Regional Innovation Ecosystems
Key factors of Technological Innovation and Entrepreneurship

Report prepared for The Ontario Ministry of Research and Innovation

October, 2013

Prepared by:

Gregory M. Spencer, M.Sc.Pl., Ph.D.

Manager - Local IDEAs
Program on Globalization and Regional Innovation Systems
Munk School of Global Affairs
University of Toronto

Executive Summary

This report examines a wide range of factors that support technological innovation and entrepreneurship in major Canadian city-regions with a special focus on urban areas in Ontario. The concept of 'regional innovation ecosystem' is used to frame and endorse the view that innovation and entrepreneurship are influenced by a set of interconnected elements that function in concert to support growth and prosperity. The current thinking on regional innovation and entrepreneurship is presented in three groups: finance; human capital, and; industrial structure. A set of quantitative indicators are provided by Local IDEAs (Indicator Database for Economic Analysis) that provide measures of the specific elements of each of the three themes. Statistical analysis is applied to these indictors in order to determine which combination of factors are most associated with technological innovation and entrepreneurship. These findings then provide an empirical basis for possible policy interventions.

The statistical analysis is separated into two parts – the first seeks to understanding the key regional factors linked to technological innovation (as measured by rates of patenting) and the second assesses the main drivers of entrepreneurship (as measured by high-tech start-up rates). It is important to note that the rates of technological innovation and high-tech entrepreneurship are strongly correlated and that the former is seen as a precursor to the latter. The most significant factors for each are as follows:

Technological Innovation (Patents)

Primary factors:
- **business expenditures on R&D**
- **PhDs in maths and sciences**

Secondary factor:
- **public expenditures on R&D**

Entrepreneurship
(high-tech start-up rates)

Primary factor:
- **business skills (MBAs per capita)**

Secondary factors:
- **business expenditures on R&D**
- **public expenditures on R&D**
- **industrial clusters**

The analysis also shows how these factors form interrelated 'ecosystems' that function as a whole. When applied to specific city regions across Ontario, the analysis helps to identify the levels of technological innovation and related entrepreneurship in each community. This evidence then enables differentiated policy recommendations depending on the state of local ecosystems. Three types of cities regions are presented:

High-performing innovation ecosystems
Guelph
Kingston
Kitchener-Waterloo
Ottawa-Gatineau
Toronto

Low-performing innovation ecosystems
Hamilton
London
Windsor

Process-based innovation ecosystems
Barrie
Brantford
Oshawa
Peterborough
Sudbury
St. Catharines-Niagara
Thunder Bay

The high-performing innovation ecosystems are city-regions that have managed to produce high-levels of patents as well as generate relatively large numbers of high-tech start-ups. Such places possess business environments that are top-spenders on R&D and have an abundance of top-level skill in combination with strong publically funded research institutions (mainly universities and research hospitals) that provide both basic scientific research and highly educated scientists. The main policy recommendations this group involve government playing a role in coordinating the various elements that are present in a manner that focuses on maintaining existing strengths and building on emerging ones. More practically, this means: a) finding the optimal balance between spurring more private R&D and the direct funding of university and hospital based research; b) targeting specialized degree programs at universities that provide greater impact on the economy; and c) ensuring that secondary schools are graduating students that can potentially fill such programs (primarily in maths, sciences and business).

The city-regions with low-performing innovation ecosystems are places that generally possess all of the key basic elements (i.e. industrial base; research institutions) required of high-performing innovation ecosystems but they are not producing innovation or entrepreurship at high levels. The main reason appears to be the the private sector finance is seriously lacking in these regions. More detailed research would need to be done in order to identify the specific reasons as to why this is the case. Overall, the main areas that need to be addressed are: a) identify why business R&D is generally lagging; b) identify whether the lower levels of highly skilled workers (particularly in business) is mainly due to lack of local training or issues of retention; and, c) better understand how these elements are organized and coordinated in each region and if there are ways to improve and enhance local institutions.

The third group of city-regions are places that do not generally possess the necessary elements needed to sustain high-performing innovation ecosystems. This is mainly due to there being no local research intensive institutions and/or the lack of an existing high-tech industrial base. This does not mean that these city-regions are not of vital economic importance to the province of Ontario but rather local economic development strategies need to be tailored to the local context. Not all places are going to be globally competitive based on their ability to continually generate new leading edge technologies and thus different approaches are required. The city-regions in this group are typically smaller urban areas that specialize some combination of agriculture, resources, manufacturing, and logistics. Such places are often key users of new technologies but not necessarily producers of them (although there are niche strengths). Important to these places is the concept of 'bottom-up' or incremental innovation whereby improvements to processes and products are achieved through all workers being directly engaged in innovation. Such methods are typically linked with higher levels of productivity and quality control. In terms of provincial-level policy one of the most important involves engaging the Ontario college system in the training of workers in vital skills that are aligned with local economic needs.

Table of Contents

1.0 Introduction

Successful economic development in the 21st century largely depends on the ability of jurisdictions to continually produce valuable innovations that are globally in demand. While private firms are ultimately the actors generating these valuable goods and services, there are many important roles for the public sector as well as NGOs. Competition is no longer primarily about offering the lowest-cost environment but rather is driven by the ability to provide an effective combination of talent, infrastructure, and institutions that fuel the production of knowledge and assist in its commercialization. There is no single or easy solution to producing and maintaining prosperous and sustainable local communities but instead it takes a wide-ranging set of factors that require coordination. This report examines the main factors associated with technological innovation as well as entrepreneurship in high-tech industries in order to highlight the key areas in which public policy can be applied.

City-regions and innovation are both highly complex, trying to understand the connections between them is exponentially so. The concept of 'regional innovation systems' has been developed in order to address this complexity by recognizing that successful local economic development is achieved via a web of joined-up policies and institutions that link the private and public sectors. A key additional perspective is that these policies and institutions are developed over a long period of time and are constructed around regions' existing competencies and strengths. There is a growing belief that such development can be better understood within an evolutionary systems approach whereby notions of path-dependent processes of learning by the blending of existing knowledge is a key driver of innovation. Such systems often function as a whole with many interrelated feedback loops (either positive or negative) that characterize that trajectories of regional economies. Language from the natural sciences is commonly borrowed in order to communicate these ideas and thus the term 'ecosystem' has become increasingly prominent when describing the complex interconnections between local institutions and innovative performance. This report combines the 'regional innovation systems' concept with the 'ecosystems' framework by proposing the term 'regional innovation ecosystem' in order to capture both the complexity and dynamics of current thinking in local economic development theory and practise. The regional innovation ecosystem approach is used in this report to frame an analysis of the key factors that are related to local levels of technological innovation and related entrepreneurship in major Canadian city-regions.

This report begins by examining the current thinking on regional economic development and innovation policy. Three broad categories are used to organize the various theoretical approaches: finance (i.e. R&D funding and venture capital); human capital (i.e. human capital, education, creative class); and, economic structure (i.e. clusters; related variety; knowledge-bases). These categories are carried forward into the empirical sections of the report by via the operationalization of these concepts into quantitative variables. These variables are arranged into a series of statistical models that test their relationship with regional levels of technological innovation (patenting rates) and entrepreneurship (high-tech start-up rates). Futhermore, these variables are analyzed in conjunction with one another in order to provide a generalized model of regional innovation ecosystems. Data are drawn from a wide range of original sources that have been collected and organized with Local IDEAs (Indicator Database for Economic Analysis). The key factors that are identified by the statistical analysis are discussed with a focus on the policy messages for Ontario and its regions.

"There is no single or easy solution to producing and maintaining prosperous and sustainable local communities but instead it takes a wide-ranging set of factors that require coordination."

2.0 Current thinking

Making sense of why some regions are able to consistently sustain innovative companies is a difficult task as there are many interrelated factors that can be linked to higher levels of technological innovation and entrepreneurship. Many studies focus on single elements of these systems, which is a useful approach as detailed understanding of them is certainly required, however the approach of this report is to distill the most prominent of these in order to develop an overall picture. This section provides a basic overview of the current thinking about the main drivers of regional innovation performance. These various frameworks are organized into three broad categories. The first of these is labelled 'finance' and covers business expenditures on research and development, public institutional (i.e. mainly universities) R&D funding, and venture capital investment. The second examines the role of human capital, and in particular, highly skilled personnel. This includes ideas that are quite broad in scope that deal with basic levels of education attainment and the occupation mix (i.e. 'creative class') to the more specific that focus on various expert communities such as maths and science PhDs and highly trained business professionals. The third and final category outlines various notions around how the existing economic structure of regions impacts regional outputs. This discussion ranges from the impact of industrial clusters, to the merits of economic diversity, to the relative balance between types of knowledge-intensive industries present locally.

2.1 Finance

In order to have a steady stream of technological innovation there must be constant investments made in research and development. There are generally two ways in which R&D is undertaken and subsequently stimulated by public sector action. One is R&D occurring directly within firms that produce technology which in many cases is encouraged by government vis-à-vis tax incentives. In Canada the main incentive program for fostering business R&D is the Scientific Research and Experimental Development (SR&ED) Program which is administered by the Canada Revenue Agency and government by the Finance Department. From a provincial standpoint additional tax incentives in most instances work in conjunction with the SR&ED program. Recently the SR&ED program has undergone a thorough review in order to address questions about its effectiveness. Canada typically lags many other OECD countries on many indicators of innovation and thus changes to the program are in the works. Specific issues include such things as whether incentives should be skewed towards small and medium sized business or include major global corporations who are often the largest spenders on R&D. With any such program there are also associated accusations of government 'picking winners' which is viewed by some as unhelpful interference in market activities. While there are always going to be strategic decisions made about where to direct public funds, it is often the case that 'winners pick themselves' – meaning that support is directed to areas of existing strength or firms and industries that show high degrees of promise on their own merit. This notion connects with many of the themes in the economic structure subsection of this report.

A second major policy area in which the public sector can impact innovation with financial tools is the funding of basic and applied research undertaken within public research institutions. Universities tend to be the main recipients of such funding but other institutions such as research hospitals and government labs are also included in this framework. This model is often referred to as the 'triple helix' (Etzkowitz, 2003) whereby government funds universities to perform (mostly basic) scientific research and then private firms find ways to commercialize the science. Beyond the role of funder, the task for government in this model also involves a great deal of coordination between universities and industry. This means identifying key areas of strength (typically within the local economy) and ensuring that university staffing and facilities are aligned with similar overall strategic goals. There is some debate as to how much of role universities play directly in the commercialization of science and technology developed on campus. In many cases universities have launched their own business incubators for this very purpose. There can be significant financial rewards to institutions if they manage to develop highly successful technologies in the form of royalty payments, although the precise nature of these arrangements vary at an institutional level in Canada. Such endeavours have received criticism as being too far removed from the core goal of providing education and training and thus serves as a distraction and possible misallocation of resources.

A third mechanism by which finance is directly associated with innovation and entrepreneurship is venture capital (Florida & Kenney 1988). This differs somewhat from the first two discussed in that venture capital tends to have a greater impact on the entrepreneurship of technology rather than on earlier R&D stages. Typically, a new firm with a viable technology or innovative product will require funding in order to scale the company to a point that revenues will be sufficient to fuel further growth and so at this point will seek venture capital. In return, venture capitalists will receive a share of the firm and normally a say in the strategic direction of the company. Governments can play either active or passive roles with venture capital, by either directly setting up VC funds and managing them (sometimes at arms-length) or by offering additional financial incentives to private VCs in order to stimulate greater activity. One drawback of VC is that it tends to be limited in scope in terms of the range of industries that it assists. This is due to the typical VC model that demands fairly rapid returns on investment derived from very high-growth firms. Such companies tend to occupy certain technology spaces such as software whereby new markets can be conquered relatively quickly.

2.2 Human capital

Technological innovation and entrepreneurship are ultimately achieved by applying talents of highly skilled individuals. Perspectives on the role of human capital in regional innovation systems range from the broad to the highly specific. One general view is that the role of human capital is of utmost importance to the overall economic health of regions. A common way of framing this concept is by examining the overall levels of educational attainment of the labour force, often with a focus on the share of the population that has obtained post-secondary qualifications. The basic model is that certain economic activities demand highly skilled workers who are drawn to certain regions due to greater opportunities. An alternative view is the 'creative class' thesis put forward by Richard Florida (2002). Instead of examining levels of educational attainment the creative class perspective is built upon a set of occupations than involve the production of knowledge. An additional departure from more traditional human capital approach is the idea that firms and industries will locate where the greatest pools of talent exist. Furthermore, members of the creative class choose to reside in regions that have certain amenities and characteristics. Thus local economic development policy can be conceived as an exercise in constructing highly 'liveable' environments that will attract certain kinds of people who in turn attract economic investment and growth. This view remains highly controversial from a number of perspectives (Peck 2005; Glaeser 2005).

Beyond the general view on the role of highly skilled personnel in regional economic development there are more detailed takes that examine more specific elements of the labour pool that are directly engaged in the invention of new technologies and its commercialization. On the innovation side this specificity goes in two directions from overall levels educational attainment. One is to look at the top-end by narrowing the focus to those with graduate-level qualifications and especially those with doctorates. A second is to concentrate on only those with degrees in maths and sciences. Taking such perspective is justified by the educational profile of those who file successful patent applications. A similar tack is taken on the entrepreneurship side whereby the focus is narrow to those with MBAs. Together these two groups certainly represent an elite subsection of the labour market and such approaches receive criticism as a result. Alternatively, it is suggested that bottom-up innovation is most effective when achieved through input from those working directly on the shop floor. While there is significant evidence to believe that this approach does indeed generate productivity enhancements via process innovation, it is not generally thought of as a means of achieving technological innovation in products which is the focus of this report.

A third perspective on the impact of human capital on innovation takes a somewhat more indirect and passive approach by examining the overall cultural diversity of the workforce. The thinking in this regard relates to basic evolutionary processes and how new knowledge is produced from making novel combinations of existing knowledge. Local cultural diversity represents an opportunity for knowledge production as many different perspectives and experiences are situated in close proximity and thus there are greater probabilities for novel combination. There is a degree of evidence that suggests that higher levels of cultural diversity have an impact on aggregate economic outcomes of regions (Ottaviano & Peri, 2006) but further analysis also point to the benefits being heavily weighted to 'cultural economy' sectors rather than science and technology (Spencer G. M., 2011).

2.3 Industrial Structure

A third general category of factors that have an impact on the innovative and commercial outputs of regional economies is the industrial structure or mix of economic activities that are present in the local economy. These include theories regarding industrial clustering, evolutionary processes derived from the variety of industries, and the specific knowledge-bases of industries. In each case arguments are built on some variation of the idea that the existing industrial mix is a major determining factor on the level of current and future innovation and growth. From a policy perspective the suggestion is that sound economic development practises focus on enhancing existing strengths rather than importing economic activities that are novel to the region.

Clusters are an economic development concept that have gained a great deal of currency over the past 15-20 years after being popularized by the Harvard academic Michael Porter (1998). The basic theory is that a set of interrelated economic activities, including suppliers, customers, and supporting institutions, operating in close physical proximity strengthens personal relationships and enhances learning thereby generating overall greater economic outcomes. From an innovation point of view it is argued that 'thicker' social dynamics in clusters increase knowledge spillovers between firms and from related institutions such as universities resulting in higher levels of inventiveness. Furthermore, close physical proximity and regular interaction allows for more exchange of 'tacit' knowledge and the construction of local cultures or 'ways of doing things' that cannot be easily copied or replicated elsewhere. Empirical evidence shows that clusters do indeed tend to generate greater aggregate economic benefits (Spencer, Vinodrai, Gertler, & Wolfe, 2010) but a direct relationship to innovation is more elusive.

A second set of ideas concerning the industrial structure of regions and the impact

"From an innovation point of view it is argued that 'thicker' social dynamics in clusters increase knowledge spillovers between firms and from related institutions such as universities resulting in higher levels of inventiveness"

on innovation and growth comes from an emerging school of thought called ‘evolutionary economic geography’ (Boschma & Frenken, 2006). The central theories of this school relate to basic evolutionary principles whereby new firms and industries evolve from novel combinations of pre-existing firms and industries largely via trial and error processes of selection and survival. Additionally, levels of (industrial) diversity have significant impacts on these processes as they determine the range of possible new ventures. In terms of innovation, the same ideas operate in generally the same manner whereby new technologies and knowledge are developed by combining existing technologies and knowledge in novel ways. A key concept in both cases is the notion of ‘related variety’ (Frenken, Van Oort, & Verburg, 2007) which builds on the idea that diversity is an essential component of evolution with the view that previously unrelated knowledge has an ‘optimal cognitive distance’ (Nooteboom, 2000). The twist is that new combinations of closely related knowledge are not valuable because they are not sufficiently novel and that new combinations of wide divergent knowledge are highly unlikely because there is little-to-no common ground, thus there is an optimal level of cognitive distance that has high potential for both novelty and value. In a practical sense this means that if a region contains a variety of related technologies and/or industries then it has a greater potential for innovation and growth. This view represents a refreshing of the long-standing debate between the relative merits of local diversity (urbanization economies) versus specialization (localization economies).

A third perspective examines the general types of knowledge present in regional economies. A growing literature on industrial knowledge-bases contends that not all type of knowledge and knowledge production processes are the same and should be understood and treated differently. The leading theory in this regard is the concept of three ‘knowledge-bases’ which are labelled ‘symbolic’, ‘synthetic’, and ‘analytic’ (Asheim & Gertler, 2005) (Asheim & Hansen, 2009). These groupings classify economic activities in a similar manner to subjects in school whereby symbolic knowledge describes arts, culture, and humanities, synthetic knowledge contains applied engineering and applied sciences, and analytic knowledge encompasses natural sciences and mathematics. To continue the school analogy as different subject have different pedagogies, learning and knowledge production is seen as having different characteristics between firms and industries of various types. Or in other words, the creative process which produces art and culture, differs from innovation which produces technology, which differs still from scientific discovery (Spencer). The key applied message is that the differences between arts & culture and science & technology should be reflected by specific policies instruments rather than be lumped together.

2.4 summary

While these theories are not an exhaustive list they form a relatively wide overview of many of the key ideas that inform both current academic research and related economic development policy making. It should also be noted that these particular theories have been specifically chosen because they can be operationalized within the quantitative methods put forth in this report. Other key ideas that cannot be readily quantified have been excluded for this reason. A key example of this is the role that local institutions play in coordinating and organizing the key factors discussed at greater length in this section. While such ideas are excluded from the empirical components of this report they are returned to during the concluding policy discussion.

3.0 Data and methods

As discussed in the previous section regional innovation and local economic development is highly complex with many contributing factors. The empirical section of this report attempts to quantify each of the main ideas presented thus far and compare them in statistical models that help to identify which factors have the greatest influence on innovation and entrepreneurship. Variables are constructed from data that has been compiled in Local IDEAs (Indicator Database for Economic Analysis) a research project undertaken by the Program on Globalization and Regional Innovation Systems (PROGRIS) at the Munk School of Global Affairs and the University of Toronto. This data comes from a wide variety of original sources, both public and private. The main unit of analysis is Census Metropolitan Areas (CMAs) which are defined by Statistics Canada as urban conurbations of at least 100,000 population. CMAs have a clearly identifiable core municipality and extend to surrounding communities based on the daily flow of commuters within a local labour force. As of the 2006 Census there were 33 CMAs in Canada. Smaller urban areas (Census Agglomerations) are excluded from the analysis as many of the variables (especially ones dealing with finance) have negligible presence in regions of less than 100,000 population. 2006 is the base-year of the analysis as it is the most recent year where data exists in order to construct a full set of variables.

3.1 Dependent Variables

The analysis uses two main dependent variables (technological innovation and entrepreneurship) with one secondary variable (median incomes). Technological innovation is measured by the average number of patents filed with the USPTO per year between 2005 and 2007 and standardized by the population between the ages of 16-64. The USPTO is the original data source although this dataset has been cleaned (by Prof. Dieter Kogler at University College Dublin) for the purpose of clearly identifying the patents that contain at least one inventor who was resident in Canada. Fractions are used to sum the patents in the cases where more than one inventor is listed. While patents are not perfect measures of technological innovation, as not all technologies are patented and not all industries patent at the same rate, it is generally accepted as the best proxy measure based on consistency and availability of data.

The second main dependent variable captures the entrepreneurship related to technological innovation by measuring the rate at which high-tech businesses are formed within regional economies. This variable is also standardized by the size of the adult population. The original data is supplied by Dun & Bradstreet which provides a comprehensive database of businesses which can be segmented by detailed industrial classifications. Business counts within high-tech industries are counted in 2001 and 2006 in order to calculate the rate of growth. This variable is intended to act as a proxy for overall levels of dynamism with key technology intensive industries. The main shortcoming is that it is not able to measure the amount of technological commercialization occurring within established firms. It is important to recognize that the two dependent variables are strongly correlated with one another and that technolgical innovation is understood to be a precursor to high-tech entrepreneurship.

3.2 Independent Variables

The independent variables in the analysis are organized and grouped along the same lines (finance; labour; industrial structure) as in section 2 of this report (please see Table 1). Additional structural variables are also included in order to capture general factors such as overall regional population and relative costs (rents). There are three finance variables: public R&D; business enterprise R&D; and, venture capital.

"Variables are constructed from data that has been compiled in Local IDEAs (Indicator Database for Economic Analysis)"

Table 1 - Overview of variables

Category	Concept	Label	Description	Year	Source
Finance	Public R&D funding	PubRD	University R&D funding per working age population (ages 16-64)	Average 2005-2007	CAUBO
	Private R&D expenditures	BERD	Private R&D expenditure per working age population (ages 16-64)	Average 2005-2007	Impact Group/ Statistics Canada
	Venture Capital	VC	Venture capital per working age population (ages 16-64)	Average 2005-2007	Thomson Reuters
Human Capital	Educational attainment	BA	Percentage of adult population with at least a bachelors degree	2006	Census
	Creative class	CC	Percentage of employed in creative class occupations	2006	Florida; Census
	R&D specialists	MSPhD_1000	Number of adults with a PhD in maths or science per 1,000	2006	Census
	Business specialists	MBA_1000	Number of adults with an MBA degree per 1,000	2006	Census
	Cultural diversity	Cdiversity	Numbers equivalent entropy measure country of birth	2006	Spencer; Census
Industrial Structure	Propensity of industrial clusters	PctCluster	Share of employment in local industrial clusters	2006	Spencer et al.; Census
	Related variety of industrial structure	RVariety	Variety of specific industrial categories (4-digit NAICS) within general industrial categories (2-digit NAICS)	2006	Boschma; Census
	Arts & culture knowledge-base	Symbolic	Share of employment in 'symbolic' knowledge industries	2006	Asheim, Gertler; Census
	Engineering knowledge-base	Synthetic	Share of employment in 'Synthetic' knowledge industries	2006	Asheim, Gertler; Census
	Natural science knowledge-base	Analytic	Share of employment in 'analytic' knowledge industries	2006	Asheim, Gertler; Census
General Variables	Relative costs	Rents	Average residential rent	2006	Census
	Size of region	Population	Total Population	2006	Census
Dependent Variables	Technological innovation	Patents	Number of patents per 10,000 working age population (ages 16-64)	2006	USPTO; Kogler
	Technology commericalization	HTFormation	Business formation rate of high-tech companies between 2001 and 2006	2001-2006	Dun & Bradtsreet
	Incomes	Income	Average full time employment income	2005	Census

The original sources include the Canadian Association of University Business Officers (CAUBO), The Impact Group/Statistics Canada, and Thomson-Reuters. In each case the average annual amounts between 2005 and 2007 are standardized by the adult population in 2006.

Each of the human capital variables are derived from the 2006 Census of Population. The educational attainment variable is simply a percentage of the adult population (ages 16-64) that have earned a bachelor's degree (or higher). The work of Richard Florida (2002) informs the 'creative class' variable which is a percentage of the labour force employed in certain occupations (i.e. knowledge-intensive and non-routine work). Both the R&D specialist and business specialist variables are rates expressed as a number per 1,000 adult population. Cultural diversity uses the place of birth categories in the census to populate an entropy measure (Beckstead & Brown, 2003; Spencer, 2011).

The five variables that measure aspects of industrial structure are also derived from the 2006 Census of Population. The cluster variable measures how much of total regional employment is within local clusters as defined by Spencer, et al. (2010). Related variety is based on the concept and methods of Frenken and his colleagues (Frenken, Van Oort, & Verburg, 2007) and specifically measure the amount of 4-digit NAICS variety within 2-digit NAICS categories. The three 'knowledge-base' variables use cross-tabulations of educational attainment and industry (4-digit NAICS) in order to produce the symbolic, synthetic, and algorithmic categories. Industries with above average levels of post-secondary qualifications are included and then classified according to mix of field of study.

Two additional independent variables (population; costs/rents) are included in the analysis in order to account for general local conditions. The overall scale of regions is measured with a straightforward population variable in order to estimate general scale-effects. Larger regions seem to have greater levels of knowledge-producing assets and this variable attempts to specify these impacts. The second variable is average residential rents sourced from the 2006 Census. This variable serves as a proxy for assessing the differences in overall costs between regions. Ideally this variable would more directly measure business costs but there is no consistent and reliable data source that provides this possibility.

3.3 Statistical Analysis

The analysis includes 3 dependent variables and 15 independent variables. In order to better understand how they relate to one another a series of regression models are constructed. The first four models (please see Figure 1) use patents as the dependent while incorporating the independents in stages according to the major themes (finance, labour, industrial structure, and general). With each of these models the significant variables are carried forward to a fifth model. The same method is applied a second time using high-tech formation rates as the dependent. In some cases (notably human capital) not all of the independent variables are incorporated in the models as there is a high degree of covariance between some pairs (please see Table 5). These statistical models provide an empirical basis for the development of a generalized model of regional innovation ecosystems.

4.0 Findings

A basic descriptive analysis of the data shows that there are widely divergent outputs and contributing factors between city-regions across Canada and within Ontario. Most of the largest urban areas in the country, especially Ottawa-Gatineau, Toronto, Vancouver and Calgary, are doing relatively well as are a select number of smaller urban centres such as Kitchener-Waterloo, Guelph and Kingston. City-regions that have traditionally relied on resource-based industries as well as many smaller regions with a manufacturing history are having a difficult time succeeding in a globally competitive knowledge economy. Urban size and history are not the only determinants however, as many of the smaller urban success stories have had similar industrial pasts but have managed to find ways to develop strong innovation systems.

4.1 Regional output

The two most prolifically innovative regions in Canada are Ottawa-Gatineau and Kitchener-Waterloo. Their patenting rates (per adult population) are 16.8 and 13.9 respectively, which is significantly more than other urban areas in Canada where rates are less than 10 (please see Table 3 in Appendix A). Both regions have benefited from being home to large globally competitive technology firms (Nortel and RIM/Blackberry) although these firms are in various stages of decline. The degree to which these firms have contributed to overall local prosperity and how each city will cope without their past influence remains an open question, but it should be noted that these regions do indeed have healthy innovation ecosystems regardless. Vancouver is the next most innovative city region as measured by patents fuelled by a diverse knowledge-based economy. The next three on the list are more surprising – Windsor, Kingston and Guelph three smaller Ontario cities. Windsor is home to a large amount of manufacturing, automotive in particular, and it would seem that this base has generated a significant level of innovation. Kingston and Guelph are both relatively small regions but with significant research intensive universities. The main difference between the two is that Guelph also has a strong manufacturing base. The regions at the bottom of the table are typically places that have traditionally relied on resource extraction as the main driver of their economies. This is a fairly well-known story about the Canadian economy but it also represents an opportunity as there is no significant reason why firms in such industries cannot partake in world-leading innovative activities.

A similar list of regions performs best at entrepreneurship as measured by the rate of high-tech start-ups. The main observable difference is that the larger urban areas seem to outperform the smaller ones. Toronto, Ottawa-Gatineau, Calgary, and Vancouver, each with at least one million residents, occupy the top four positions. Kitchener-Waterloo, Guelph, and Windsor on the other hand fall out of the top ten despite producing high levels of patents. There seems to be at least a partial disconnect between the geography of technological innovation and entrepreneurship.

4.2 Supporting Factors

As with the dependent variables, there is generally a high level of variation between regions on many of the finance, human capital, and industrial structure variables. This is particularly true in the case of finance (please see Table 4 in Appendix B), which is the most fluid and mobile of the contributing factors. Public R&D funding, as reported by the Canadian Association of University Business Officers which tracks funding flowing through universities and research hospitals, is unsurprisingly highest (on a per capita basis) in smaller urban regions that have a relatively large university presence. Kingston, Guelph, Saskatoon, Hamilton, and London represent the

"Urban size and history are not the only determinants however, as many of the smaller urban success stories have had similar industrial pasts but have managed to find ways to develop strong innovation systems"

top five regions. Conversely, a number of regions lack any significant public research institution and therefore report no funding whatsoever. Private R&D expenditures skew more towards larger urban areas (with a few notable exceptions) and are also influenced by differences in provincial policies that link to the federal SR&ED program. Ottawa-Gatineau, Guelph, Montreal, Calgary, Kitchener-Waterloo, and Toronto are the top six locations for private R&D spending on a per capital basis. Once again there are some regions that are home to negligible levels of private R&D spending including Sudbury and Thunder Bay which report no expenditures. Venture capital funding shows a roughly similar pattern to that of the private R&D expenditures. It should be noted however that VC data are highly volatile and can be significantly affected by large one-off deals.

Geographic patterns of human capital factors are also highly unequal across Canada's urban system, although not as radically as finance. Larger cities tend to have the strongest human capital profiles although there are a number of notable exceptions (please see Table 5 in Appendix B). Ottawa-Gatineau, Toronto, Vancouver, and Calgary rate overall as the top regions for human capital. There is a high level of covariance across the individual variables with the exception of maths and science PhDs which tends to be highly influenced by the presence of universities (especially in smaller urban areas). The M&S PhDs variable is also highly correlated with public R&D funding which together essentially indicate the relative importance of universities within the local region. It is important to note the regions at the bottom of the list do not have significant research universities. In particular, cities such as Brantford, Barrie, and Peterborough have similar industrial histories to places such as Guelph, Kitchener-Waterloo, and Kingston but strikingly dissimilar human capital profiles.

A great deal of current regional outcomes are directly tied to the industrial composition of the local economy which is rooted in long-term historical processes. City size is also a closely related factor as larger urban areas benefit from various aspects of economies of scale and are also more able to sustain a more diverse economic base. The top four Canadian regions, based on the five industrial structure variables, support this notion (please see Table 6 in Appendix B). Calgary, Montreal, Toronto, and Vancouver rank as the four best overall with the synthetic industry variable as the only one that is significantly inconsistent with the index score. This is largely due to synthetic industries being primarily resource and manufacturing-based which tend to locate in smaller urban regions mainly for reasons of cost and congestion. The bottom of the table is dominated by regions that are characterized as smaller urban areas that are specialized in non-knowledge intensive sectors, often in resources or basic manufacturing. These cities are likely going to struggle to compete in the 21st century global economy and will need to find ways to reinvent themselves.

4.3 Statistical Analysis

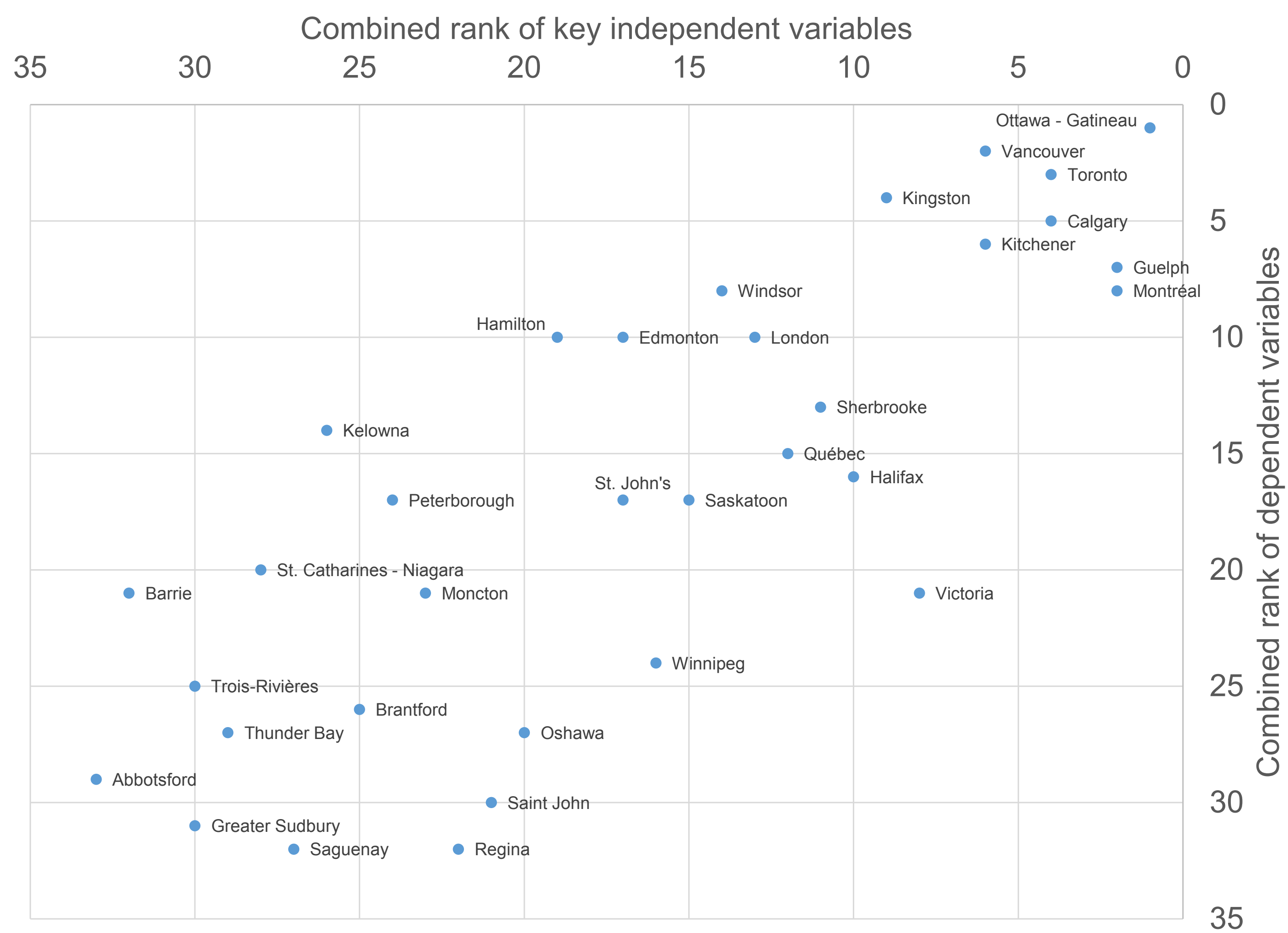
The first set of five regression models test the relationship between the sets of independent variables and patenting rates for the 33 census metropolitan areas (please see Figure 3 in Appendix C). Models 1 through 4 isolate each group of variables based on the finance, human capital, industrial structure, and general categories. These models identify the statistically significant variables which are then carried forward to the 5th model which then tests these factors together. Of the first four models, Model 1, which incorporates the three finance variables, is the strongest predictor of patenting rates. Specifically, business R&D is the most significant factor followed by public R&D funding which has a much weaker relationship with patenting. Venture capital is not a statistically significant variable. Model 2 is the second strongest overall model. In this case, maths and science PhDs are the most significant variable with cultural diversity showing a weak relationship. Models 3 and 4 are generally weak models overall with analytic industries and rents displaying a degree of significance. Model 5 is statistically a strong model for predicting patenting rates in regions. It shows that business R&D and maths and science PhDs as the two main contributing factors.

The second set of five regression models following the same blueprint as the first five except that they test for relationships with entrepreneurship as measured by high-tech business formation rates by region (please see Figure 4 in Appendix C). Model 6 is not a particularly strong predictor of high-tech start-ups but as with model 1, business R&D and public R&D funding are both statistically significant variables. Model 7 is a relatively strong model as MBAs per capital is highly correlated with business formation rates. Model 8 is the strongest of the initial models with clustering as the important contributing factor associated with high-tech start-up rates. Model 9 shows that larger cities are statistically more likely to have higher levels of entrepreneurship. When each of the significant variables are combined in model 10, business expertise, as measured by MBAs per capital, emerges as the most important factor associated with high-tech business formation rates.

4.4 Summary

The overall message from the analysis is that no single factor can effectively predict why technological innovation and its commercialization happen at greater degrees in some places more than other. Furthermore, the factors that predict levels of technologi-

Figure 1 - Combined rankings of key independent and dependent variables



cal innovation are not the same ones that predict levels of entrepreneurship. The picture is complex but not impossibly so. The general model that emerges from the analysis in this report is that clusters of R&D intensive firms, research intensive universities, and a pool of highly skilled labour in regions are all necessary components of highly innovative and prosperous regions. It is important to note that these factors are not necessarily 'naturally' aligned with one another as they span public and private organizations. The models presented are not able to perfectly quantify factors and predict outcomes and so the suggestion is that the 'softer' contributing factors such as the institutions and organizational capacity of regions makes up a great deal of the unexplained element.

When looking at the Canadian urban system as a whole, a fairly clear pattern emerges whereby there are three distinct groups of regions. Based on the indictors in this report there are eight regions that can lay claim to having well-functioning innovation ecosystems (please see Figure 1). Ottawa-Gatineau, Toronto, Vancouver, Calgary, Kitchener-Waterloo, Kingston, Montreal, and Guelph are clearly ahead of the rest of the pack in terms of both technological innovation and entrepreneurship as well as the key supporting factors. Most of these are well-known with the possible surprises being Kingston and Guelph. A common element between all of these regions is the local presence of highly respected research-intensive universities. At the other end of the spectrum there is a group of 15 regions that do not perform well on technological innovation, high-tech start-ups or the key supporting factors. They tend to be smaller regions with economic-bases that have been historically driven by natural resources or manufacturing. None of these regions are home to major research-intensive universities. These regions do not have, and likely will not ever have, the assets that are necessary for supporting successful innovation ecosystems. A third group of ten regions is perhaps the most interesting as they are in between the top and bottom of the rankings while generally possessing the necessary ingredients for successful innovation ecosystems they are not performing as well as they might. It is this group that may be most responsive to public policy interventions.

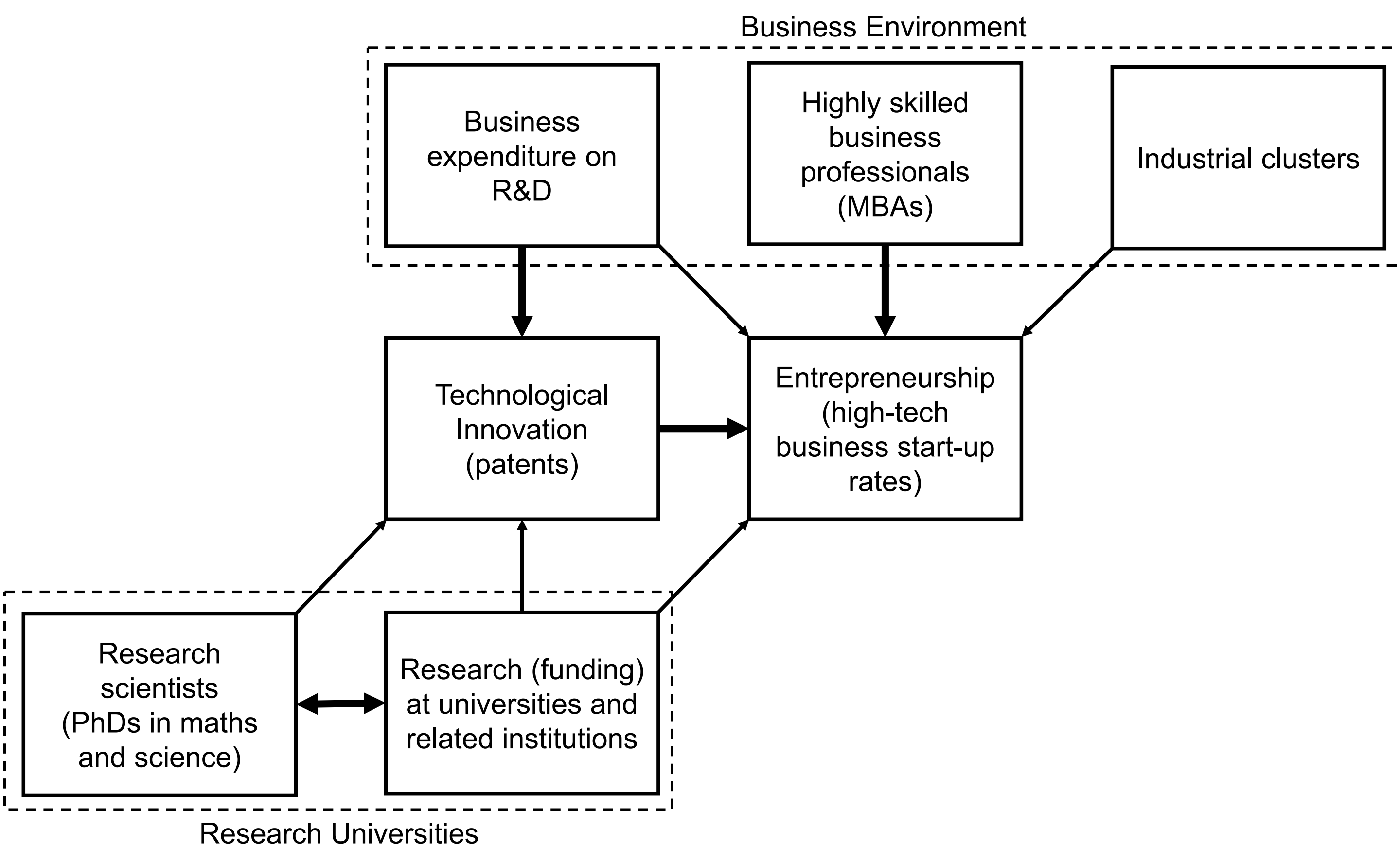
5.0 Conclusions and Policy Discussion

The statistical analysis presented in this report allows for some useful generalizations about how regional innovation ecosystems tend to function in the Canadian context. These findings are also able to inform policy making on a practical level. The analysis is also generally congruent with recent studies at the national level that highlight Canada's relative strengths in research but weakness in commercialization (Industry Canada 2011; Council of Canadian Academies 2013). That being said this gap is particularly evident in some regions more than others. While a general model of successful innovation ecosystems can be gleaned from the analysis it is very important to note that not all regions currently possess the public institutions or private sector economic base in order to sustain a thriving high-tech economy. Thus it is essential to keep in mind that any policy recommendations informing economic development strategies need to be highly cognizant of local context and realities.

A number of generalizations are evident from the analysis and when taken in conjunction with one another form a general model of regional innovation ecosystems for Canadian urban areas (please see Figure 2). The key observations are:

- the factors that influence rates of technological innovation are not the same factors that influence the rates of entrepreneurship;
- a combination of spending (particularly in the private sector) plus a wealth of highly skilled research scientists are the most important factors that drive technological innovation;
- the presence of highly trained business specialists is the key factor for entrepreneurship;
- the presence of highly respected research-intensive universities is an es-

Figure 2 - A model of regional innovation ecosystems in Canadian city-regions



sential component of successful regional innovation ecosystems, and that basic scientific research matters, but the supply of highly trained scientists matters more;
- city size matters – especially to commercialization as there tends to be more business expertise in larger urban areas, and;
- some city-regions do not possess research-intensive universities, high concentrations of business expertise, or the economic profile necessary to become high-tech economies.

There are a number of straightforward policy recommendations to be made from these observations. First is that a continued effort spark investment in private R&D is essential. The details of exactly how this is done cannot be answered in this report but it is important to keep in mind which sectors in which locations are most likely to benefit from public sector involvement. A second general policy area is that higher-educational institutions with a research focus need to be world-class. The ongoing basic scientific research within universities as well as the training of highly skilled scientists and business professional are both essential goals. A third recommendation is that work needs to be done to ensure that technological innovation gets translated into commercially successful products. Incubators and other mechanisms for assisting particularly new and small business need to be supported and connected to the wider innovation ecosystem. A fourth overall policy message is that the various elements of successful regional innovation ecosystems need to be orga-

Table 2 - Regional typologies and policy recommendations

Region Type	Ontario City-Regions	Policy Recomendations
High-performing innovation ecosystems	Guelph Kingston Kitchener-Waterloo Ottawa-Gatineau Toronto	• Identify key local strengths in order to focus supporting policies • Continue to spur business expeditures on R&D • Continue to support universities through funding of research and supply of training opportunities for highly skilled personel
Low-performing innovation ecosystems	Hamilton London Windsor	• Identify specific areas of weakness • Spur further business investment in R&D • Continue to support universities through funding of research and supply of training opportunities for highly skilled personel • Work to improve local institutional coordination and cooperation
Process-based innovation ecosystems	Barrie Brantford Oshawa Peterborough Sudbury St. Catharines-Niagara Thunder Bay	• Focus on 'bottom-up' and incremental innovation processes • Supprt colleges and build linkages to local labour market needs • Link to nearby high-performing innovation ecosystems

nized and coordinated, preferably at the local level. By using the terms borrowed from natural science such as 'ecosystem' there is a danger that it will be interpreted from a policy perspective that intervention can only do harm to the 'natural' state which provides an optimal context. This layer on top of the common disdainful refrain of government 'picking winners' leaves many to believe that less government involvement is ideal. While private firms are indeed the ultimate drivers of innovation, they do not do so in a vacuum. Many factors beyond the direct control of companies have major impacts on their competitiveness. This is not to say that economies should be controlled in a top-down manner but that the most effective method for developing successful regional innovation ecosystems is by building networks and relationships through local partnerships and organization.

With these general messages in mind there need to be some specific points made concerning the current state of city-regions in Ontario (please see Table 2). As was outlined in the findings there are three distinct sets of regions that perform at varying levels on measures of innovation, entrepreneurship, and the key supporting factors. Of the eight regions in Canada that have relatively successful innovation ecosystems, five are in Ontario. It is important to try and further understand what is going right in Ottawa-Gatineau, Toronto, Kitchener-Waterloo, Kingston , and Guelph so that this success can be sustained and that key lessons can be transferred to other regions that are not performing as well. The second group of ten regions contains three in Ontario. Hamilton, London, and Windsor appear to have the basic characteristics necessary for building successful high-tech economies but they appear to be lagging. The weakest element from these innovation ecosystems is private sector R&D. Why this is the case requires further research but understanding this could shed additional insights on regional level policy. The final set of 15 regions contains seven cities in Ontario. These places have the greatest need for assistance but also pose the greatest dilemma. Many, if not all, of these regions (Oshawa is a possible exception) do not possess the basic assets necessary for sustaining a globally competitive high-tech economy. The questions then becomes should these assets be added or should an alternative approach to economic development be pursued? With the former there would need to be massive investments made in greatly expanding the higher-education system in Ontario by either adding new institutions or enhancing existing ones with a current focus on undergraduate education. It highly questionable whether this route is feasible or even desirable. A possible alternative is to place a greater focus on bottom-up innovation that takes place on the 'shop floor'. The desired effect is to increase productivity levels and increase competitiveness based on efficiency (rather than novelty). This approach necessitates a different set of policies, particularly around education whereby the college system is likely to play a larger role. In any case one of the most important policies lessons is that local context must be well understood in order for sound decisions to be made concerning the future of regional innovation ecosystems in Ontario and Canada.

Appendix A - Dependent Variables

Table 3 - Regional output variables

	Technological Innovation		High-tech Entrepreneurship		Incomes		Overall
CMA	Patents per 10,000 adult pop.	Rank	High-tech business formation rate	Rank	Median Emp. Income	Rank	Rank
Ottawa - Gatineau	16.8	1	12.8	2	$33,892	1	**1**
Toronto	6.0	8	13.1	1	$30,350	6	**2**
Calgary	5.5	9	12.8	3	$31,572	3	**2**
Kitchener	13.9	2	7.5	11	$30,719	5	**4**
Guelph	6.5	6	7.1	13	$31,470	4	**5**
Vancouver	9.2	3	11.2	4	$27,596	16	**5**
Windsor	7.5	4	6.5	16	$30,060	9	**7**
Kingston	6.6	5	10.5	6	$26,663	20	**8**
Hamilton	3.8	18	8.9	8	$30,186	7	**9**
Edmonton	4.9	11	7.0	15	$30,115	8	**10**
London	4.7	12	7.0	14	$28,727	12	**11**
Montréal	4.6	13	10.4	7	$26,731	19	**12**
Québec	4.3	14	6.4	17	$28,192	15	**13**
Halifax	2.1	24	8.9	9	$27,219	17	**14**
Barrie	3.7	19	5.1	23	$30,059	10	**15**
Oshawa	1.5	25	3.9	28	$33,863	2	**16**
Sherbrooke	3.9	17	8.0	10	$24,303	30	**17**
St. John's	0.7	32	11.0	5	$26,022	23	**18**
Saskatoon	5.5	10	4.3	27	$25,702	24	**19**
Kelowna	6.1	7	5.5	21	$23,692	33	**19**
Brantford	3.7	20	3.2	29	$28,311	13	**21**
Victoria	4.0	16	4.5	26	$26,329	22	**22**
Peterborough	4.2	15	5.1	22	$24,497	29	**23**
Moncton	1.0	30	7.1	12	$25,068	25	**24**
St. Catharines-Niagara	2.7	21	5.9	19	$24,750	27	**24**
Thunder Bay	0.6	33	5.7	20	$28,213	14	**24**
Winnipeg	2.6	22	5.0	24	$26,624	21	**24**
Regina	1.4	27	3.1	32	$29,210	11	**28**
Greater Sudbury	1.3	28	3.2	30	$26,793	18	**29**
Trois-Rivières	1.1	29	6.4	18	$24,059	31	**30**
Saint John	0.8	31	4.9	25	$24,981	26	**31**
Abbotsford	2.4	23	3.1	31	$24,541	28	**31**
Saguenay	1.5	26	2.6	33	$23,999	32	**33**

Appendix B - Independent Variables

Table 4 - Finance variables

	Public R&D Funding		Private R&D Expendiature		Venture Capital		Overall
CMA	Public R&D $ per Adult Pop.	Rank	Business Enterprise R&D $ per Adult Pop.	Rank	VC $ per Adult Pop.	Rank	Rank
Guelph	$3,230	2	$1,799	2	$763.4	1	**1**
Ottawa - Gatineau	$818	13	$3,468	1	$315.7	2	**2**
Montréal	$765	14	$1,443	3	$188.4	6	**3**
Sherbrooke	$1,384	6	$264	16	$188.5	5	**4**
Kitchener	$877	12	$1,241	5	$91.3	10	**4**
Calgary	$644	17	$1,427	4	$112.2	8	**6**
Vancouver	$682	15	$828	8	$145.0	7	**7**
Victoria	$913	11	$264	17	$200.9	4	**8**
Québec	$1,323	7	$489	12	$68.0	14	**9**
Toronto	$505	18	$1,171	6	$84.5	11	**10**
Saskatoon	$1,900	3	$223	20	$84.4	12	**10**
Kingston	$3,683	1	$303	15	$6.2	21	**12**
Winnipeg	$659	16	$342	13	$97.0	9	**13**
Edmonton	$1,216	8	$224	19	$50.2	15	**14**
London	$1,459	5	$245	18	$0.7	23	**15**
Halifax	$945	10	$183	21	$41.8	16	**16**
Hamilton	$1,510	4	$161	23	$3.0	22	**17**
St. John's	$1,129	9	$137	27	$9.4	19	**18**
Saint John	-	28	$678	9	$6.6	20	**19**
Moncton	$204	25	$22	31	$206.4	3	**20**
Peterborough	$402	19	$311	14	-	26	**20**
Windsor	$241	24	$660	10	-	26	**22**
Oshawa	-	28	$1,104	7	-	26	**23**
St. Catharines-Niagara	$113	26	$144	26	$70.3	13	**24**
Brantford	-	28	$573	11	-	26	**24**
Saguenay	$300	22	$104	29	$27.4	18	**26**
Regina	$322	21	$159	24	$0.1	24	**26**
Trois-Rivières	$279	23	$76	30	$34.1	17	**28**
Barrie	-	28	$178	22	$0.0	25	**29**
Thunder Bay	$400	20	-	32	-	26	**30**
Kelowna	-	28	$148	25	-	26	**31**
Abbotsford	$22	27	$107	28	-	26	**32**
Greater Sudbury	-	28	-	32	-	26	**33**

Table 5 - Human capital variables

CMA	University Degree: % 16-64 with Bach-elors Degree	Rank	Creative Class: % labour force in 'creative class'	Rank	Maths & Science PhDs: Maths & Science PhDs per 1,000 Adult Pop.	Rank	Business Experts: MBAs per 1,000 Adult Pop.	Rank	Cultural Diversity: Entropy Measure (Place of Birth)	Rank	Overall: Rank
Ottawa - Gatineau	28.7%	1	41.5%	1	7.6	3	15.0	2	2.7	7	**1**
Toronto	26.7%	2	35.2%	3	3.5	14	15.3	1	6.7	1	**2**
Vancouver	24.6%	4	33.8%	4	4.5	9	10.4	5	4.7	2	**3**
Calgary	24.7%	3	35.8%	2	4.1	11	10.3	6	3.1	3	**4**
Victoria	23.6%	7	33.4%	5	5.6	5	11.0	3	2.1	15	**5**
Montréal	21.0%	9	33.1%	6	3.7	13	10.6	4	2.7	8	**6**
Guelph	23.9%	6	31.0%	11	8.1	2	6.3	16	2.3	13	**7**
Halifax	24.0%	5	33.1%	7	4.9	7	10.2	7	1.3	25	**8**
Kingston	21.7%	8	32.2%	10	10.7	1	7.5	12	1.6	23	**9**
Kitchener	18.4%	14	28.3%	18	5.1	6	8.1	11	2.8	6	**10**
Hamilton	17.5%	20	29.1%	15	3.3	16	7.1	14	2.9	5	**11**
Saskatoon	19.4%	11	29.2%	13	5.7	4	4.5	23	1.7	19	**11**
London	18.3%	16	27.9%	19	4.6	8	6.0	17	2.3	12	**13**
Winnipeg	19.0%	12	29.2%	14	3.2	18	5.3	19	2.6	10	**14**
Edmonton	18.3%	17	29.0%	16	4.0	12	4.9	20	2.6	9	**15**
St. John's	18.8%	13	32.9%	8	3.4	15	8.6	9	0.9	30	**16**
Québec	20.2%	10	32.7%	9	3.3	17	10.0	8	0.8	31	**16**
Sherbrooke	17.6%	19	28.5%	17	4.2	10	8.1	10	1.0	29	**18**
Windsor	17.8%	18	24.6%	30	2.7	19	7.1	15	2.9	4	**19**
Regina	18.4%	15	30.7%	12	2.1	21	5.3	18	1.7	21	**20**
Moncton	16.1%	21	27.6%	20	1.8	23	7.4	13	1.1	27	**21**
Oshawa	13.1%	27	27.1%	23	0.8	31	4.8	21	1.9	16	**22**
Thunder Bay	14.8%	22	25.5%	28	2.1	20	3.4	30	1.8	18	**22**
Kelowna	12.6%	30	26.7%	24	1.8	24	3.6	26	1.9	17	**24**
St. Catharines-Niagara	13.1%	28	23.4%	31	1.3	27	3.7	25	2.2	14	**25**
Saint John	14.1%	24	27.2%	21	1.3	29	4.0	24	1.1	28	**26**
Peterborough	14.5%	23	27.1%	22	2.1	22	2.9	33	1.3	26	**26**
Greater Sudbury	13.2%	26	24.9%	29	1.8	25	3.4	28	1.5	24	**28**
Abbotsford	11.6%	32	21.5%	32	0.7	32	3.4	29	2.4	11	**29**
Trois-Rivières	13.6%	25	26.5%	25	1.3	28	3.4	27	0.7	32	**30**
Saguenay	12.5%	31	25.9%	26	1.6	26	4.8	22	0.7	33	**31**
Barrie	12.6%	29	25.7%	27	0.5	33	3.4	31	1.7	20	**32**
Brantford	11.1%	33	21.5%	33	0.9	30	3.1	32	1.6	22	**33**

Table 6 - Industrial structure variables

	Industrial Clusters		Related Variety		Symbolic Industries		Synthetic Industries		Analytic Industries		Overall
CMA	% Emp. in Clusters	Rank	RV Index	Rank	Share of Emp.	Rank	Share of Emp.	Rank	Share of Emp.	Rank	Rank
Calgary	42.0%	2	10.2	2	24.8%	12	16.6%	5	5.9%	9	**1**
Montréal	35.0%	4	10.1	3	31.0%	1	13.9%	17	6.5%	6	**2**
Toronto	42.1%	1	9.9	6	30.6%	3	13.5%	21	6.9%	3	**3**
Vancouver	40.5%	3	10.4	1	29.0%	5	13.8%	18	6.0%	8	**4**
Halifax	19.0%	13	9.8	8	27.4%	6	13.9%	15	6.5%	5	**5**
Québec	7.1%	28	10.0	5	30.4%	4	15.3%	8	6.9%	4	**6**
Hamilton	21.7%	8	9.9	7	24.0%	13	14.2%	14	4.3%	21	**7**
St. John's	19.9%	12	9.4	18	25.6%	8	13.7%	19	6.0%	7	**8**
Guelph	21.7%	9	8.9	26	22.4%	17	14.9%	11	7.0%	2	**9**
Victoria	24.1%	7	9.5	14	26.1%	7	12.1%	29	5.5%	11	**10**
Edmonton	18.9%	14	10.1	4	19.9%	30	17.1%	3	4.6%	18	**11**
Sherbrooke	9.9%	23	9.2	20	25.5%	9	16.2%	6	5.2%	12	**12**
Ottawa - Gatineau	16.7%	17	8.9	27	30.6%	2	12.8%	25	8.1%	1	**13**
Kitchener	20.3%	11	9.4	17	21.8%	20	14.6%	13	5.1%	13	**14**
Kelowna	16.8%	16	9.8	9	20.6%	25	15.0%	9	2.9%	32	**15**
Greater Sudbury	16.6%	18	9.1	23	20.5%	27	16.7%	4	4.1%	22	**16**
Moncton	8.8%	25	9.7	10	23.6%	15	11.6%	32	5.0%	14	**17**
Trois-Rivières	0.0%	32	8.8	29	25.1%	10	19.8%	2	4.0%	25	**18**
Saguenay	3.5%	30	7.8	31	25.0%	11	23.3%	1	3.8%	26	**19**
London	10.9%	22	9.3	19	23.2%	16	12.5%	28	4.8%	15	**20**
Windsor	21.0%	10	7.4	33	20.0%	29	15.6%	7	4.1%	23	**21**
Saskatoon	15.1%	20	9.6	12	20.6%	26	12.7%	27	4.6%	17	**21**
Kingston	7.5%	27	9.2	21	23.7%	14	11.8%	31	5.6%	10	**23**
Barrie	24.4%	6	9.0	24	20.7%	24	13.1%	24	3.1%	30	**24**
Regina	15.4%	19	9.5	16	20.9%	22	10.9%	33	4.5%	19	**25**
Winnipeg	1.8%	31	9.5	15	22.3%	18	12.0%	30	4.7%	16	**26**
Oshawa	8.3%	26	8.8	28	22.2%	19	13.9%	16	4.0%	24	**27**
St. Catharines-Niagara	12.6%	21	9.6	13	19.9%	31	13.5%	20	3.1%	29	**28**
Brantford	18.5%	15	9.6	11	17.7%	33	13.4%	22	2.6%	33	**28**
Saint John	0.0%	32	8.4	30	21.0%	21	14.8%	12	4.4%	20	**30**
Abbotsford	28.5%	5	9.2	22	18.3%	32	12.8%	26	3.0%	31	**31**
Thunder Bay	8.9%	24	7.8	32	20.3%	28	14.9%	10	3.4%	28	**32**
Peterborough	4.2%	29	9.0	25	20.8%	23	13.1%	23	3.5%	27	**33**

Appendix C - Statistical Analysis

Table 7 - Corrleation coefficients

	Patents	HTFormation	Incomes	PubRD	BERD	VC	BA	CC	MSPHD	MBA	CDiversity	PctCluster	RVariety	Symbolic	Synthetic	Analytic	Rents	Population
Patents																		
HTFormation	0.50																	
Incomes	0.49	0.34																
PubRD	0.28	0.36	0.15															
BERD	0.74	0.53	0.65	0.15														
VC	0.36	0.27	0.26	0.48	0.57													
BA	0.56	0.76	0.45	0.51	0.60	0.51												
CC	0.49	0.77	0.41	0.40	0.62	0.40	0.92											
MSPHD	0.58	0.54	0.28	0.87	0.44	0.52	0.76	0.66										
MBA	0.53	0.79	0.39	0.25	0.60	0.35	0.88	0.87	0.54									
CDiversity	0.47	0.52	0.45	0.01	0.40	0.15	0.53	0.36	0.20	0.53								
PctCluster	0.34	0.53	0.37	-0.01	0.33	0.19	0.49	0.37	0.15	0.53	0.74							
RVariety	0.14	0.40	0.05	0.16	0.05	0.09	0.38	0.41	0.18	0.38	0.35	0.50						
Symbolic	0.30	0.69	0.15	0.21	0.45	0.29	0.71	0.80	0.39	0.86	0.30	0.31	0.35					
Synthetic	-0.14	-0.12	-0.17	-0.15	-0.09	-0.05	-0.25	-0.19	-0.23	-0.17	-0.23	-0.16	-0.34	0.05				
Analytic	0.46	0.73	0.39	0.50	0.63	0.57	0.91	0.90	0.69	0.88	0.32	0.33	0.34	0.83	-0.14			
Rents	0.49	0.37	0.54	0.06	0.37	0.15	0.37	0.30	0.23	0.34	0.67	0.66	0.39	0.07	-0.40	0.16		
Population	0.26	0.60	0.24	-0.03	0.39	0.12	0.53	0.49	0.12	0.65	0.79	0.64	0.43	0.63	-0.08	0.49	0.36	

Figure 3 - Factors associated with patenting rates in Canadian city-regions

	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t	β	t	β	t	β	t	β	t
PubRD	0.001	1.97 *							-0.002	-2.02 *
BERD	0.004	5.83 ***							0.003	3.67 ***
VC	-0.006	-1.55								
MSPHD			0.72	2.89 ***					1.504	3.53 ***
MBA			0.12	0.60						
CDiversity			0.96	1.98 *					0.425	1.01
PctCluster					8.7	1.45				
RVariety					-0.7	-0.67				
Symbolic					-23.0	-0.77				
Synthetic					-6.8	-0.25				
Analytic					158.4	2.00 *			-92.61	-2.17 **
Rents							0.014	2.65 **	0.002	0.39
Population							0.000	0.61		
Constant	1.679	2.65 **	-0.86	-0.73	8.19	0.76	-5.690	-1.56	1.689	0.52
N		33		33		33		33		33
R2		0.61		0.48		0.29		0.25		0.76
Adjusted R2		0.56		0.42		0.16		0.20		0.70
F		14.82 ***		8.80 ***		2.24 *		4.90 **		13.45 ***

* p < 0.1   ** p < 0.5   *** p < 0.01

Figure 4 - Factors associated with high-tech business formation rates in Canadian city-regions

	Model 6		Model 7		Model 8		Model 9		Model 10	
	β	t	β	t	β	t	β	t	β	t
PubRD	0.001	2.37 **							0.001	1.89 *
BERD	0.003	3.58 ***							0.000	0.63
VC	-0.006	-1.42								
MSPHD			0.24	1.41						
MBA			0.55	4.11 ***					0.47	3.04 ***
CDiversity			0.42	1.30						
PctCluster					7.96	2.21 **			3.34	0.89
RVariety					0.06	0.10				
Symbolic					20.30	1.14				
Synthetic					-2.06	-0.13				
Analytic					92.54	1.95				
Rents							0.005	1.17		
Population							0.000	3.49 ***	0.000	0.93
Constant	4.810	7.32 ***	1.51	1.90 *	-4.00	-0.62	2.588	0.93	2.082	2.39 **
N		33		33		33		33		33
R2		0.40		0.67		0.65		0.39		0.69
Adjusted R2		0.34		0.63		0.58		0.35		0.64
F		6.51 ***		19.29 ***		9.88 ***		9.43 ***		12.17 ***

* p < 0.1   ** p < 0.5   *** p < 0.01

References

Asheim, B. T., & Gertler, M. S. (2005). The geography of innovation: Regional innovation systems. In J. Fagerberg, D.C.Mowery, & R. Nelson, *The Oxford Handbook of Innovation* (pp. 291-317). Oxford: Oxford University Press.

Asheim, B., & Hansen, H. K. (2009). Knowledge bases, talents, and contexts: on the usefulness of the creative class approach in Sweden. *Economic Geography*, 85, 425-442.

Beckstead, D., & Brown, M. (2003). From Labrador City to Toronto: The industrial diversity of Canadian cities, 1992-2002. *Statistics Canada*.

Boschma, R. A., & Frenken, K. (2006). Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography*, 6, 273-302.

Council of Canadian Academies (2013). *PARADOX LOST: Explaining Canada's Research Strength and Innovation Weakness*. Ottawa (ON): Advisory Group, Council of Canadian Academies.

Etzkowitz, H. (2003). Innovation in innovation: The triple helix of university-industry-government relations. *Social Science Information*, 42(3), 293-337.

Florida, R. L., & Kenney, M. (1988). Venture Capital, High Technology and Regional Development. *Regional Studies*, 22(1), 33-48.

Florida, R. (2002). *The Rise of the Creative Class*. New York: Basic Books.

Frenken, K., Van Oort, F., & Verburg, T. (2007). Related variety, unrelated variety and regional economic growth. *Regional Studies*, 41(5), 685-697.

Glaeser, E. L. (2005). Edward L. Glaeser, review of Richard Florida's rise of the creative class. *Regional Science and Urban Economics*, 35(5), 593-596.

Industry Canada. (2011). I*nnovation Canada: A Call to Action. Ottawa* (ON): Independent Panel on Federal Support to Research and Development, Industry Canada.

Nooteboom, B. (2000). Learning by interaction: absorptive capacity, cognitive distance and governance. *Journal of management and governance*, 4(1-2), 69-92.

Ottaviano, G. I., & Peri, G. (2006). The economic value of cultural diversity: evidence from US cities. *Journal of Economic Geography*, 6(1), 9-44.

Peck, J. (2005). Struggling with the creative class. *International journal of urban and regional research*, 29(4), 740-770.

Porter, M. E. (1998). Clusters and competition: new agendas for companies, government, and institutions. In M. E. Porter, *On Competition*. Cambridge, MA: Harvard Business Review Books.

Spencer, G. M. (2011). Local diversity and economic activity in Canadian city-regions. In H. Bathelt, M. P. Feldman, & D. F. Kogler (Eds.), *Beyond Territory: dynamic geographies of knowledge creation, diffusion, and innovation* (pp. 46-63). New York: Routledge.

Spencer, G. M., Vinodrai, T., Gertler, M. S., & Wolfe, D. A. (2010). Do Clusters Make a Difference? Defining and assessing their economic performance. *Regional Studies*, 44, 697-715.