of all university start-ups are headquartered in the same state as the university from which they spun out. Between 1980 and 1999, university start-ups in the United States created $33.5 billion in economic value, at an average of $10 million per start-up and by 2007, 3,388 university start-ups were still operational. In 2009, at least 596 start-ups based on university licenses were created across the country, and 658 new products were introduced to market (Association of University Technology Managers, "AUTM U.S.Licensing Activity Survey, 2009, http://www.autm.net/Surveys.htm.). Other studies view the creation of a high technology cluster on Route 128 in Boston and Silicon Valley in California as a direct result of university spinoffs from MIT and Stanford (Saxenian 1994; Shane 2004). Similarly, the ''Cambridge Phenomenon'' in Cambridge, UK is considered a direct result of technology transfer from the University of Cambridge (Segal Quince Wicksteed 1985; Segal Quince Wicksteed 2000).

In the effort to commercialize a new technology, Lockett et al. (2005) observe that licensing to an existing corporation, rather than spinning-out, has traditionally been the more popular mode of university technology transfer. Licensing does not, however, benefit all universities uniformly and factors that influence the productivity of university licensing include the quality of faculty research, the size and capability of technology transfer organizations (TTOs) within the university, and the incentive mechanisms designed for academic scientists.[5] Hughes (2011: 437) argues that spin-offs and licensing are among the least frequent forms of university–industry interaction in comparison with "people-based interactions" through recruitment, consulting and contract-based research which are "most frequently developed and mediated through informal, softer relationships, which permit a reflexive relationship between basic and applied research" (see also Agrawal and Henderson 2002).

Consulting and contract research, which occurs when a firm contracts with a university researcher to conduct R&D on its behalf, are other widely used mechanisms for establishing R&D collaboration between universities and firms. These types of projects tend to involve applied research rather than fundamental research and the R&D is typically bound by explicit contracting between parties whereby tacit academic knowledge is codified upon transfer, or a researcher contracts with a firm to develop an idea for commercialization. Firms benefit from knowledge that can generate profit and improve the skills and knowledge base of its scientific workforce and universities gain income to fund basic research, access to star scientists, and employment and research opportunities for graduate students. Similar to contract research, hiring academics as consultants typically involves interaction between the academic and industry or government to find the best and most appropriate solution to a particular problem. Consulting is particularly beneficial to universities, as academic consultants generate income and build linkages with the business community on a local, national, and international scale, which not only increases the relevance of knowledge generated in a university, but also helps industry researchers enrich their conceptualization of research questions and approaches (Lockett et al. 2005).

Other important knowledge transfer mechanisms include graduate student and faculty researcher mobility back and forth between industry and academia, the joint use of university technical infrastructure such as common laboratories, and firm access to academic publications and other codified forms of knowledge diffusion such as conferences and workshops (Cohen, Nelson and Walsh, 1994).[6]

[5] According to Apax Partners (2011), net licensing income flowing to US universities topped US$1.3bn in fiscal year 2003, and UK universities reaped licensing income worth 22.4m pounds (US$40m).

[6] In their study of Swiss firms, Arvanitis et al. (2005) found that more than 50% of knowledge and technology transfer firms find informal, personal contacts to gain general information on technological opportunities coupled with educational activities to be the most important forms of knowledge and technology transfer with universities.

Dynamics Supporting Successful Local University-Industry Linkages

Much of the literature on the role of universities in regional innovation systems emphasizes the relational nature of knowledge exchange and the importance of social learning processes facilitated by local networks. According to this view, a smoothly functioning innovation system is characterized by an intensive set of networks and relationships which generate a continuous flow of information and exchange of knowledge between the components of the subsystems (Wolfe et al. 2011a). The critical role of universities to regional economic development therefore underscores the value of understanding the dynamics and factors that support the development of networks and other mechanisms to facilitate linkages between university and industry. Several institutional factors and policies serve to build university capacity to respond to the continually changing R&D and knowledge requirements of local firms, build the absorptive capacity of local firms to make use of this knowledge, and build the human capital and intellectual property that underpins local knowledge flows.

Building the capacity for universities to respond to the changing R&D demands of local firms

There are several dimensions to the process of building institutional capacity to respond to the knowledge and R&D demands of local firms. First, policies need to be developed at an institutional level that will support the development of an entrepreneurial culture and willingness to cooperate with industry. Sonka and Chicoine (2004) suggest that the universities must establish organizational strategies that align with and support the goal of facilitating university-industry knowledge transfer and linkages and explicitly seek to contribute to technology-based regional economic development. Senior leadership of the institution dedicated to innovation, entrepreneurship and establishing linkages with local industry are responsible for generating and implementing these types of institutional strategies, allowing researchers to respond to opportunities as they arise (Thorp and Goldstein 2010). Second, by developing and sustaining links with local businesses, community-based organizations, and governmental authorities, universities can also improve the balance between labour market supply and demand in knowledge-intensive industries by acquiring labour market information and developing programs to meet local labour market needs (OECD 2007).

Third, universities also create programs to support institutional entrepreneurship, which is increasingly enabled by deregulation of research and knowledge activities and the granting of more decision-making authority and flexibility to universities to respond to the demands of the changing environment. The OECD (2007: 122) observes that “new legislation has opened the way to regional co-operation with firms and made it possible for universities and polytechnics to align their research portfolio to regional demand, especially in advanced regions” and that this deregulation “reduces limitations and disincentives for higher education staff to work on joint projects with firms”. Geiger and Sá (2008) observe that in the effort to strengthen partnerships with industry, American universities have made major changes to their departments and curricula, created more interdisciplinary research, and expanded teaching opportunities within science-based fields of study.[7] Notably, new organizational structures such as research centres and institutes have been established to facilitate university-industry partnerships and new strategies for hiring faculty in the most prolific boundary-crossing science-based disciplines. Universities have also begun to employ aggressive business model tactics for advancing science-based research such as procuring resources from corporate partners and fostering the flow of knowledge and talent between industry and academia. For example Arizona State, Cornell, the University of Wisconsin at Madison and the University of Albany have built robust collaborations with major corporate partners, bridging science-based disciplines more closely to regional needs and economic development (Geiger and Sá 2008).

Fourth, Oosterlinck (2001) argues that in order to build the capacity to respond to the R&D and knowledge needs of local firms, universities must find and balance the right mix of mechanisms and processes to support knowledge transfer. These include a system to manage and monitor contract research in the area of industrial innovation which provides the necessary know-how and processes for legal, financial and human resources management to meet the volume of research contracts generated by the university, and an active knowledge management policy that enables the institution to screen for novelty and inventiveness, determine a discovery's economic potential and to eventually support researchers to write patent and claim structures.

Building the absorptive capacity of local firms

Responding to the R&D needs of local firms only makes sense if local firms have sufficient capacity to make use of the new knowledge that is being generated. The strength of local university-firm partnerships is conditioned by the firm's ability to build an internal knowledge base and research capacity to effectively capture and deploy the knowledge acquired from universities and other research institutes – this constitutes the firm's "absorptive capacity (Cohen and Levinthal 1989). High absorptive capacity is therefore a precondition for cooperation between firms and research intensive universities (Arvanitis et al, 2005, 6). The overlap between the outside knowledge and the firm's knowledge base heightens the potential for reconfiguration and/or augmentation of the firm's stock of knowledge and increases the likelihood that this knowledge would be applied towards the development of a new or improved product, process or practice. Firms with high levels of "absorptive capacity" are more likely to engage with local universities and other research institutions, and these collaborative local partnerships facilitate the flow of tacit and codified knowledge from universities and other research institutes to firms.

[7] For example, the Stanford Technology Ventures Program was developed in the mid-1990s by Tom Byers for the Stanford School of Engineering – it offers a curriculum on entrepreneurship (Thorp and Goldstein, 2010, 49) STVP plays a large role at Stanford University in educating future scientists and engineers about high-technology entrepreneurship. STVP believes that in addition to technical skills, students need to know how to identify market opportunities and to take leadership roles in business. To meet this goal, we offer introductory courses, and advanced courses, such as entrepreneurial marketing, finance, strategy, and innovation. http://stvp.stanford.edu/teaching/

This in turn increases the potential for creating economic value through the creative application of that knowledge.

In order to encourage greater university-industry collaboration and improve the absorptive capacity of firms to benefit from the knowledge transfer process, firms and universities need a shared understanding of how research contributes to market innovation in companies. On one hand, because the absorptive capacity of companies is a crucial variable in determining the value that can be secured from using university research in company innovation processes, universities need to improve their understanding of company absorptive capacity as a function of their relationships with firms that seek to apply their research. On the other hand, firms require their own internal capacity to understand and value how academic knowledge could benefit them, as well as the relevant management processes for individuals to secure the internal commitment and resources needed to participate in projects. In addition, a culture of open innovation as well as staff who are capable of working with academic researchers is required for the firm to get the maximum benefit from its relationship with the university (Ternouth et al, 2010). Absorptive capacity includes the ability of the partners to collectively recognize the potential for using university research outcomes in business; localize the research outcomes to the company context and specific business needs, commit the necessary resources to embed the localized knowledge as an intellectual asset of the company, and develop the systems to evaluate and commit resources to a project and diffuse and exploit the results throughout the business (Ternouth et al, 2010).

Building human capital

In addition to its role as a generator of new knowledge, universities shape, supply and diffuse the human capital that supports regional innovation. As Howard (2005: 122) observes, "undergraduates and graduates have become key players as individual researchers, development engineers, technical leaders, and entrepreneurs" and as faculty researchers and students flow to industry and start-ups, "they provide an effective form of technology transfer". Of particular significance is the university's contribution to local entrepreneurial activities. Universities attract students who will create significant wealth later in their careers whether they end up working for local leading edge firms or start-ups, or founding companies based on university IP. Entrepreneurs who found start-ups often locate their companies close to their alma mater and employ technical graduates from the university. University training also supplies firms with workers who have important research skills; university graduates are capable of accessing scientific research in their field to solve problems (Apax Partners, 2011).

Intellectual Property policies

Another key factor supporting successful local university-industry linkages is the development of effective institutional intellectual property (IP) policies. Corbin (2010) argues that technology transfers from universities to the commercial sector are more likely to take place as orderly economic transactions contractually protected by IP rights. A key aspect of successful policies is the creation of rights that allow intellectual property owners to control access and use. According to Corbin (2010), the challenge for policy makers, therefore, is to find the optimal balance between incentives to create IP (including protection rights) and incentives to diffuse IP to local firms. Geiger (2010) emphasizes the importance of finding the right mix of incentives and suggests that if universities became more flexible about their IP policies, industry would be more open to collaborating. Effective policies also need to address "the practicalities of implementation", including the obligations of participants and mechanisms for sharing and trading of IP. Finally, because many academics know little about IP and its economic relevance, Ghafele (2012) suggests the need for IP entrepreneurship and awareness raising programs, as well controlling transaction costs associated with the transfer of IP by using online IP exchanges, fostering IP brokerage and IP fairs. While IP policies typically fall under individual institutional responsibility, however, because of their critical importance to knowledge transfer and the innovation process, intellectual property rights are highly complementary to other components of national innovation policy cannot be considered in isolation of the country's broader innovation strategy" (Corbin 2010: 21).

Venture Funding

Finally, successful university-industry knowledge transfer, particularly in the form of entrepreneurial start-ups, requires access to early stage funding. While venture capitalists make critical contributions to supporting local university-industry linkages by providing important sources of financial support and expertise, most tend to be more interested in short-terms gain on an investment and few are willing to take on the risk of investing at the embryonic research stage. Nordfors et al, (2003: 13) contend that today's venture capitalists have become too risk averse, tending to focus on the later stages of technology development which has resulted in a "widening and deepening of the 'Valley of Death' between public funded long-range basic research and industry-financed product development." As a result, a steady stream of predictable and sustainable government funding programs and incentives, especially for specialist early-stage capital or seed funding, is needed to fill this crucial gap (Apax Partners, 2011; Rasmussen et al, 2006). Government funding mechanisms bridge the structural financing gap at the heart of university technology transfer, and these mechanisms are particularly important due to the propensity for larger venture capital firms to avoid making investments in early-stage research (Apax Partners 2011). According to the OECD (2007), incentives that include long-term core funding as well as additional strategic funding schemes are critical for supporting successful local university-industry linkages in the form of joint research with firms, the provision of services to SMEs and the promotion of enterprise formation, and funding linked to regional priorities that support collaborative research should be made available.

Challenges to University-Industry Knowledge Transfer in Canada

According to the European Commission (2007: 6), knowledge transfer involves "the processes for capturing, collecting and sharing explicit and tacit knowledge, including skills and competence" as well as "both commercial and non-commercial activities such as research collaborations, consultancy, licensing, spin-off creation, researcher mobility, and publications". The ability of universities to play a critical role in regional economic growth depends on the way they interact with firms to transfer knowledge, while the challenge for firms is how to monitor the scientific knowledge that universities generate, and how to effectively deploy that knowledge to solve their practical problems. Mismatches in these dynamics present several important barriers to the university-industry knowledge transfer process. According to Bruneel et al. (2010), these barriers to university-industry collaboration are either related to orientation-related barriers that refer to differences in the primary missions of universities and industry, or to transaction-related barriers that refer to conflicts over intellectual property and university policies and regulations. In this context, several barriers to university-industry knowledge transfer are evident in Canada.

'Cultural Divide' Between University and Industry

One of the key challenges to university-industry collaboration is conflicting views of the purpose of research. University researchers tend to select topics that are viewed by their peers as interesting and valuable and that they can publish through the peer review process. In contrast, firms are interested in developing new products and services and tend to see the long-term orientation of university research, potential conflicts over intellectual property, and rules and regulations imposed by universities or governments as the key barriers to collaboration. The collision of these two different world-views, or attitude orientations, can lead to insurmountable conflict during research partnerships leading to an inability to pursue research collaborations fully. Firms and universities are managed with different logics and objectives and while market efficiency is the key driver for firms, higher education institutions have a focus on the provision of knowledge and training. Many firms, especially those without knowledge and technology transfer activities, assume that their R&D questions would not be of interest to academics, while many academics operate under the assumption that the research interests of universities do not correspond to the presumably more application-oriented interests of business (Arvanitis et al., 2005, 12). Similarly, Pavitt (2003) discusses "organizational cultural differences" as a major problem complicating university-industry collaborations, and reports that because the natural pace of activity tends to be slower for universities, managers often complain that universities operate on extended time lines and demonstrate little regard for the urgent deadline of business, which acts as a deterrent especially to smaller entrepreneurial firms unused to such arrangements.

Absorptive Capacity Differs According to Firm Size

Another challenge facing university technology transfer in Canada is the lack of receptor firms that have sufficient capacity to make full use of university-generated research or to work collaboratively with Canada's strong network of public research institutes. Recent reports from the Council of Canadian Academies (2009) and the federal Science, Technology and Innovation Council (2009) have documented the low levels of business expenditure on research and development (BERD) in Canada as a major impediment to the operation of the Canadian innovation system and a critical contributor to Canada's low level of productivity performance. The lack of firm-based R&D restricts their potential to adopt and use the intellectual property resulting from university-based research.

The constraints on firm interaction with universities also differ by firm size. Smaller firms cite time, resource, and staffing constraints to collaboration more highly than larger firms which tend to have dedicated research staff and enter into university-industry collaborations more frequently (Arvanitis 2005).[8] Large firms with over 1,000 employees are the most likely to collaborate with universities and other public research institutes because most of these firms are already engaged in R&D activity sometimes via contracting research activity and have therefore successfully built a capacity to absorb and utilize public-generated research (Douglass 2005; Cohen, Nelson and Walsh 1994). The predominance of SMEs in the Canadian economy constitutes a particular challenge for the dissemination and commercialization of university based research because small and medium-sized enterprises have fewer linkages to universities, are slower to adopt new technologies, and less likely to invest in research and development. While Currie (2011) also finds that large firms in Canada are more likely to collaborate with a university than small firms, he argues that policy makers need to focus on encouraging collaboration between smaller firms and universities because small firms are found to be more innovative per dollar of R&D.

Knowledge Flows Vary According to Sector

In the process of developing policy initiatives to improve university-industry linkages, policy makers must consider that firms in certain sectors will more readily engage in R&D collaborations with universities than firms from other sectors. Furthermore, providing policymakers with insight on how different sectors of industry use university research, should help with the establishment of policies and programs for funding innovation that reflect and support a more nuanced understanding of a region's university-industry interface. Instances of successful university-industry technology transfer in some industrial sectors have ushered in ground-breaking discoveries and innovations with economic impact at local, national and in some cases, international levels. Hughes (2011) reports that engineering technology, business

[8] For example, a study comparing industry-university R&D collaborations in 11 European regions identified the positive correlation with firm size and R&D intensity as the most important common feature among these different regions (Fritsch (2002) cited in Arvanitis (2005)).

and financial studies, and mathematics and computing provide fertile ground for university-industry knowledge and technology transfer activities, while according to Laursen and Salter (2004), firms in sectors related to chemicals, machinery, and electrical equipment most commonly engaging in collaborative university research. Geiger (2010) isolates different patterns of industry utilization of academic research and different degrees of university-industry collaborations in the U.S. across the four sectors of "big pharma" and biotechnology, electronics and computing, materials, and the military-industrial-academic innovation system. However, Howard (2005: 123) observes that "connecting the academic research base with the industry", even in sectors that lend themselves particularly well to knowledge transfer, remains both "an ongoing challenge, as well as a potentially important opportunity." For example, Cohen, Nelson and Walsh (2003) observe that university research in the U.S. had little direct effect on industrial R&D outside of a few technologies such as drugs, other areas of medicine, sophisticated organic chemical products and some areas of electronics.

The biotechnology sector has demonstrated particular success with university-industry technology transfer. According to DeVol et al. (2006), Harvard ranks 1st in terms of biotech research as measured by papers and citations, followed by University of Tokyo and University of London, nine of the top ten biotech patent holders are at U.S. universities, one out of every five nanotech patents stems from the University of California system, and MIT is first in outcome measures including factors such as licensing income and startups. Numerous factors, including academic culture, human capital, and public policy constraints to industry dynamics influence the success of university biotech transfer. The absorptive capacity of the surrounding region also has a significant impact on the success of a university's biotech commercialization efforts. Ultimately, DeVol et al (2006: 22) conclude that even though "advances in bio- and nanotechnology promise further improvements in health, quality of life, and economic performance", and a more complete understanding of the technology transfer process is needed to "accelerate the pace at which such benefits reach society at large" there is "no single model for tech transfer success". As a result, DeVol et al. (2006) argue that policymakers should continually review the policies of other competitive nations, establish consistent and transparent policies that recognize the importance of IP protection and that encourage entrepreneurial capitalism and minimize the social and economic implications associated with failure.

Weak Tech Transfer Mechanisms

Another challenge to the transfer university research to industry lies in the commercialization of university generated research. University-industry technology transfer mechanisms include technology transfer offices in universities, research parks affiliated with universities, university-industry consortia, research institutes and centres of excellence, regional development organizations, and a greater emphasis on the promotion of spin-off firms. These mechanisms perform a wide range of functions, including the negotiation of industrial research contracts, the identification of opportunities for university research in the marketplace and the facilitation of licensing or patenting of research results or the spin-off of new firms (Geiger 2004; Geiger and Sá 2008). The commercialization of intellectual property (IP) in the form of licensing of new firm start-up activities is typically overseen by university staff in technology transfer offices (TTOs) located within academic institutions. Over the last two decades, TTOs have grown in number, size, and cost. In 2006, approximately 20 per cent of the TTOs had more than fifteen professionals (AUTM, 2006). The financial returns from TTOs vary significantly, but the most successful have gross returns of between $20 million and $60 million, while most have returns under $5 million (Kenney and Patton, 2009, 1410).

TTOs are critical intermediaries in the commercialization process but are often viewed as inefficient and under-resourced, and their staff is perceived to lack experience in managing commercialization efforts. Lacking a true home in the academic structure, they are treated like auxiliary enterprises and expected to pay their own way and are often under resourced (Geiger and Sa). Kenney and Patton (2009: 1411, 1419) underscore the fact that, "simply put, a badly managed [technology licensing office] can impede technology transfer". TTOs operating in an under-resourced, under-staffed or disadvantaged position in the institution "can foster ineffective decision-making, unreasonable demands" and negatively affect the willingness of firms to collaborate with the university for the purposes of tech transfer. A study of the knowledge transfer activity between high and low research intensive U.K. universities determined that universities with clear strategic priorities aimed at intensifying knowledge transfer had higher rates of knowledge transfer activities compared to institutions with an adequate capability to undertake knowledge transfer through a TTO Hewitt-Dundas (2012). Therefore, if the rate of knowledge transfer is to be increased, universities must embrace knowledge transfer as a strategic priority, and this priority must be aligned with the institution's broader goals and objectives.

Part II - Key Policies and Programs to Facilitate University-Industry Knowledge Transfer and Commercialization

Because many government sources of funding for R&D require matching funds from the private sector, academic institutions have begun to pursue more active linkages with industry, and "the university-industry relationship is growing more complex and entwined" (DeVol et al. 2006). There is a growing tendency to analyze the strengths and vulnerabilities of the university technology transfer process to maximize its contribution to the commercialization process and ensure the greatest possible return on public investment. Yet while university knowledge transfer is the most influential factor increasing opportunities for technology commercialization, this does not occur uniformly across industrial sectors and regions (Breznitz and Feldman 2010). Emphasizing variation in knowledge transfer activities, Breznitz and Ram (2011) argue that universities are located in specific geographic environments and historical contexts, which shape their ability to commercialize technology. Consistent with findings about the wide variation and context-sensitivity of university knowledge transfer activities, (Breznitz and Ram 2011) argue that it is dangerous to adopt models that have worked well in other national jurisdictions without paying careful attention to the institutional context in which they operate and how well they may be adapted to fit different national or regional contexts. Because "there is no silver-bullet method suitable for university technology transfer everywhere", it is critical to analyze how a variety of other factors influence university capacity to advance technology commercialization (Breznitz and Ram 2011:13).

As the considerable body of research generated by the Innovation Systems Research Network demonstrates, the distinctive regional realities of the Canadian innovation system require policy solutions that are tailored to the capabilities and needs of those distinctive regions (Wolfe et al, 2011a). The emphasis here is on identifying key policy initiatives and best practices relevant to the role of universities in the technology transfer process in other places in order to draw insights about the formation of collaborative networks between university researchers and industry, mechanisms that facilitate technology transfer, and the role of intermediaries in supporting the knowledge receptor capacity of industry to inform national and regional policy efforts in Canada. This section of the paper provides a brief review of international best practices in commercialization and technology transfer, followed by a more detailed discussion of subnational knowledge transfer policies in Canada and elsewhere with the intention of highlighting potential models and relevant policy lessons for Canadian policymakers. This includes an assessment of institutional and public policies as well as managerial practices that can yield new insights for reforming existing policies and creating new mechanisms for supporting academic entrepreneurship (Grimaldi et al. 2011; Hughes 2011).

Policy initiatives operating at supranational, national, regional, university and corporate levels support the development of university-industry linkages, and policymakers at all levels devote substantial resources to encourage university spin-off activity (Yusuf 2007).[9] Rasmussen et al. (2006: 519) distinguish between 'top-down' government initiatives and 'bottom-up' initiatives which emerge from within universities, and between formal policy initiatives and more informal arrangements which often play "an even more significant role". Rasmussen (2008) argues that government initiatives can encourage 'bottom-up' institutional innovation by providing resources for direct use in commercialization projects or to develop professional expertise in technology transfer in the university sector. This section traces the interaction effect between government policy and individual institutional innovations operating at national and sub-national levels operating in Canada and other OECD countries.

National Innovation Policies and Programs

With the U.S., Germany, France, and several East Asian countries in the lead, national governments across the OECD are increasing the number and impact of policies to promote

[9] Funding agencies such as SBIR[9] in the US, OSEO[9] in France and Sitra and Tekes in Finland are examples of these types of initiatives.

university research and encourage university-industry linkages (UILs). National and subnational governments are the “principal architects of the national innovation strategy” because they “set the parameters for higher education, and…craft the incentive mechanisms as well as the institutions that influence business decisions regarding where to locate, what to produce, how much to spend on research, and the degree to which firms link up with universities in developing technologies” (Yusuf, 2007: 15). In other words, national higher education and innovation strategies set the stage for the emergence of UILs by determining the amount and distribution of expenditures on tertiary education and research across institutions, what disciplines benefit from increased funding, what financing arrangements research institutions have and how much autonomy they enjoy.

National strategies in countries as diverse as the U.S., Australia, the U.K., and Canada exemplify an increasing activism in higher education and innovation policy. Australia has been particularly active, and its 2009 strategy document, *Powering Ideas – An Innovation Agenda for the 21st Century* identified seven priority areas including the intention to double the level of collaboration between Australian businesses, universities and publicly funded research agencies over the next decade and to encourage international collaborations on research and development (Commonwealth of Australia, 2009). A companion strategy from the Department of Education, Employment and Workplace Relations, *Transforming Australia's Higher Education System*, announced the introduction of a new Joint Research Engagement program to “give greater emphasis to end-user research by encouraging and supporting collaborative research activities between universities, industries and end users” (Currie, 2011: 222). In Canada, the federal government's 2007 Science and Technology (S&T) Strategy, *Mobilizing Science and Technology to Canada's Advantage*, sets out a comprehensive, multi-year science and technology agenda that targets research funding to the four priority areas of environmental science and technologies, natural resources and energy, health and related life sciences, and information and communications technologies. Part of the strategy articulates the government's commitment to encouraging S&T collaborations between business, academic, and public sectors.[10] Each of these strategies seeks to reinforce national competitiveness by supporting the development of regional innovation systems and specialization in regional universities and typically involves measures to encourage collaboration among universities, local industry, local government, research centres, and NGOs, and often to develop specialized education programs targeted to regional economies.

Innovation Policy and Programs in the EU, the US and the UK

The US and the UK are two of the national contexts that often provide the closest comparators for Canada, and policymakers often look to the European Commission for new approaches to innovation policy. Examples of several key programs are briefly reviewed here. The European Commission encourages member states to actively promote and support the pooling of resources

[10] http://www.ic.gc.ca/eic/site/ic1.nsf/eng/00871.html Accessed on March 9, 2012.

among research institutions and has created a trans-European network of *Innovation Relay Centres (IRCs)* to facilitate transnational technology transfer. Based in 33 countries, IRCs provide customized assistance for university-industry partnerships, with a special focus on SMEs. Providing close collaboration for smaller universities and firms with a leading European university knowledge transfer association has created "a simple and effective system which allows universities to share information on new, commercially relevant technologies in a structured manner with companies across Europe" (European Commission, 2007, 9).

Two particularly salient examples of innovative approaches to university-industry knowledge transfer in the EU include the EU Drivers Project and the European Institute of Innovation and Technology. Funded under the European Commission's Lifelong Learning Program, the *EU-Drivers Project* is designed to improve regional cooperation between universities, private sector companies and local governments to enhance the innovation capacities of European universities.[11] Another recent example is the European TTO CIRCLE, a network of tech transfer offices at Europe's 25 largest public research organizations that have joined forces on technology transfer with the aim of increasing the market and societal impacts of publicly-funded research. European TTO CIRCLE members have committed to boosting innovation in Europe through a set of initiatives including: fostering the use of their knowledge portfolio; sharing best practices, knowledge and expertise; performing joint activities; establishing informal channels of communication with policymakers; organizing training programs; and, developing a common approach towards international standards for the profession of technology transfer.

Despite its highly fragmented and decentralized institutional structures supporting innovation, the U.S. is commonly regarded as the most innovative knowledge-intensive national economy in the world. Sonka and Chicoine (2004) find that federal agencies and university administrations employ quite variable operating and funding mechanisms, and while the same approach is unlikely to work as well in other national contexts, they suggest that this fragmentation or "messiness" may be the 'secret sauce' for U.S. comparative advantage in the global, knowledge economy. Although the fragmentation no doubt remains, it is also evident that the federal government in the U.S. has begun to place increasing importance on advancing the technology transfer and commercialization process.[12]

Commencing with the Bayh-Dole Act in 1980 that removed restrictions on the universities ability to patent research results developed with federal funding and encouraged universities to become more active in managing the patenting and licensing of their intellectual property, the federal government has established several other programs directly relevant to the role of

[11] For more info on EU-Drivers project:
http://www.oecd.org/document/38/0,3746,en_21571361_45834904_46841638_1_1_1_1,00.html and http://www.esmu.be/eudrivers.html

[12] For example, In 2011, President Barack Obama issued a Presidential Memorandum entitled "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses" that articulated the importance of innovation to the American economy and the intentions of the US government to actively advance the technology transfer and commercialization processes (White House 2011a).

universities in the technology transfer and commercialization process.[13] The *Small Business Administration* (SBA) serves as the coordinating agency for several of these programs including the *Small Business Innovation Research* (SBIR), the *Small Business Technology Transfer* (STTR), and the *Federal and State Technology* (FAST) programs. Established in 1982 to facilitate the absorption of new technology by small and medium-sized enterprises, the SBIR program provides research support and funding to small firms, and often provides an important signal to venture capital funds of the commercial potential of the projects (Branscomb and Auerswald 2001). The STTR program provides joint venture opportunities for small businesses and non-profit research institutions, but requires small firms to formally collaborate with a research institution; while the FAST program strengthens the technological competitiveness of socially and economically disadvantaged small businesses to improve the participation of small technology firms in the innovation and commercialization of new technology (Holly, 2010). In addition, the *Partnerships for Innovation (PFI)* program managed by the National Science Foundation supports regional economic development through knowledge transfer from universities, focusing on smaller institutions to broaden participation in the innovation process. The PFI acts as an umbrella for two complementary programs that each focus on different stages but are both concerned with the movement of academic research into the marketplace: the *Building Innovation Capacity* (BIC) program emphasizes the commercialization of knowledge created by universities and the *Research Alliance Competition* (RAC) program emphasizes the commercialization of activities emerging from NSF-funded research alliances.[14]

The UK government's aim is to make the UK "the most attractive place in the world to start and invest in innovative technology companies" and to make the UK Government "the most technology friendly in the world". The shift in policy emphasis toward university-industry technology transfer in the late 1990s introduced a number of programs to facilitate the exchange.[15] Most notably, the Higher Education Funding Council for England (HEFCE) established a *Higher Education Reach-out to Business and the Community Fund (HEROBC)* in 1999, which was subsequently incorporated into the Higher Education Innovation Fund (HEIF)

[13] The Bayh-Dole Act has been discussed at length elsewhere. For a more detailed discussion see Mowery et al. (2004) and Kenney and Patton (2009).

[14] A research alliance is defined as a research partnership formed for mutual benefit, and funded by NSF, between/amongst universities and other entities. The number of estimated awards for both programs is 22, and the anticipated total funding is $15million, subject to the availability of funds and quality of proposals received. Awards for the BIC may be up to $600,000 with a duration of two years, and for AIR may be up to $800,000 with an award duration of up to two years.

[15] The 1998 White Paper from the Department of Trade and Industry, *Our Competitive Future: Building the Knowledge Driven Economy* emphasized the importance of strengthening and exploiting university research capability. The 2000 White Paper in 2000, *Excellence and Opportunity: A Science and Innovation Policy for the 21st Century*, outlined proposals for investing in the science base and stimulating strong links with universities to ensure that excellence in science and engineering was translated into innovative products and services. Most recently, the *Blueprint for Technology* outlines a number of new policy measures including efforts to attract entrepreneurship to the UK, an Entrepreneur Visa program which aims to link viable business ideas with UK investors, an independent review of the intellectual property framework, and a new 'peer to patent' system which draws on expertise on a global basis to maintain patent quality.

to provide core funding to help universities implement organizational and structural arrangements to develop strategic approaches to their relations with business and to improve the transfer of knowledge and skills (HEFCE, 2000). Funding is awarded on a formula-driven basis and granted according to individual university performance in commercialization activities, as well as wider regional economic and cultural engagement. This expanding regional role is also evident in the engagement of universities in local and regional economic partnerships and strategies, the proliferation of science parks and incubation facilities linked to universities, university presence on regional science and industry councils in England, and most recently in their shaping of 'science cities' in a number of English regions (Uyarra, 2008).

Building on the policy orientation to S&T outlined in the *Science and Innovation Investment Framework 2004-2014*, the *Department for Business Innovation and Skills (BIS)* has a mandate to promote the transfer of knowledge generated and held in higher education and public sector research institutions to the wider economy. Among the knowledge transfer funding programs administered by the BIS, the *UK's Earlier Knowledge Transfer Scheme* is notable for its intention to address shortfalls in key areas related to knowledge transfer and the commercialization process. These include *the University Challenge Seed Fund* that provides seed funds for commercialization; the *Science Enterprise Challenge Fund* to establish a network of centres in UK universities, specialising in the teaching and practice of commercialisation and entrepreneurialism in the field of science and technology; and the *Training for Knowledge Transfer Practitioners* program, a one-off initiative to address the lack of suitably trained knowledge transfer professionals in universities and public sector research institutions. The BIS also funds the *Technology Strategy Board* (TSB) which operates as a business-led executive non-departmental public body and administers a number of programs that strengthen university-industry linkages. Similar to Canada's Centres of Excellence for Commercialization and Research (CECR) program and the Business-Led National Centres of Excellence, these programs in the UK include Knowledge Transfer Partnerships (KTP), Knowledge Transfer Networks (KTNs), Collaborative R&D, SMART grants, and Catapult Centres.[16]

[16] *Knowledge Transfer Networks* are national networks in a specific field of technology or business application which brings together people from businesses, universities, research, finance and technology organizations to stimulate innovation through knowledge transfer. *Collaborative research and development* (R&D) is designed to assist the industrial and research communities to work together on R&D projects in strategically important areas of science, engineering and technology, and by June 2007 a portfolio of over 600 projects was being supported with a combined business and Government investment in excess of £1 billion. The *SMART* program offers funding to small and medium-sized enterprises (SMEs) to engage in R&D projects in the strategically important areas of science, engineering and technology, and supports R&D projects. Finally, *Catapult Centres* (formerly known as technology and innovation centres or TICs) focus on a specific technology where there is a potentially large global market and a significant UK capability. These centres are expected to become an important part of the UK's innovation system and make a major long-term contribution to UK economic growth by allowing businesses to access equipment and expertise that would otherwise be out of reach, supporting them to conduct their own in-house R&D by accessing new funding streams, and orienting them towards emerging technologies.

National Innovation Policy and Programs in Canada

Canada also has a number of federally funded programs targeted to developing new partnerships between academia and industry, strengthening existing university-industry linkages, and intensifying knowledge flows and technology transfer. Canada's granting councils, *The National Science and Engineering Council (NSERC), the Social Sciences and Humanities Research Council (SHHRC), Canadian Institutes of Health Research (CIHR),* along with the *Canada Foundation for Innovation (CFI)* each have mechanisms to encourage knowledge and technology transfer. For example, NSERC's *Strategy for Partnerships and Innovation (SPI)* outlines a four point strategy that includes initiatives to build sustainable relationships, streamline industry access to NSERC sponsored research, facilitate human capital development, and address national innovation challenges, and intends to more than double the number of firms participating in NSERC innovation-focused programs over five years. It includes a suite of targeted partnership programs designed to help companies find highly-qualified people, advance R&D, and build relationships with scientists and engineers in universities and colleges across the country. The *Industrial Research Chairs* program seeks to intensify academic excellence, bolster university-industry collaboration and increase knowledge transfer between academia and the private sector, and to help build critical mass in research fields that have not yet been developed in Canadian universities but for which there is an important industrial need. It also provides an enhanced training environment for graduate students and postdoctoral fellows by exposing them to research challenges unique to industry and the opportunity for significant ongoing interactions with the industrial partners. CIHR's *Research Commercialization Programs* fund initiatives that aim to support the creation of new knowledge, practices, products and services in the health sciences and to facilitate the commercialization of this knowledge through research commercialization projects such as proof of principle projects, which encourage collaboration between academia and industry in the promotion and support of the commercial transfer of knowledge and technology resulting from health research.

The *Network of Centres of Excellence (NCE)* program has attracted international attention as a precedent-setting model for connecting research and development to national economic and social well-being. The NCE program invests in networks and centres that stimulate leading-edge research in areas of importance to Canada, build on national and international partnerships, develop and retain world-class research capabilities and create innovative knowledge and technology transfer opportunities and mechanisms. *The Centres of Excellence for Commercialization and Research (CECR)* program is one of several NCE initiatives aimed at strengthening university-industry linkages in areas of national strategic importance by helping bridge the gap between innovation and commercialization. CECR supports the operating expenses and the commercialization activities of research centres in the four key areas of the environment, natural resources and energy, health and life sciences, and information communications technologies. For example, the Centre for the Commercialization of Regenerative Medicine (CCRM) is a CECR Centre hosted by the University of Toronto, supporting the development of foundational technologies that accelerate the commercialization of stem cell- and biomaterials-based products and therapies. The focus of the CCRM is to allow its members to address the barriers faced by the Canadian regenerative medicine industry, such as the licensing of early-stage technologies to companies outside of Canada before their market value is realized. CCRM signed its first industrial partnership agreement in early 2012, a $500,000 project with EMD Millipore, the Life Sciences division of Merck KGaA to produce large quantities of stem cells for clinical trials by translating two-dimensional culture methodologies into a three-dimensional format.

There are also some examples of cross-agency collaboration to facilitate research-driven innovation. NSERC, SSHRC, CFI, the National Research Council (NRC) and the Canada Excellence Research Chairs program have created the Automotive Partnership Canada (APC), an initiative to provide $145 million in research funding over five years to support collaborative and transformative R&D activities to help the Canadian automotive sector achieve a higher level of innovation. Projects are industry-driven and aligned with strategic research themes. Broad competencies and state-of-the-art facilities throughout its 20 institutes enable the NRC to conduct research in a wide variety of fields that impact automotive technologies, such as advanced materials, manufacturing, information and communication, alternative fuels and aerodynamics. Through NRC Automotive, a special NRC initiative, the agency is investing $30 million over five years in APC. NRC Automotive places particular emphasis on research that brings proof-of-concept technologies closer to commercialization and provides validation and demonstration of the applicability for actual use on vehicles. In addition, at least one Canada Excellence Research Chair (CERC) chair will be allocated to research that is of direct benefit to the automotive industry.[17]

Subnational Policies and Programs

In addition to national policies and programs, a number of subnational authorities, whether provincial, regional, county, or municipal, have introduced policies to support the development of regional innovation systems by enhancing the role of universities in the technology transfer and commercialization process. Kitagawa and Woolgar (2008) argue that these subnational policies and the increasing regional governance of science and innovation are evidence of "an on-going process for harnessing multi-level partnerships and multi-actor spaces, and networking for local economic development". However, the extent to which regional governments can harness universities for local and regional economic development depends on the university's location, research, and cluster generating potential (Yusuf 2007). While there is no optimal

[17] The Canada Excellence Research Chairs (CERC) is a new program that will strengthen Canada's ability to attract the world's top researchers and develop research programs in the four priority research areas noted in the Government of Canada's Science and Technology (S&T) Strategy. Up to 20 Research Chairs will be awarded throughout the country and each chair will receive up to $10 million over seven years to conduct research in areas of strategic importance to Canada.

policy mix as yet, Yusuf (2007: 14) has identified a "small handful of policy tools" that subnational governments can use to support university-industry linkages including:

- research grants for specialized research facilities with links to local business;
- intermediary organizations or industrial extension agencies to link university researchers and firms, especially small firms that have difficulty accessing and using research;
- alliances between university research departments and firms using regional or national bodies as intermediaries;
- state or quasi-state agencies can provide venture capital for university spinoffs;
- finance incubators that offer the university supplementary research funding contingent on consulting contracts;
- serviced land and infrastructure adjacent to universities to attract firms, to subsidize the training of industrial workers and to extend tax incentives to firms that locate there.

In this context, the following section provides a brief review of selected subnational innovation policies and programs in the US, Europe, and Canada. In various efforts to emulate the success of regions such as Boston's Route 128, Austin's Silicon Hills, and California's Silicon Valley, Sonka and Chicoine (2004) observe that state governments have individually and collectively instituted policies and programs to exploit research universities as drivers of innovation and high technology-based economic growth. For example, the National Governors Association (NGA) report, *Investing in Innovation*, reflects the increased emphasis on universities as key drivers of knowledge generation and partners with industry (Geiger and Sa, 2008). The NGA's involvement in advocacy for federal policy changes to support the development of regional approaches to innovation underscores the important role of state governments in setting laws, funding education and research, leveraging federal funding and advancing university-industry knowledge flows.

Numerous initiatives in individual states encourage university-industry collaborations, a few of which are mentioned here. According to Geiger and Sa (2008), *California* has one of the most extensive and well-resourced state policies for linking academic research and economic development, and supports numerous public and private sector driven programs to support university-industry linkages. For example, Walshok (2002) highlights the high levels of intellectual capital, the vast business and financial networks, and the breadth and depth of the advanced skills and knowledge of the human capital that underpin innovative success in the San Diego region.[18] In 1990, the Georgia Research Alliance (GRA) was created to enable the business community and universities to forge a permanent cooperative arrangement with the

[18] Driven by the policy entrepreneur Richard Atkinson, The University of California at San Diego formed CONNECT, a downstream operation focused on increasing the contribution of UC research to the California economy, and the ability of The California Institutes for Science and Innovation to create large scale research institutes for university-industry collaboration in science-based fields. Other initiatives include the Energy Biosciences Institute and the California Institute for Regenerative Medicine (CIRM), and state support for Discovery Grants that strengthen the University of California's links with industry.

state to make investments in scientific capacity and infrastructure, enhance university-industry interactions and to improve collaboration among the state's universities. Georgia's Centers of Innovation program provides intermediary organizations that tailor their approaches to the characteristics of their locales and the targeted industries. Because it was initially a less engaged and less supportive state government, *Arizona* faced more challenges in launching technology-based approaches to economic development, but around 2000 consensus began to emerge among the state's political, business and higher education communities around the importance of investing in research and technology to stimulate economic growth, and legislation was passed that gave universities considerable responsibility. The 2002 Bioscience Roadmap identified research strengths in Arizona and Science Foundation Arizona, a coalition of three regional industry associations dedicated to advancing research and commercialization in the state, was subsequently established to award $35 million in state funding allocated to support research and infrastructure in the biosciences. Through a combination of deliberate planning, public investment, and private sector support, Phoenix was established as a bioscience hub by 2007.

Provincial and Regional Innovation Policies in Canada

Canadian provinces have also developed a number of strategies, programs and policies that support university-industry linkages. An exhaustive account is beyond the scope of this review but a few illustrative examples are briefly mentioned here. Ontario has an elaborate system of programs that support university-industry knowledge flows and the technology transfer and commercialization process. The majority of these programs operate under the purview of the Ministry of Economic Development and Innovation (MEDI), while a smaller proportion is administered by other ministries, including the Ministry of Agriculture, Food and Rural Affairs (OMAFRA). For example, MEDI's $161-million Life Sciences Commercialization Strategy, launched in 2010, coordinates new and existing life sciences initiatives to facilitate the commercialization of bio-medical research and technologies by attracting and supporting top scientific talent, facilitating greater university-industry collaboration, and improving international marketing and promotion activities. Three key initiatives of the strategy include: support to commercialize genomics research ($114.6-million GL^2 fund); support for the medical and assistive devices sector ($21.4-million HTX-administered fund); and support for early stage Ontario biotechnology companies ($7-million MaRS-administered fund).

Quebec's *Research and Innovation Strategy* includes initiatives such as financial assistance to university researchers for research training in an industrial context, support for proof of concept centres and university development corporations, the introduction of incubation vouchers to enable businesses to draw on the services of technology incubators, and financial support for technology transfer organizations (Government of Québec, 2010: 7). In Alberta, the Alberta Innovates-Technology Future organization administers a number of programs that promote public and private sector collaboration and support knowledge and technology transfer across several industries including the *Alberta Biomaterials Development Centre* (ABDC); *Centres for*

Research & Commercialization which provide collaborative university-industry research hubs in the energy and environment sector; *nanoAlberta* devoted to R&D in nanotechnology; and the *Alberta Regional Innovation Network System*. Similar to the Ontario Regional Innovation Centres program, the Alberta Regional Innovation Network system is an integrated province-wide system that coordinates Regional Innovation Networks that provide entrepreneurial SMEs access to services and supports on a geographical basis.[19]

Facilitating technology transfer to local firms: The role of intermediaries

A wide range of innovation support organizations bridges the gap between the demand and supply sides of the regional innovation system, playing crucial roles in the acquisition and diffusion of technological ideas and know how. These may include technology centres, technology brokers, business innovation centres, and other organizations in the higher education sector which facilitate the interface with the private sector and mechanisms for financing innovation, such as venture capital firms (Nauwelaers and Reid 1995). These intermediaries facilitate the transfer of knowledge between those who generate it and those who use it—in this case, between universities and local industry. Some see the role of intermediaries as primarily a linear one, to fill information gaps and "pair up universities with firms which may be interested in receiving specific assistance" (Nabeshima 2005). Others see the purpose of intermediaries as broader than simple technology transfer, and also see the creation of enduring linkages and "the founding of structures and dynamics" as important intermediary functions (Smedlund, 2006). The demand pull approach differentiates between the effect of macro, meso, and micro level intermediaries on the regional knowledge system, and emphasizes that the mission of a local intermediary is to serve local firms by establishing contacts, arranging networks, and offering resources, as well as to "make the region attractive for entrepreneurs and allure anchor tenants to the region" Smedlund (2006: 218). Patry and Moorman (2012) point out that although leading countries have "built intermediary research organizations according to their own institutional traditions and cultures", they share a number of similar characteristics. Although some of these organizations are too new to fully assess their impacts, there is an emerging consensus that they are successful in helping improve private sector innovation. Several examples of technology transfer intermediaries are outlined below.

Technology and Innovation Centres (TICs)

Technology and Innovation Centres (TICs) are increasingly seen as critical intermediary organizations that deliver governmental and public sector programs, policies and strategies to promote innovation. The Hauser Report in the U.K. provides an international comparison of TICs in the 12 countries of Germany, South Korea, Sweden, France, China, Denmark, USA, Japan, Singapore, Israel, Belgium, and the Netherlands and finds that although their roles within

[19] http://www.albertainnovates.ca/programs.aspx Accessed on March 14, 2012

their respective national innovation systems differ, they each make important contributions to national and regional innovation (Hauser 2010). Undertaking a wide variety of activities, TICs conduct basic and applied research from the initial discovery phase to industrial development for commercialization, support innovation in SMEs by providing knowledge, equipment and applied research, provide technical and commercialization services to both large and SME firms, and contribute to the development of a highly skilled workforce.

Based on its review of the role of international research institutes, the Hauser Report recommended the establishment of a network of applied research institutes or TICs to act as an elite, business-centred innovation and research system focusing on sectors where the U.K. has existing research and industrial capability that it can leverage for substantial economic benefit (Hauser 2010). TICs are intended to bridge the gap between basic university research and the market commercialization of new technologies, helping to bridge the commercialization gap, or 'valley of death' by translating new research findings into the early stages of commercialization and making technologies investment ready. Although organizations of this type already existed in the U.K., the Hauser Report argued that they lacked national focus and that new ones needed to be created in key sector areas. Finally, the report recommended that the government should establish the new TICs in locations that enhance existing facilities and leverage research excellence and industrial capability and capacity to absorb new innovations (Hauser 2010).[20]

Combining complex formal governance structures with autonomous sub-units, the German model of Fraunhofer Institutes is often referred to as one of the most successful example of a national network of TICs, leading to "an ability to rapidly and flexibly set up expert networks" (Hauser 2010: 12). Just over 60 years old, the Fraunhofer Gesellschaft (Society) is a central element of Germany's innovation system, mandated to increase the competitiveness of German industry by promoting the use of new technologies. Government funding is shared by the federal government and the Länder, with funds received from industry R&D contracts matched by the governments (Council on Competitiveness 1992). Today the Fraunhofer Society has over 80 research units world-wide, including 60 institutes in Germany, and employs approximately 18,000 people, primarily scientists and engineers, with a budget of approximately €1.65 billion (Fraunhofer 2011), with more than two-thirds of that funding coming from contract research. As Patry and Moorman (2012: 66) argue, "the singular devotion to using research for economic benefit and intense customer service orientation" are defining features of Fraunhofer institutes that could be incorporated in a Canadian model.

In Belgium, stand-alone organizations operate at the interface between university-based research and applied R&D. The Inter-University Micro Electronics Centres (IMEC) in Belgium was created in 1984 and is a non-profit, independent research focusing on microelectronics in the

[20] The recommendation to establish intermediate knowledge translation centres was bolstered by the 2010 Dyson report, *Ingenious Britain: Making the UK the Leading High Tech Exporter in Europe* which suggested the establishment of a new set of centres of excellence in research fields of strategic economic importance that would provide space for interaction, promote the movement of staff between university and industry, and house expensive equipment of importance for a particular sector that were beyond the resources of a particular firm or university.

ICT, healthcare, and energy sectors. Like other applied research institutes, IMEC sits between university and industry, conducting research that is applicable to industry. IMEC is perhaps best known for its work on scaling down semiconductors and improving their energy efficiency (IMEC 2010). The main objectives for IMEC is to conduct scientific research that is 3 to 10 years ahead of industry's needs in microelectronics design and technology within the ICT realm, and to strengthen the industrial ecology in Belgium in microelectronics (Helleputte and Reid 2004). For IMEC to accomplish its mission, the organization requires clear insight into the needs of industry, a particular challenge in ICT where the time-to-market is extremely rapid, and also required an international focus in order to create the necessary knowledge linkages and to connect to industry. To help build a regional innovation ecosystem, IMEC began focusing on technology transfer activities, particularly the incubation of spin-off firms based on IMEC-produced intellectual property (Helleputte, et al. 2004; Moray and Clarysse 2005).

Other examples of the TIC model described in Arnold et al. (2007) include:

- SINTEF (Norway) exists to use applied research to drive industrial development in a country where industry's absorptive capacity was historically low but has now increased substantially. Established by academia, it maintains close linkages with the university system, especially in Trondheim.
- GTS network, translated as Authorized Technological Service Institutes (Denmark) are designed for an SME economy, where services such as measurement and certification are still a major part of industrial demand for knowledge services. GTS institutes have their origins in a mixture of institutions set up by industrial organisations, research associations and testing establishments.
- VTT, Technical Research Centre of Finland, is a combination of both a 'technology push' research focus in the style of SINTEF and a more 'test and services' tradition, in an economy that has recently become highly research-intensive but that otherwise has more in common with the resource-based economy of Norway than with the comparatively advanced manufacturing economy of Sweden. VTT is also among the institutes that has a defence component.
- TNO's (Netherland), Netherland's Organization for Applied Scientific Research origins are in a number of small advisory organisations providing 'industrial extension services' and evolved from there into a 'technology push' institution whose capabilities also include defence.
- Arsenal Research, part of the ARC group, (Austria) is a combination of various test and measurement house that have been merged and that are moving into applied research.

Applying the TIC Model in Canada

Although various institutions in Canada, such as CRIM and CRIQ in Quebec, perform some of the functions of the TICs, there is a clear need for a more formalized mechanism to coordinate these events in the Canadian context. Because they focus on the practical benefits of research and create conditions whereby individual companies with specific needs can easily instigate research and develop innovative technologies, Patry and Moorman (2012: 65) strongly advocate for the creation of Canadian innovation centres “where academic researchers and the private sector come together to collaborate – a cooperative undertaking that could be a catalyst for improving [Canada’s] productivity.” In their overview of TIC-like initiatives in other countries like the USA (California), Germany, Finland, Australia and the UK, they argue that TICs can act as innovation hubs, drawing together researchers and business leaders, entrepreneurs and IP experts, and technicians and students without compromising investments in fundamental discovery-driven research.

Patry and Moorman identify two key characteristics that TICs share in common: the research agenda for the centres is determined through a collaborative process between academic researchers and private sector companies; and each centre has a physical location that serves as the focal point for dynamic interaction and collaboration (2012). They suggest that Canada has integrated the first characteristic in the Centres of Excellence for Commercialization and Research (CECR) program. The key to its emerging success, and the success of the international examples, is a governance model that ensures a balanced approach to tapping into the research expertise of the academic participants and incorporating and focusing research activity on the knowledge needs of the individual companies. In terms of the second characteristic, they argue that,

> . . . by bringing research infrastructure and participants together in a single location, the centres could provide a focal point where companies have access to the talent and specialized equipment that is often beyond their reach, and where researchers and graduate students are exposed to the entrepreneurial culture of business. These centres would also facilitate the exchange of tacit knowledge that is crucial to collaborative success (Patry and Morrman 2012: 68).

Reflecting on the potential for developing Canadian TICs, and citing existing research and university-industry capacity in marine technologies and resource management in Atlantic Canada, aerospace in Quebec, digital technologies and new media in the Waterloo region, automotive technologies in southern Ontario, the biochemical industry in Sarnia, uranium mining in Saskatchewan, oil extraction in Alberta and green energy and building systems in British Columbia, Patry and Moorman contend that there are significant resources and industrial expertise on which to build, and that Canada only needs to coordinate and structure its enormous inventive capacity to increase productivity. Anticipated benefits of developing Canadian TICs to encourage engagement between world-class researchers and specific companies include the more effective use of tax expenditures to directly support innovation; job creation by providing the private sector access to talent, equipment and infrastructure that they could not otherwise afford; mitigating risks involved in developing commercially unproven technologies; and establishing anchors for community economic development (2012).

Centres of Excellence and Competence Centres

Specialized Centres of Excellence emerged in the 1980s with the establishment of engineering research centres in the US, interdisciplinary research centres in the UK, and collaborative research centres in Australia. These Centres of Excellence are now ubiquitous and highly favoured by governments as a particularly effective intermediary technology transfer mechanism (Rip 2011). These centres are sustainable largely because of the growing market for strategic research, as well as increased direct support for research excellence by funding agencies and independent sponsors. Centres of excellence can be located in universities, whether pushed by special funding schemes or emerging in their own right, or can be created separately, with contributions from various actors (government agencies, industry, universities). For example, in the US, Engineering Research Centres (ERCs) created in the 1980s to foster greater university-industry collaboration are co-sponsored by the National Science Foundation, universities and indust ry. The ERCs were designed to develop basic knowledge in areas critical to the competitiveness of U.S. firms in world markets by concentrating on research areas of major industrial importance that cut across disciplinary boundaries. Close to 80 per cent of the firms participating in ERCs reported that their primary reason for joining the ERC was to gain access to new ideas generated by the centre and only 15 per cent reported that the ability to license inventions and/or software was a motivating factor in their decision to participate. The most commonly reported benefits included access to new ideas, know-how and technologies through interaction with the ERC (Feller, Ailes, and Roessner 2002, 462–64).

Through the ARC Centres of Excellence in Australia, a high level of collaboration occurs between universities and other organizations on a national and a global basis. Originally established in 2001, the funding commencing in 2011 for ARC Centres of Excellence is intended to support innovative and potentially transformational research that aims to achieve international standing in targeted fields of research, link existing Australian research strengths and build critical mass with new capacity for interdisciplinary, collaborative approaches to address the most challenging and significant research problems. Other objectives include building networks with major national and international centres and research programs to help strengthen research, achieve global competitiveness and gain recognition for Australian research, build Australia's human capital by attracting and retaining researchers of high international standing as well as the most promising research students, provide high-quality postgraduate and postdoctoral training environments for the next generation of researchers, offer Australian researchers opportunities to work on large-scale problems over longer periods of time, and establish Centres of such repute in the wider community that they will serve as points of interaction among higher education institutions, governments, industry and the private sector generally (Currie, 2011).

In Canada, Centres of Excellence operate at both federal and provincial levels with the national Networks of Centres of Excellence of Canada (NCE) and the Ontario Centres of Excellence (OCE) programs. The Ontario Centres of Excellence in particular administer three initiatives that facilitate technology transfer to local firms:

- *The Technology Transfer Partnerships program* is delivered through four program components that strengthen linkages between public research institutions and industries in the local economy.[21] The program also helps translate public research institution discoveries to market-ready discoveries and promote the exchange of knowledge and ideas between researchers and the wider economy to help the academic community better understand market realities.[22] Ontario Technology Transfer Network partners include C4, MaRS Innovation, Ontario Partnership for Innovation and Commercialization (OPIC) and the Rideau Commercialization Network (RCN).
- *The Centre for the Commercialization of Research (OCE-CCR)* is a Centres of Excellence for Commercialization and Research (CECR) Centre[23] created in 2008 by Networks of Centres of Excellence of Canada (NCE) with a grant of $15M for 5 years. The purpose of the CCR is to build on the OCE model to help establish stronger Canadian companies, accelerate speed to market of products and services, develop sustainable regional partnership models and commercialization networks, and adopt exemplary practices from around the world (Thomas, 2009). The CCR assists early stage firms and their management teams, offering advice on issues such as management, marketing, technology (intellectual property) strategy, product development and financing. The CCR seeks to become a "trusted catalyst" that brings regional players together, positions itself at the intersection of academic and industrial interests, and can draw on the strength of its vast networks to access new research, assess the viability of the business plans and tap sources of support and partnership.[24] To date, 75 patents have been filed and in 2010-2011, OCE-CCR supported the development of 11 start-up companies.[25]
- Funded by the Province of Ontario, *The Industry-Academic Collaboration Program (IACP)* is designed to leverage the full capacity of Ontario's research institutions in order to help technology-based companies create jobs and economic growth by commercializing Ontario-based research discoveries. Under IACP, Ontario Centres of Excellence (OCE) offers a suite of programs and services that serve researchers, entrepreneurs and high-potential companies who have strong potential for commercial success. Through IACP, OCE seeks to build a world-class knowledge and technology transfer network for Ontario's public research institutions, leverage more value from provincial investments in research and innovation through effective technology transfer

[21] These four program components include Technology Transfer Network, Institutional Proof-of-Principle (IPoP), Colleges Ontario Network for Industry Innovation (CONII), Knowledge Exchange.
[22] http://www.oce-ontario.org/programs-services/technology-transfer-partnerships Accessed on March 12, 2012.
[23] *The Centres of Excellence for Commercialization and Research Program (CECR)* is one of several NCE initiatives aimed at strengthening university-industry linkages in areas that are of strategic important to Canada. CECR creates centres to advance research and facilitate commercialization of technologies, products and services in four key areas: environment, natural resources and energy; health and life sciences; and information communications technologies.
[24] http://www.oce-ontario.org/about-oce/centre-for-commercialization-of-research-(ccr)/how-it-works
[25] http://ar-ra.nce-rce.gc.ca/ByTheNumbers/CECR/KnowledgeTranslation-ValorisationConnaissances_eng.asp

networks, and make use of the full capacity of public research institutions to support industry-driven commercialization activities. IACP programs are divided into three main components: Collaborative Commercialization Programs support industry-academic collaborations; Talent Programs support the development of entrepreneurial and business skills; and Technology Transfer Partnerships support technology and knowledge transfer and proof-of-principle technology demonstrations.

Innovation and Commercialization Centres, Business Incubators, and Accelerators

There are numerous examples of commercialization centres and business incubators and accelerators operating in Canada. For example, jointly funded by the governments of Ontario and Canada and established by PARTEQ Innovations, the technology transfer office of Queen's University in 2009, the *GreenCentre Canada* brings together academic researchers and industry partners to develop clean, less energy-intensive alternatives to traditional chemical products and manufacturing processes, providing a range of commercialization services to develop early-stage technologies to meet specific industry needs. Consisting of industry members who assess and validate technology opportunities, commercialization managers with experience in chemistry and materials innovation, and scientific teams in catalysis, fine chemicals/pharmaceuticals, polymers and materials and petrochemicals, the Green Centre is self-described as "an all-in-one commercialization 'ecosystem' that includes everything from technical and market assessment, scale-up and testing to intellectual property protection, business management and financial resources".[26]

The Ontario government has pledged $15-million over three years to the *Ontario Brain Institute* to stimulate collaborative research on the frontiers of neuroscience. The goal of the initiative is to make Ontario a brain science hub, bringing researchers from across the province together and to help them commercialize their discoveries related to products that treat patients with brain diseases and disorders, including Parkinson's, autism and schizophrenia (Globe and Mail, Nov 15, 2010). Through the OBI, Ontario is expected to be better positioned "to galvanize [the neuroscience sector] and facilitate partnerships between industry and academia in a new collaborative effort aimed at mobilizing scientific knowledge and improving access to technology platforms that support commercial development" in the areas of pharmaceuticals, medical devices, diagnostic and non-pharmacological interventions. Private sector partners working with OBI are also focused on developing a cluster of specialized firms in southern Ontario to exploit the full potential of the research sponsored by OBI.

Many Canadian universities are also establishing business incubators focused on students. For example, Ryerson University's Digital Media Zone, located in the heart of downtown Toronto is currently incubating 32 firms and has expanded twice in the past two years to accommodate the growing demand for its service. The Zone offers numerous resources, such as StartMeUp, a program created by Students In Free Enterprise (SIFE Ryerson), that nurtures entrepreneurial

[26] http://www.greencentrecanada.com/about-us/

ideas by giving new business creators information and advice on business planning, presenting, funding, patents, marketing and more. The University of Toronto is currently developing plans for its own incubator in Phase II of the MaRS building which is currently under construction. Similarly, the Ontario College of Art and Design recently unveiled its new *Imagination Catalyst*, "a student and alumni-centred entrepreneurship and innovation incubator/accelerator" designed to aggregate the institution's existing innovation, research, and commercialization activities. By placing students and alumni and their inventions in receptor industries and by supporting the efforts of graduating students, recent graduates, and faculty members in developing new companies, the Imagination Catalyst is expected to strengthen and integrate OCAD University's current and future industry collaborations with faculty and students in applied research and commercialization.[27]

The University of Winnipeg also announced the creation of UWIN Inc., a commercialization incubator that leverages existing campus research resources and infrastructure. This wholly owned for-profit subsidiary of the University of Winnipeg will allow it to generate revenue from third parties that may wish to use, for example, the CISCO Telepresence systems or other resources on campus, and will also allow for the commercialization of university research such as medical isotope production. One of the factors driving the strong interest in strengthening commercialization capacity is the recognition that the University's portion of income from those commercial ventures would provide a third stream of revenue, in addition to tuition fees and government grants, to assure the University's long-term financial viability.[28]

As home to over 50 technology start-up companies, with resident program staff of Ontario Centres of Excellence, National Research Council IRAP and Communitech, Waterloo's *Accelerator Centre* has become a key centre for the local innovation community. The Accelerator Centre along with the Ontario Centres of Excellence and the University of Waterloo technology transfer commercialization office (WatCo), are partners in the Accelerator for Commercialization Excellence (ACE) which works closely with other commercialization entities such as Communitech to provide seamless access to commercialization resources for start-ups, entrepreneurs, and investors in the Waterloo Region.[29] Communitech (2011) categorizes the Accelerator Centre as an "enabling organization", a necessary element in innovation ecosystems.

In November, 2009 the Ontario government also announced plans to invest up to $26.4M (24 per cent of the $107M project) in Kitchener to create the Communitech Hub: Digital Media and Mobile Accelerator, bringing the combined federal and provincial total to $31.4 million. The Hub, which opened in October 2010, provides an attractive location in the heart of the region for entrepreneurs, companies and academic institutions to interact in a 30,000 square foot state-of-the-art roof. Among the many features of the Hub are the immersive 3D H.I.V.E (Hub

[27] http://www.ocadu.ca/about_ocad/articles/news_releases/20120228_imagination_catalyst.htm Accessed on March 8, 2012.
[28] http://www.uwinnipeg.ca/index/uw-news-action/story.756/title.encouraging-commercial-opportunities-through-uwin-inc Accessed on March 8, 2012.
[29] http://www.acceleratorcentre.com/about

Interactive Virtual Reality Environment) provided by Christie Digital, one of the key private sector partners, 3D-capable event space, and virtual conferencing facilities. In addition to Christie, the Hub has also representatives from some of the larger firms in the region, including RIM, Open Text and Agfa. Through a wide range of programs administered by Communitech, the Hub's mission is to build global digital media by mentoring tenant start-ups, creating linkages with more established companies in the region, and helping secure financing for digital media ideas. The facility has space to accommodate more than 100 digital media start-ups and Communitech is already working with more than 200 start-up firms in the region through its Executive in Residence program and mentoring activities. The Hub also contains separate facilities to house students from the University of Waterloo's VeloCity program, its entrepreneurial residence program, side by side with the other companies being incubated in the facility (Knowles 2011).

Case study of a key intermediary: the MaRS Discovery District

The MaRS Discovery District, located adjacent to the University of Toronto and major downtown teaching and research hospitals, is driven by the demand-pull model of tech transfer, conducting market research for young companies, providing incubation and business advisory services, linking to the relevant industry leaders, and connecting emerging companies (many of which are affiliated with publicly sponsored research hospitals and universities) to the local and international angel and venture capital communities (Treurnicht, 2008, 28). The MaRS Discovery District houses several technology transfer programs, most of which are funded by the federal government and the Government of Ontario.

As a Centres of Excellence for Commercialization and Research (CECR) funded by the federal government, *MaRS Innovation* (MI) is the official commercialization agent for the intellectual property generated in the areas of therapeutics, medical devices and diagnostic imaging, information and communications technologies, and advanced manufacturing and clean technologies by its 17 members.[30] Located within the MaRS Discovery District, MaRS Innovation taps into the $1 billion of annual research and development in Toronto's growing research hub, though it remains a separate, not-for-profit organization with an independent mandate, board of directors and staff. MaRS Innovation is designed to build linkages between Toronto's academic, health care and research communities to support the development of a health sciences cluster, enabling MaRS Innovation to bundle research assets together, from both a scientific and business perspective, while keeping the individual integrity of the IP intact.

[30] Members include: Baycrest Centre for Geriatric Care, Centre for Addiction and Mental Health, Holland Bloorview Kids Rehabilitation Hospital, MaRS Discovery District, Mount Sinai Hospital, OCAD University, Ontario Institute for Cancer Research, Ryerson University, St. Michael's Hospital, Sunnybrook Health Science Centre, The Hospital for Sick Children, Thunder Bay Regional Research Institute, University Health Network, University of Toronto, Women's College Hospital, York University. Accessed on March 3, 2012: http://www.marsinnovation.com/

The commercialization process involves several steps. Members send their research disclosures to MaRS and after MaRS Innovation has chosen the most commercially promising discoveries from the hundreds of submitted prospects, it attracts investors interested in these technologies. MI then establishes an agency agreement between itself and the member organization for the commercialization of a specific discovery, ensuring that institutional intellectual property policies are compatible. A "deal team" is formed of the member's Technology Transfer Office, the inventor or discoverer, and MaRS Innovation which may bring on experts in product development or regulatory matters. Where it makes scientific and business sense, MI will bundle compatible discoveries together from across their membership with the purpose of creating a bigger and potentially more viable prospect for investors, for example in the area of imaging technologies. MI also manages and funds the process of patent filing and issuance, develops a business case for the intellectual property, and undertakes project planning on its commercialization. The organization also finds funding to bridge the technology gaps to strengthen the discovery's business case. Once these steps are completed, MI proceeds "aggressively" to promote the discovery to appropriate investors when discovery is "most ripe" for investment.[31]

MaRS Innovation has helped launch seven companies so far[32], including VitalHub, a spin-off of Mount Sinai Hospital that uses an iPhone-based system to give health professionals remote access to patient records and test results from a hospital's internal data network. MI also creates value by monetizing their member's physical property through its Monetizing Member Assets (MMA), which has helped sell the excess capacity of the new Toronto Centre of Phenogenomics to companies like Novartis whose interests align closely with the Centre.

Beyond MaRS Innovation, MaRS provides several other services, funded by the provincial government under the Ontario Networks of Excellence program, in partnership with key industry, government and academic stakeholders that support knowledge flows and technology transfer across a broad range of sectors:

- *MaRS Incubator:* Emerging science and technology firms eager to be part of the MaRS community can apply to be part of the MaRS Incubator which provides space for academics, researchers, entrepreneurs, mentors, investors across the innovation spectrum with the opportunity to meet, share ideas and collaborate.
- *Excellence in Clinical Innovation and Technology Evaluation (EXCITE)* partnership was created to establish effective pre-market evidence development and evaluation of medical technologies. EXCITE will harmonize health technology evaluation into a single, premarket evidence-based evaluation process for technologies with disruptive potential and specific relevance to health system priorities.[33] MaRS EXCITE represents a partnership between health system (Ontario Health Technology Advisory Committee),

[31] http://www.marsinnovation.com/how-we-work/inventors/
[32] Lawes, 2011.
[33] http://excite.marsdd.com/ Accessed on March 14, 2012

the government (MOHLTC and MEDI), Academia (Council of Academic Hospitals of Ontario and academic centres specializing in clinical trials methodology and execution, classified as "Methodological Centres" and other specialized areas of health technology evaluation), and industry (MEDEC and HTX).[34]

- *MaRS Commons* is a physical space and a community that supports the most promising web and mobile startups, helping these emerging companies grow successful global businesses through a combination of education, networking and mentorship.[35] The MaRS Commons community consists of 3 pillars: mentors and staff; startups and partners from industry and academia.
- *MaRS Health IT Innovation*: launching with a flagship conference on June 7-8, 2012, MaRS Health IT Innovation is an initiative in partnership with some of Ontario's most recognized healthcare associations. The anticipated organization is expected to unite industry, academia, innovators and the system's change-makers in an effort to accelerate the design and adoption of validated technology solutions, helping them to grow within the Ontario healthcare system before they scale nationally and internationally; and build an environment of cohesive innovation – a place where vendors, innovators, academia and investors can exchange ideas centred on mutual gain.[36]
- Funded by the Province of Ontario under the purview of the Ministry of Economic Development and Innovation, the *Investment Accelerator Fund (IAF)* is a seed fund that assists emerging Ontario technology companies to bring their products and services to market. The fund provides a comprehensive platform of resources, people, connections and funding that entrepreneurs and innovators can access to launch their new ventures. The IAF program is managed by MaRS and delivered through the Ontario Network of Excellence (ONE), a collaborative network of organizations across Ontario, designed to help commercialize ideas. The IAF invests in early stage, privately-held companies with no significant revenue or institutional investment. These companies must demonstrate their potential to achieve high growth and be enabled by truly innovative technologies that can provide the new venture with sustainable competitive advantage.[37]
- *The Business Acceleration Program (BAP)* provides a suite of services as well as educational and funding programs. They're designed to strengthen and accelerate the growth of Ontario's high-potential technology companies and entrepreneurs with the tools they need to succeed to move successfully into the global marketplace. BAP is funded by Ontario's Ministry of Economic Development and Innovation. It's coordinated by MaRS. And programs are delivered through member organizations of the Ontario Network of Excellence (ONE).[38]

[34] http://excite.marsdd.com/who-is-involved/
[35] http://www.marsdd.com/aboutmars/initiatives/
[36] http://www.marsdd.com/aboutmars/initiatives/mars-health-innovation/ Accessed on March 14, 2012
[37] http://www.marsdd.com/aboutmars/partners/iaf/
[38] http://www.marsdd.com/aboutmars/partners/bap/

Part III – Emerging Best Practices for Creating and Sustaining University-Industry linkages

In response to the growing number initiatives from national and regional governments, universities themselves are becoming more entrepreneurial in their approach to knowledge and technology transfer activities, actively seeking to build direct connections with industry to pursue both individual and joint commercialization opportunities. As the preceding survey makes clear, there is a great deal of variation in the choice and combination of strategies and individual tools, across nations, regions and at the local level. In addition to the numerous initiatives adopted by national and regional government to facilitate the flow of research and knowledge from institutions of higher education to local innovation systems, universities have also experimented with a wide range policies and programs to facilitate these linkages by providing faculty with time and facilities to conduct research, encouraging faculty consulting, establishing technology transfer (TTOs), licensing (TLOs) and industry liaison offices, developing institutional intellectual property policies, building technology parks on or near campuses, and establishing co-operative education programs that facilitate student learning and human capital exchanges. This section provides a more detailed examination of the range of practices employed by universities to build linkages with industry.

Regional Economic Development Strategies

There is a great deal of variation in universities' orientation to the regional economies in which they are located and while many remain relatively disengaged, others make ambitious commitments to engage with industry, explicitly building efforts at forging university-industry collaborations for the purposes of regional economic development into their institutional goals, objectives and strategic plans. Many OECD countries have strengthened the partnership role of universities with regional stakeholders by requiring higher education governance to include regional representation and encouraging the participation of higher education institutions in regional governance structures (OECD 2007). In other countries, regional governance innovations are driven within individual institutions. Breznitz and Ram (2011) observe that a strong mission statement reflecting an institution's commitment to economic development in general and technology and research commercialization in particular facilitates the development of commercialization culture within the university. For example, the *Georgia Institute of Technology*, or 'Georgia Tech', established the Georgia Tech Research Corporation (GTRC) to facilitate the commercialization of innovations produced within the institution. Composed of the Innovation Commercialization and Translational Research (ICTR) office, the Industry Collaborations and Affiliated Licenses (ICAL), and the International Contracts and Technology Transfer (ICTT) office, these organizations work together to provide a 'one-stop shop' for firms seeking strategic collaborations with the university through sponsored research, licensing, and new venture agreements.[39] Other examples include Macquarie University in Australia that has a

[39] http://www.industry.gatech.edu/about/ Accessed on March 15, 2012.

clearly articulated third mission framework expressed in terms of a Community Outreach Vision to 'engage with the community and to promote open access to high quality scholarship and services', Sweden's Chalmers University of Technology, and the Norwegian University of Science and Technology (NTNU) which has generated approximately 120 spin-off companies over the last 20 years.

Inter-Institutional Coordination for Regional Economic Development

Higher education institutions within regions have begun to coordinate tech transfer activities with each other, thereby advancing efforts at strategic engagement for regional economic development. As the OECD (2007) observes, when research institutions collaborate and leverage joint assets to improve and diversify their services to regional firms and public sector employers, they can also attain critical mass to expand their research and commercialization activities. In the UK, the *SETsquared Partnership* program joins up the four universities of Bath, Bristol, Southampton and Surrey to offer a comprehensive, strategic approach to maximize the universities' impact on the UK economy (Department of Science and Innovation, 2006). The SETsquared Partnership is a collective academic enterprise, jointly delivering the complete range of services from all four universities from entrepreneurial education for students and staff, through licensing of intellectual property, spin-out company creation and support for high technology spin-in companies from the local community, to collaboration with established corporations and small and medium enterprises.

Regional inter-institutional collaborations are also evident in Canada. For example, the *Springboard Atlantic* network has a mandate to support the commercialization of research in Atlantic Canada. Providing resources to universities and colleges in Atlantic Canada to encourage the transfer of knowledge and technology to the region's private sector, the network includes fourteen universities and five provincial community colleges.[40] Similarly, the *C4 Network* fosters resource coordination, cooperation with government and industry, multi-disciplinary research collaboration and commercialization of health sector related activities among ten universities and research institutions in Southwestern Ontario.[41] The *Rideau Commercialization Network* (RCN) was created in 2011 and is comprised of the technology transfer activities at Queen's University, PARTEQ Innovations[42], the Royal Military College of Canada, St. Lawrence College, Kingston General Hospital, Carleton University and the Ottawa

[40] http://www.springboardatlantic.ca/

[41] C4 members include McMaster University, WORLDiscoveries™ the University of Western Ontario, Robarts Research Institute, Lawson Health Research Institute, the University of Guelph, the University of Waterloo, Wilfrid Laurier University, the University of Windsor, Hamilton Health Sciences and St. Joseph's Healthcare. http://www.c4ontario.ca.

[42] PARTEQ Innovations is the not-for-profit technology transfer office of Queen's University. PARTEQ works with institutional researchers and the business and venture capital communities to bring early stage technologies to market. While primarily focused on discoveries generated by Queen's University, PARTEQ also offers its services to the Royal Military College of Canada, Kingston General Hospital, St. Lawrence College and Carleton University. http://ottn.wordpress.com/2011/04/06/ottn-and-parteq-create-the-rideau-commercialization-network-to-bring-eastern-ontario-innovations-to-market/ Accessed on March 12, 2012

Technology Transfer Network.[43] Under the RCN, Eastern Ontario's universities and research institutes and their research commercialization offices will pool resources to grow the region's innovation capacity. In 2011, the RCN was awarded $1 million from the Ontario Centres of Excellence Technology Transfer Partnership (OCE-TTP) program for staffing, infrastructure and Proof-of-Principle project funding. Research commercialization experts from the Ottawa Technology Transfer Network[44] and PARTEQ will work together to increase the impact of innovations from Eastern Ontario's academic research base by sharing their expertise and resources to advance these discoveries towards the market.

Industrial Liaison Programs

Another important technology transfer mechanism that has emerged in recent years is the establishment of industrial liaison programs within higher education institutions. The industrial relations offices of higher education institutions are highly diversified and range from narrowly focused technology transfer (TTO) or technology licensing (TLO) offices to more ambitious initiatives with a wide portfolio of industry-research partnership, technology transfer, industrial expansion and technical assistance or industry education and training partnerships (OECD 2007). According to ProTon Europe (2007), knowledge transfer and industrial liaison programs include:

- traditional internal administrative technology licensing offices;
- external entities which manage IP commercialization on behalf of the university;
- business development units that build linkages between industry and academia;
- business development units integrated with technology licensing offices to attract industrial research funding;
- partnership development of science parks, working alongside a technology licensing; function to attract and retain firms to the university owned and managed research park;

Industrial liaison offices improve accessibility for firms by providing a single point of contact for all research purposes, but regardless of the form these offices take, there is consensus that they need to be well-resourced, well-managed and staffed with properly trained officers in order to effectively leverage industry engagement (Mongeon, 2009). Studies on the organization of TTOs stress the importance of focusing university efforts through one office that has had success in commercializing technology, and the size, reach, and comprehensiveness of services, as well as the use of an independent legal team (Breznitz and Ram, 2011).

[43] http://ottn.wordpress.com/2011/04/06/ottn-and-parteq-create-the-rideau-commercialization-network-to-bring-eastern-ontario-innovations-to-market/ Accessed on March 12, 2012.

[44] The Ottawa Technology Transfer Network (OTTN) was established in 2005 between the research commercialization activities of the University of Ottawa, the Ottawa Hospital Research Institute (OHRI), the Children's Hospital of Eastern Ontario (CHEO) Research Institute and the University of Ottawa Heart Institute. Accessed on March 12, 2012: http://ottn.wordpress.com/2011/04/06/ottn-and-parteq-create-the-rideau-commercialization-network-to-bring-eastern-ontario-innovations-to-market/

In the US, the *MIT Industrial Liaison Office* provides firms with unlimited access to a number of resources including specialized information services and conference series. Comprised of specialists in licensing, business development and legal matters, experienced in transferring technologies across a broad array of fields, including the physical sciences, life sciences and information technology, the mission of the *MIT Technology Licensing Office* is to attract commercial investment in the development of inventions and discoveries flowing from research at the Massachusetts Institute of Technology, Lincoln Laboratory and the Whitehead Institute for Biomedical Research. The Office of Technology Management (OTM) at the University of Illinois at Urbana-Champaign details six specific steps that faculty go through with assistance from tech transfer professionals once a disclosure is filed including screening, assessment, protection, marketing, licensing, and compliance (Sonka and Chicoine 2004). Georgia Institute of Technology, several units deal with the technology commercialization process but most of the work is done at the Advanced Technology Development Centre (ATDC) which focuses on start-up firms, and the Office of Technology Licensing (OTL) which oversees licensing and patenting activities (Breznitz and Ram 2011). The University of British Columbia's *University-Industry Liaison Office* (UILO) has addressed the technology funding gap for early stage start-ups that do not require high levels of capital by creating its own Prototype Development Program (PDP) which facilitates the development and commercialization of early stage inventions with scarce resources by providing the management and funding necessary to validate and realize the commercial potential of the technology and has since been used as a model in other Canadian universities.[45]

Collaborations between Universities and Public Research Organizations

Collaboration between universities and other public research organizations creates opportunities for knowledge transfer, forging new partnerships, establishing creative inter-disciplinary research initiatives, and further developing existing networks (Rip 2011). In the Netherlands, *Wageningen University and Research Centre* combines an agricultural university and dedicated agricultural research institutes. In France, there have been various collaborations among universities, the national basic research organization, the Centre National de la Recherche Scientifique (CNRS), and the Institut National de la Recherche Agronomique. In Germany, the Excellenz Initiativ has stimulated new initiatives, such as the establishment of Karlsruhe Institute of Technology, a merger between the university and the major public research institute in Karlsruhe (Rip, 2011).

Movement of Researchers between Academia and Industry

Staff exchanges, which entail the movement of researchers between research institutions and industry, is another effective mechanism for creating and sustaining university-industry networks

[45] http://www.uilo.ubc.ca/uilo/knowledge-mobilization/channels/commercialization/prototype-development

and partnerships (The European Commission 2007). The European Commission has been an active proponent of such activities through the *Marie Curie Industry-Academia Partnership and Pathways* (IAPP) scheme, an initiative that supports the development of long-term collaborations through the exchange of researchers. Funding for IAPP projects covers activities such as the exchange of tacit 'know-how' and experience through two-way or one-way secondments of research staff between commercial and non-commercial partners, the recruitment of experienced researchers from outside the partnership for knowledge transfer and researcher training, and networking, workshops and conferences involving external researchers and the partners' own research staff.[46] Arrangements tend to be less formal and depend on individual institutional policies in the US. MIT has a history of senior faculty leaving to direct industrial research centres while retaining university linkages and some researchers working in government or industry retain academic titles and professorial appointments in order to preserve their academic linkages (Howard 2005).

Executive or Entrepreneur in Residence (EIR) Programs

Another way of injecting entrepreneurial thinking into academic research is by including entrepreneurs in academic endeavors (Thorp and Goldstein, 2010). Universities may invite entrepreneurs or executives from the private sector with relevant experience to join the academic ranks on a full or part-time basis in order to engage with faculty and students to encourage the development of a more entrepreneurial approach to scientific research. Though EIR programs are used most often in business and engineering schools, the University of North Carolina has extended the entrepreneur-in-residence concept to include medical schools and departments of economics, chemistry and policy studies. The Columbia Business School's Executives in Residence Program was one of the first of its kind when it was established over thirty years ago. A hallmark of the program is one-on-one counseling sessions in which executives advise students on their prospective career choices. Executives, who are often retired or semiretired, also teach classes and participate in student-run conferences, and often maintain long-term relationships with the school. One of the major advantages of an EIR program is that it helps "demystify the landscape of government grants", helping entrepreneurs understand the breadth of support available to them, and attracts senior entrepreneurs to a given region, providing them with a way to get involved with the local technology and academic community (Communitech, 2011, 26). Many organizations in Canada that promote knowledge flows and university-industry technology transfer have executive or entrepreneurs in residence programs, including the 13 Regional Innovation Centres that comprise a key part of the Ontario Network of Excellence and include organizations such as Communitech, MaRS, and Hamilton's Innovation Factory.

[46] http://cordis.europa.eu/fp7/mariecurieactions/iapp_en.html Accessed on March 11, 2012.

Industry-Government-University Knowledge-Sharing

Consistent with "the triple-helix model" of evolving networks, in which the university can play an enhanced role in innovation, another trend is to provide opportunities for knowledge-sharing not just between academia and industry but also with government (Langford et al., 2006; Rasmussen et al. 2006). A wide range of activities occur in this area from formal institutional partnerships to knowledge-sharing events. For example, *TRLabs* is Canada's largest information and communications technology research consortia consisting of five off-campus research labs in Edmonton, Calgary, Saskatoon, Regina and Winnipeg, with partners from industry, six universities, three colleges, the federal government and three provincial governments. Coordinating research activities with local and regional industry clusters, TRLabs employs 120 researchers, professionals seconded from industry, and faculty, and also trains students to enhance Canada's ICT expertise. In 2010, TRLabs adopted a new 'market pull commercialization model' that fast tracks innovation to market by creating a single window into the innovation system for industry seeking TRLabs' applied research, technology development, or commercialization support services.

The Creation of 'Innovation Campuses'

In conjunction with state governments, some higher education institutions in the U.S. have developed "innovation campuses" that feature the intentional co-location of academics and industry to facilitate and streamline the commercialization process.[47] Several innovation campuses have been established across the US, including Kansas State University's Olathe Innovation Campus, the Missouri Innovation Campus, the Nebraska Innovation Campus, South Dakota State University's Innovation Campus and the Akron Innovation Campus in Ohio. In Australia, the University of Wollongong has its own Innovation Campus. The Centennial Campus at North Carolina State University is a particularly interesting example of an innovation campus or 'technopolis' that has "radically advanced the notion of integrating industry and academe" (Geiger 2004: 207). Part of a strategy to make North Carolina State one of the country's leading land grant universities, it attracted several major corporations such as ABB, Lucent, and Red Hat to locate on the campus as anchor tenants followed by government offices and the gradual relocation of academic units. The crucial factor for the location of major firms and academic departments was the opportunity for close interaction with students and faculty and building on "interaction [as] the foremost principle", the entire campus is designed to facilitate formal and informal contacts (Geiger 2004: 208). Organized into the four R&D 'neighbourhoods' of advanced materials, advanced communication technologies, biosciences/biotechnology, and environmental technologies, university classrooms are interspersed with industrial offices and labs, and the campus also includes a business incubator and a venture capital fund to support start-up firms. Additional supports for the knowledge

[47] http://www.insidehighered.com/news/2012/02/27/midwestern-colleges-launch-campuses-built-public-private-collaboration Accessed March 13, 2012.

transfer process include a Partnership Office that facilitates connections between tenants seeking expertise and scientists seeking contact with industry, and access to both informal contacts and formal courses for industry researchers seeking to enrich their learning and knowledge base. Taken together, "the initiatives have vaulted NC State into national recognition for technology transfer and particularly for spawning start-ups firms" and its model for university-industry collaboration "generates more technological innovation and technology transfer than piecemeal efforts existing elsewhere" (Geiger 2004: 209).

The preceding summary documents the wide range of institutional mechanisms that have been adopted by higher education institutions over the past two decade to facilitate the flow of research and innovative knowledge from their laboratories into the hands of local industry and the receptor community. However, it would be a mistake to assume that a successful approach to leveraging investments in higher education research can rely on a careful selection of some of the best practices outlined above, without reference to the receptor of capacity of the local innovation ecosystem within which they are located. The final section of the paper turns to a discussion of the innovation ecosystem and its importance for leveraging investments in higher education research.

Part IV - Building an Innovation Ecosystem: An Advanced Approach to Leveraging *Localized* Knowledge Transfer

University-industry knowledge transfer is a highly interactive process that generates mutual benefit for local firms, research organizations and their surrounding economies. Firms benefit from access to new ideas, research facilities, highly trained human capital, patented and licensed intellectual property, and increased technological capacity – all of which support the innovation process. Universities benefit from increased revenues from entrepreneurial activity such as licensing income and professorial consulting, capital gains from selling shares in academic start-ups, and donations to universities from successful entrepreneurs, as well as greater access to industry facilities and opportunities for sponsored research (Grimaldi et al. 2011; Commission of the European Communities 2006). Local economies with robust university-industry linkages are advantaged with a deep pool of flexible and skilled talent, a concentration of jobs in creative industries, and high levels of public and private investments in existing and emerging industries of strategic importance. Furthermore, during times of economic downturn, these local economies are capable of mobilizing economic assets to pursue a different, yet viable, source of growth (Wolfe, 2009).

As such, governments world-wide continue to search for the most effective means of supporting collaborations between industry and research institutions, encouraging initiatives that reduce the cultural gaps between those sectors, and developing the policies and conditions to enable the exchange of ideas and knowledge on a *localized* basis. Government decision-makers have established a number of policy initiatives and mechanisms to intensify the degree of networking and linkages between actors within a regional innovation system. These emerging approaches to innovation underscore the key role of national and regional governments as both funders and drivers of university-industry knowledge flows. National governments in particular need to provide leadership, policy direction, and funding for research and its related infrastructure, and to encourage alignment among research universities, research parks, technology incubators, and other relevant actors in the local and regional innovation system.

The Localized Nature of Knowledge Transfer

Regardless of the model adopted to facilitate knowledge flows between university and industry, all are based on the underlying premise that location matters. Due to the person-embodied nature of knowledge transfer, universities are considered an essential element in regional innovation systems and their presence is critical for stimulating the formation of clusters, especially in knowledge-intensive industries. Proximity to the source of the research is important in influencing the success with which knowledge generated in the research laboratory is transferred to firms for commercial exploitation, or process innovations are adopted and diffused across developers and users. The most frequently cited explanation for this proximity effect is the need to gain access to tacit knowledge, or at least knowledge that is not yet published in scientific papers. Conversely, the role of proximity declines when useful knowledge is readily available in more codified forms that can easily be transmitted and accessed across broad distances. Proximity may also be more important for the transfer of relatively new research results in science-based fields, where personal access to those conducting the research is critical for the effective transfer of its insights (Feldman 2000; Adams 2002; Arundel 2001).

In light of the positive impact of proximity on university-business collaborations, Currie (2011) argues that provincial and municipal governments have as important a role to play in encouraging university-industry linkages as national governments. Clusters offer a highly effective means for leveraging scarce public resources and aligning policy strategies across the different jurisdictional scales—from the local to the national—in the Canadian federation. In North America (Plosila 2004), Europe (OECD 2007) and Australia (Howard 2005), state and regional governments are increasingly interested in creating clusters around complementary industry segments, and developing related critical masses of talent, technology and capital for sustaining and improving their regional economies. Because of its importance to global competitiveness, technology transfer is a major focus of these cluster efforts, particularly in advanced manufacturing, information technologies and biosciences. To facilitate these processes, coalitions of state and regional governments, business foundations and higher education institutions are increasingly developing technology-based visions, strategies and action plans. Higher education institutions are focusing on contributions to regional economic development that go well beyond their traditional emphasis on basic research to include building human capital through specialized curricula, customized training and lifelong learning, contract research and consulting activities that provide technical assistance and problem solving to local firms, as well as taking leadership roles in regional economic development. From a policy perspective, state-level politicians have committed sizeable investments in spite of severe fiscal constraints and timelines of a decade or more in efforts to better position their economies around technology and knowledge sectors.[48]

In order to fully advance efforts at local knowledge transfer, several different dimensions must be aligned. National and provincial governments should align their policies and spending to support the development of local and regional clusters; private sector players should offer advice and guidance to new start-ups, supporting the entry and growth of related firms into an area and consistently communicating their needs to local universities and research institutes. All three sectors should form a national network to share know-how and best practices on how to improve cluster competitiveness and reinforce cluster development. Fuller advantage can be taken of these existing national organizations with regional strengths by aligning their activities more closely with those of university technology transfer offices, the rapidly expanding research and technology transfer activities of the community colleges, and existing cluster organizations (OECD 2007).

The Innovation Ecosystem Approach

The drive to establish policies and institutional frameworks that intensify competitiveness in a knowledge-based economy is universal. To this end, political decision-makers from several leading economies have adopted the innovation ecosystems approach to intensify efforts at supporting and leveraging the flow of knowledge throughout their respective economies. This approach is a sophisticated way of seeing the innovation system as a whole that enables policy makers to pay close attention to the collaborative, interdependent nature of the innovation process and identify the best means of stimulating productive networks and relationships within and across disciplines and sectors of comparative advantage. Furthermore, the innovation ecosystem approach focuses on the constantly evolving relationships between a wide spectrum of innovation partners and draws attention to how their interactions affect knowledge creation, the rate of knowledge diffusion, knowledge transformation to innovation and the expansion of that innovation (Mercan and Goktas, 2011). Wolfe (2009: 38) explains:

> …this approach analyzes not just the existing institutions of regional economic growth, such as universities, research parks, large anchor firms and smaller start-up firms, but also the dynamics of how they interact with each other…Rather than targeting institutional research infrastructures to specific sectors or specializations, regional innovation systems are shifting to 'hubs' or 'communities for innovation' that allow for more agile responses to shifting technology and market conditions. Finally, a regional knowledge ecosystem

[48] For example, in Australia, the Queensland, Victorian, and the Australian Capital Territory governments have made substantial commitments to infrastructure investments. Programs and incentives are now offered involving universities in areas such as sponsored research, access to equipment and facilities, lifelong learning and customized job training, technical assistance expertise and problem-solving and entrepreneurial assistance and support.

> perspective emphasizes the leveraging of local and regional infrastructures to fuel the regional innovation process through the collaboration of multiple partners including research parks, universities, large research-driven firms, start-ups, investors and other professionals.

Stanford University's Innovation Ecosystems Network, defines an innovation ecosystem as

> the inter-organizational, political, economic, environmental, and technological systems through which a milieu conducive to business growth is catalyzed, sustained, and supported. Value is co-created for the innovation ecosystem through events, impacts and coalitions/networks that emerge from a shared vision of the desired transformations.

Innovation ecosystems consist of countless individuals, communities, organizations, material resources, rules and policies across large and small businesses, universities, colleges, government, research institutes and labs, and financial markets within a given region which collectively work towards enabling knowledge flows, supporting technology development, and bringing innovation to market (Wessner, 2007; Washington Economic Development Commission, 2009: 1-2; Jackson, 2011; World Resources Institute, 2011; NSF Directorate for Engineering, 2010). Innovation ecosystems embody an organic, bottom-up approach to economic development, and when the components work together, they are capable of achieving impressive short-term outcomes and longer-term economic and social impacts (Washington Economic Development Commission, 2009; Gault, 2010).

Communitech (2011: 9) explains that a thriving innovation ecosystem is characterized by knowledge creation, enabling organizations[49], an entrepreneurial culture, technology, entrepreneurs, government, and financing expertise. An innovation ecosystem is sustainable when it provides the *assets* and *resources* necessary for building relationships between partners, promoting the growth and responsiveness of the system to changing internal and external catalysts, and translating knowledge generated by research organizations to industry investors (Jackson, 2011; TECNA, 2011). These assets include entrepreneurial capacity, business acumen, risk capital, R&D enterprise, technology commercialization, human capital, physical infrastructure, an industrial base, global linkages, networking opportunities, a culture that is supportive of innovation and a community mindset, supportive government policies and quality of life (TECNA, 2011). The list of resources needed by academic and private sector entrepreneurs within an innovation ecosystem can be grouped into six broad categories: networking – achieved by attending events/conferences designed to assist entrepreneurs in

[49] Communitech defines "enabling organizations" as an organization "that provides leadership to a specific industry, effectively bridging, bonding and directing multiple partners in delivering toward a common agenda. They assume responsibility for being ahead of the curve, taking on issues and opportunities at an industry level. Different than old-style associations, enabling organizations think deeply about industry and company needs, and apply considerable strategy and intentionality in engineering outcomes that deliver robust tech clusters, resulting in more jobs, more companies and more wealth. They're key players in the business ecosystem." Examples of enabling organizations include, but are not limited to, business incubators, economic development agencies, trade associations, off-shoots of universities and tech councils" (TECNA, 2011:10).

connecting to other innovation ecosystem actors; capital – includes providing direct funding to entrepreneurs and facilitating connections to funding providers; representation – ensures that the entrepreneur's interests are communicated through lobbying activities; knowledge – gained through participation in seminars, webinars, programs and courses, web resources and print media, etc; services – includes the provision of an incubator, CEO in Residence, mentors/coaches/counselors, peer-to-peer groups, web services, etc; and support – includes the promotion of innovation and commercialization, publicity and recognition, workforce development, etc. (TECNA, 2011)

The Role of Universities in Innovation Ecosystems

Local research universities have an important part to play in advancing knowledge flows within an innovation ecosystem. These institutions are hubs for the research and innovation activity, agents of knowledge exchange and catalysts of technological innovation. Research universities have a formidable capacity for producing knowledge, generating research and creative talent, and advancing mechanisms of knowledge transfer for uptake and innovative application by firms. Lester (2005: 3) identifies a number of ways universities contribute to local innovation processes, which in turn ensures the health of their respective ecosystem. He asserts that

> …universities can help to attract new human, knowledge and financial resources from elsewhere. They can help to adapt knowledge originating elsewhere to local conditions. They can help to integrate previously separate areas of technological activity. They can help to unlock and redirect knowledge that is already present in the region but not being put to productive use.

Local universities in cities like Cambridge, Massachusetts, Ann-Arbor, Michigan, and New Haven, Connecticut play a substantive role in developing thriving innovation ecosystems. These universities, and others like them, contribute to the sustainability of innovation ecosystems particularly through the flow of university graduates into the market as well as the flow of new knowledge generated by university-based research into society through public channels (Xue and Zhou, 2011). The relationship between universities and other actors in a healthy innovation ecosystem is constantly evolving with universities cooperating more closely with private firms and research institutes and establishing more complex interactions, which include joint research, skills training and human capital exchange.

In considering the development of Israel's high-tech ecosystem, the importance of the local research university is readily discerned. During the pre-emergence stage of its technological development success, Israel created a plethora of policies and institutions to support entrepreneurship and innovation; the establishment of the Office of the Chief Scientist (OCS) in 1969 was among those initiatives. The OCS was mandated to provide grants to civilian research and development projects with export potential, and later it became a major source of funding for technology transfer from universities to industry so as to encourage the speedy commercialization of the new technologies that were developed in labs and research institutes (De Haan and Golany, 2011). Since then, the national government has established grants and programs to support university research and pre-competitive research cooperation with industry. Steeped in a rich history of public support for university-industry knowledge flows over several decades, all seven of Israel's universities are actively engaged in transferring research results to the private sector. Of those seven universities, the Technion, a science and technology oriented research university, stands out as a vital agent in advancing knowledge transfer and contributing to the sustainability of the country's innovation ecosystem. The Technion has been particularly effective in knowledge transfer through the work of its students and graduates. The majority of Israeli-educated scientists and engineers are Technion graduates, constituting over 70% of the country's founders and managers of high-tech industries. Furthermore, as a result of the skilled capabilities of Technion graduates, Israel has the highest concentration of high-tech start-up companies anywhere outside of the Silicon Valley. High-tech industry now accounts for more than 54 per cent of Israel's industrial exports and over 26 per cent of the country's exports.[50] Israel's local universities with their capacity to encourage technology transfer through its TTOs and leverage knowledge transfer through its alumni has made remarkable strides in strengthening the national innovation ecosystem.

As suggested above, research partnerships between universities and industry are critical components of an innovation ecosystem and may have substantive spillover effects. However, there is substantial variation across existing university-private sector partnership models, which reflects the diversity of the innovation ecosystem itself; this means that there is no single approach for creating a successful research partnership within an ecosystem. External factors influencing the development of university-industry partnerships include macro-economic and macro-institutional factors operating at national and regional levels, such as, for example the Bayh-Dole Act in the US, or national policies to support Triple Helix approaches to commercialization. Internal factors include the level of entrepreneurial activity within the university, and institutional technology-transfer policies and technology-transfer organization. University culture also has an effect on its technology transfer capacity and studies highlight the importance of the university's mission statement, the research and commercialization activities of employees and the administration's attitude towards commercialization. Cumulatively, these factors significantly influence the nature of university-industry knowledge flows, and ultimately affect the health and sustainability of the innovation ecosystem.

The Pervasiveness of Innovation Ecosystems

Jurisdictions like Finland, Denmark, Korea, China, Sweden, UK, and Australia have established policies and institutions aimed at promoting a robust innovation ecosystem. In each of these innovation ecosystems, local universities are critical institutions in ensuring knowledge flows. Finland in particular is internationally recognised as a leader among R&D intensive countries;

[50] Technion, "Fast Facts." http://www1.technion.ac.il/en/about

knowledge transfer between business and universities has been one of the key factors in Finland's innovation and economic success. This success has been largely attributed to the supply of highly trained graduates in R&D intensive sectors and the development of institutions that support knowledge exchange to sustain the Finnish innovation ecosystem (World Economic Forum, 2011). To further this effort, in 2010 Finland established another post-secondary institution called Aalto University; this new "innovation university" is a merger between three Finnish universities: The Helsinki School of Economics, Helsinki University of Technology and The University of Art and Design Helsinki.[51] The university is designed to provide strong multidisciplinary education and research and encourage linkages between industry in sectors of strategic advantage, which would ultimately have economic and social spill-over effects. In general, the Finnish innovation ecosystem is enriched by its local universities which provide the local economy with a highly trained workforce, and in particular, a significant number of science and engineering graduates to further bolster its strong innovation capacity in ICT.

The innovation ecosystem approach has also found fertile ground at both national and regional levels in the United States and Canada. In particular, the American government credits a strong national innovation ecosystem for making possible innovation in entire industries, including automobiles, steel, chemicals and materials, pharmaceuticals, computers and information technologies, emerging biotechnologies, and the internet (President's Council of Advisors on Science and Technology, 2004, 2008). Notably, the United States has developed a complex IT ecosystem that transcends state boundaries. In their assessment of the health of and performance of the American information technology ecosystem, Iansiti and Richards (2005: 5) describe the degree of interaction between firms in the industry as "truly astounding with hundreds of organizations frequently involved in the design, production, distribution, or implementation of even a single product." More recently, the Obama administration has committed to building up the American IT ecosystem. To this end, President Obama has developed a comprehensive strategy that will expand access to high-speed Internet, modernize the electric grid, increase the availability of wireless spectrum to support high value uses, and secure cyberspace. Additionally, the Administration is supporting basic research that will foster future revolutions in information technology (The White House, 2011b). The successful actualization of these initiatives will require a collaborative effort on behalf of all of America's innovation ecosystem actors across the public and private sectors.

At the subnational level, California's S&T innovation ecosystem,[52] Northeast Ohio's high-tech ecosystem,[53] Boston's Route 128 high-tech ecosystem, and New York City's IT ecosystem are

[51] Aalto University, "Aalto – An Internationally Unique Concept" http://www.aalto.fi/en/about/
[52] California Council on Science and Technology. (2011). "Innovation 2 Innovation: An Assessment of California's Innovation Ecosystem." Phase 1 Report. Prepared for the California Legislature. http://www.ccst.us/publications/2011/i2i_phase1.pdf
[53] Ohio State. "Ohio Third Frontier and Ohio's Innovation Ecosystem Create Environment Where Inc. 5000 Fastest-Growing Companies Can Succeed" Press Release. Ohio Third Frontier, Columbus, Ohio. December 8th, 2010. http://www.prnewswire.com/news-releases/ohio-third-frontier-and-ohios-innovation-ecosystem-create-environment-

excellent examples of innovation hotbeds that have benefitted from the strong collaborative partnerships forged between local research universities, government, venture capital communities, entrepreneurial companies and individual innovators to leverage the flow of knowledge exchange and technology transfer and bolster regional economic development. Similarly, there are a number of thriving regional/local innovation ecosystems in Canada. In Ontario, regions like Kitchener-Waterloo, the Greater Toronto Area (GTA), Ottawa and London demonstrate the capability of innovation ecosystems to successfully harness the greatest potential of different technologies, sectors and markets in support of localized knowledge transfer. For instance, the Waterloo innovation ecosystem provides a rich interface for thousands of innovation actors and organizations across different sectors, including students and faculty from four leading post-secondary education institutions – University of Waterloo, University of Guelph, Wilfrid Laurier University and Conestoga College; staff from 150 local research institutes; an established venture capital community; and other enabling organizations like the Communitech Hub and the Accelerator Centre. Together, these actors, their assets and resources feed into the development of key industries, including high tech, financial services, education/research, manufacturing, service sector, health/life sciences. As of 2009, the Waterloo region's technology ecosystem boasted the following statistics (Communitech, 2011: 17):

- $18B tech sector revenue
- $84 million deal flow in 2009 alone
- 711 tech firms employing 30,000 people
- $350M worth of private sector R&D conducted in the Region
- 631 patents granted per million (3x national average)
- 200+ tech start-ups benefitted from more than 7,000 hours of venture services offered free of charge by Communitech and the Accelerator Centre
- $300M venture and angel financing raised funds in 14 months

While a number of innovation ecosystems have developed around specific industries and technologies, particularly ICT, there is a notable dearth of rigorous analysis on innovation ecosystems in Canada that emerge from the intersection of two or more distinctly different, yet overlapping sectors. Addressing this gap, Wolfe et al. (2011b) examined the flows of knowledge and technology between the information and communications technology sector (ICT) and financial services in the GTA to determine how those flows contribute to the innovation process. A number of actors and institutions beyond the financial services sector and the ICT sector were identified as having an influence on the flow of knowledge and technology. In particular, research labs and local universities played an integral role in providing a number of financial services firms and ICT firms not only with new knowledge to drive the development of innovative ideas, but also a supply of highly-qualified graduates which facilitated the development of local expertise. One example is RiskLab Toronto – a partner of the international

where-inc-5000-fastest-growing-companies-can-succeed-111516649.html For more information, refer to: www.OhioThirdFrontier.com network of RiskLabs – a University of Toronto research-based initiative sponsored by Algorithmics that conducts university-industry research initiatives in the mathematical sciences for risk management. The RiskLab addresses the financial services sector's need for cutting-edge research and highly qualified personnel. Through industry sponsored projects, faculty, postdoctoral fellows and graduate students develop fulsome interactions with practitioners from local and international financial institutions (Wolfe et al, 2011b: 33).

This research on the GTA's financial services-ICT nexus illustrates the necessity of situating the question of how to leverage public investments in higher education research within the broader context of the local innovation ecosystem and the specific sectors and clusters which provide the local receptor capacity for the outputs of that research. Our discussion of the innovation ecosystem approach reinforces the need for academic and civic leaders, industry partners, and policy decision-makers from multiple levels of government to work together, employing the innovation ecosystem approach which considers the full spectrum of actors, institutions, assets and resources necessary to ensure the free flow of knowledge and technology between the ICT and financial services sectors in order to maximize the innovation potential of that complex, dynamic and highly interactive interface.

Conclusion

Canada's innovation system currently faces a number of critical challenges. One of the challenges facing university technology transfer is the weak linkages between the knowledge generation process in institutions of higher education and the capacity of private firms to adapt the knowledge being generated for commercial purposes. A key issue is the lack of receptor capacity that is capable of making full use of university-generated research. The policy scan provided in this paper indicates that there is no uniform approach being applied across the wide range of institutions and levels of government that are tackling this issue in their respective jurisdictions. However, it has identified a number of common underlying themes. These include the use of a new range of collaborative ventures that link institutions of higher education and networks of private firms to leverage the benefits of publicly funded research to a broader cross-section of firms and promote a more effective integration of different elements of the innovation system. The danger, as always, rests in a tendency to adopt models that have worked well at other institutions or in other jurisdictions without paying attention to how well they may fit into a particular innovation ecosystem, in other words to assume that 'one size fits all'. The process of knowledge transfer must be viewed in the context of the institutional structures and firm capabilities defined by the specific characteristics of the local or regional innovation system in which they are grounded. The key lesson to be drawn from this review is that institutions of higher education must work to align their efforts to improve knowledge transfer capabilities with the realities of the local innovation systems in which they are embedded.

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