Research Funding: Key to Clusters

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J. Adam Holbrook and Bruce P. Clayman*
Centre for Policy Research on Science and Technology (CPROST)
Simon Fraser University
515 West Hastings Street
Vancouver, B.C. V6B 5K3

Summary

The Canadian federal government's *Innovation Strategy* has among its aims the creation and nurturing of internationally recognized knowledge-based industrial clusters. The collective efforts of the principal federal granting agencies (NSERC, SSHRC, CIHR and CFI), which are the chief funders of university research, are an integral part of the Government's programs to meet the objectives set out in its existing policies for regional economic and social development and the *Innovation Strategy*. We have determined the research investments by each of the agencies in each of 27 distinct regions/cities of Canada. The award of R&D grants by the agencies' peer review committees is at arm's length and represents an informed assessment of the quality of R&D proposals. When normalized by population or by the number of highly qualified personnel in a region, these ratios are good indicators of the "productivity" of the region in terms of intellectual property. A useful way of comparing the research intensities of Canadian cities is to plot them against the proportion of highly qualified persons in the population, which is a good measure of its receptor capacity. We have investigated other indicators such as university enrolments, industrial R&D expenditures, research publications, international comparators and reported measures of innovativeness in an attempt to correlate them with cluster formation and activity. The existence of several, globally competitive, clusters in Canada is well-documented and clear linkages to university research have been traced through studies of licensing and spin-off activities. The Biotechnology and Information and Communication Technology (ICT) sectors are examples of areas where there appears to be a clear linkage between granting agency investment and industrial activity

Background

The Canadian federal government's Science and Technology (S&T) policies over the past decade have shown a clear pattern. Over this period, major policy decisions have included:

- a major shift from direct support of S&T activities within the federal laboratory system to increased levels of direct support of basic and early-stage applied research in the university sector
- a shift from direct support for industrial research and innovation to indirect methods such as the Scientific Research and Experimental Development (SRED) tax credit program
- the federal government's *Innovation Strategy* which (with respect to leading-edge S&T) includes a major target: to rank among the top five countries in the world in terms of Research and Development (R&D) performance

*contact information: jholbroo@sfu.ca and clayman@sfu.ca

The *Innovation Strategy* states that among the aims of federal innovation policy is development, by 2010, of at least 10 internationally recognized technology clusters. One useful definition of a "cluster" is:

> "…a geographic concentration of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g. universities, standards agencies, trade associations) in a particular field that compete but also cooperate."[1]

Research by the Innovation Systems Research Network (ISRN) on industrial clusters in Canada and their role in the national system of innovation has confirmed the expectation that one of the common factors is the presence of a large, publicly funded, research institution (usually a university) at the centre of the cluster.[2]

The elements that make a national, provincial or regional economy vibrant and prosperous today are fundamentally different from those of the past. There is growing recognition that regional clusters are a key to economic development. It is generally recognized that developed countries are moving from economies based primarily on tangible assets to ones based on commercialization of intellectual property (IP) and other intangible assets. In these new economies, concepts such as patents, copyrights, customer relationships, brand value, unique institutional designs, the value of future products and services and their structural capital (culture, systems and processes) are critically important to businesses in a region. Economic performance is determined by a region's effectiveness in using its comparative advantages to create and expand knowledge assets and convert them into economic value.

These "economics of place" are driven by the ability to attract, retain and expand human capital and infrastructure and leverage them for economic and social development. In practical terms this means the ways that these assets, usually located in urban areas in the region, are mobilized and how knowledge which is created (often in universities) is transferred from the laboratory to production facilities.[3]

There are four Canadian federal granting agencies: the Natural Science and Engineering Research Council (NSERC), the Social Sciences and Humanities Research Council (SSHRC), the Canadian Institutes of Health Research (CIHR) and the Canada Foundation for Innovation (CFI). Their collective efforts are an integral part of the government's programs to meet the objectives set out in its existing policies for economic and social development and in its *Innovation Strategy*. The granting agencies have the collective ability to support the creation and development of clusters, by concentrating funds in institutions that have the capacity to develop new technologies. These funding activities may also be considered as part of the federal Government's intentions in its program of support for urban areas, whether or not it is a formal part of its planned urban policy.

According to Statistics Canada, in 2002:[4]

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[1] Porter, M., "*Location, Competition, and Economic Development: Local Clusters in a Global Economy,"* Economic Development Quarterly **14(1)** 15-34 (2000)

[2] See Wolfe, D.A. and M.S. Gertler, "*Clusters Old and New: Lessons from the ISRN Study of Cluster Development,*" in "*Clusters Old and New,*" edited by D.A. Wolfe, McGill-Queens University Press, Montreal and Kingston, 2003.

[3] Porter does not suggest the presence of a large public sector research institution is a necessary condition for the existence of a cluster.

[4] Statistics Canada reports, Catalogue 88-001-XIB

- total R&D expenditures in Canada were $20.7 billion or 1.85% of Gross Domestic Product (GDP)
- the federal government spent $4.0 billion on research in 2002; of that $2.2 billion was spent in federal laboratories
- Canadian industry performed $11.2 billion worth of R&D; of that $3.4 billion was funded by foreign sources
- the university sector performed $6.9 billion worth of R&D

The expenditures that make up "research and development" are defined by Statistics Canada. While most of their R&D expenditure statistics are collected through annual surveys, their calculation of university R&D expenditures is based on a complex estimation process. Unless otherwise stated, this report conforms to Statistics Canada definitions.

Indicators of investment in new knowledge

Research and development expenditures are indicators of levels of investment in knowledge and innovation.[5] In Canada, the peer-review system for allocating R&D funding results in a distribution of R&D funding by region/city that reflects the perception of peer reviewers at the granting agencies and other stakeholders that these resources will be transformed into ideas – intellectual capital – at some point in the near future. As with other forms of investment, perceived opportunity influences this allocation of resources. Often current outputs (economic activity, production, profits, etc.) do not reflect forecast conditions. Conversely, current conditions may not reflect levels of R&D inputs.[6] An aggregation of R&D expenditures in a city/region allocated by informed, but arm's length, stakeholders reflects an independent evaluation of the ability of a region to generate knowledge. Output indicators measure the current (or recent past) ability of the region to develop or adopt and adapt ideas. It may be difficult to differentiate the economic and social outcomes of ideas imported from outside the region from those originating from specific ideas developed in the region. A region could conceivably have a very high level of high-tech manufactures but a relatively low level of knowledge generation, as has occurred in some Asian economies. Thus economic output indicators alone are unreliable indicators of S&T activity in a region.

The issue is not so much the lack of data, but the need for an analysis of the data in ways that increase understanding of the critical issues and are also relevant to policy development. In a country as geographically diverse as Canada, most cities are the centres of economic regions. There are a few exceptions – these are dealt with later – but it is possible to look at Canada as a number of economic "islands" (or regions), each centred on a single site of economic activity. Addressing individual clusters becomes more complex. Often individual, site-specific data are not available or are suppressed through aggregation by Statistics Canada because of their confidentiality requirements. In any case, statistics on individual clusters comprise current data (or, more likely, data from the recent past), but the ability to produce knowledge (and thus IP) can provide a forecast of how the cluster is likely to perform in the near future. A practical test is measurement of the ability of the city or region to use its knowledge development resources effectively.

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[5] by Vannevar Bush in 1945 for example, and then the OECD in 1963

[6] For example, university R&D expenditure is not a good predictor of high-tech employment (see Z. Acs, "*Innovation and the Growth of Cities,*" Elgar, Cheltenham, UK, 2002)

The existing distribution of R&D performers across the country has been established by a mixture of economics, history and politics. For subsequent analysis in this study, research funded by and performed in federal research establishments is excluded, since they are not usually funded on a basis that takes into account local economics or local knowledge receptor capabilities. As noted above, two pillars of federal S&T policy are the basic and applied research performed by universities (which injects IP into a community's economy) and the applied research and development performed in industrial laboratories. Provincial and Private Non-Profit (PNP) funders and performers are excluded because they are relatively small contributors to the nation's overall R&D effort and, by extension, do not by themselves significantly influence economic and social activities at the municipal or regional level.

The link between R&D funding and the innovativeness of an economy, regional or otherwise, is based on the premise that R&D funding decisions are exogenous. As noted above, the award of R&D grants by peer review committees is at arm's length, and represents an informed assessment of the quality of R&D proposals. Similarly, industrial R&D decisions, while they are often made within the institution in which the work is performed, usually reflect an assessment of what the overall market served by the enterprise in question is likely to require in the future – not its current product line. By contrast, government R&D expenditures are driven not by local priorities but by national priorities – thus, although there may be exceptions, federal and provincial governments' own research expenditures do not usually fall into the "free market" concept of competition for research funding or generation of ideas.

Since intellectual property is the outcome of R&D activities, highly qualified human resources, the "means of production" of that product, are an essential element in determining the R&D competitiveness of a location. This is closely related to the "receptor capacity" of a region, since not only must the IP be produced, but there must also be a commercial infrastructure that can absorb the IP. This receptor capacity is often closely linked to the number and viability of university spin-off companies.

In a number of articles and books, Richard Florida (see for example Florida, 2002[7]) provides arguments in support of the intuitively attractive notion that cities that are attractive places to live are also attractors of knowledge-based workers, and thus have a competitive advantage over those cities that are not seen in such a favourable light. Gertler *et al.*[8] have confirmed that this is the case for Canadian cities. In particular there is a correlation between the percentage of highly qualified personnel (HQP) and the level of high-tech output (the Milken[9] Techpole index), but an even stronger correlation between the cities' standing in Florida's "Bohemian" index (a measure of factors such as the percentage of the work force who derive their income from artistic activities) and the Techpole index.

A statistic such as annual expenditure on R&D in a given region is difficult to interpret without some national yardstick. Individual regional performances should be compared to the national

[7] Florida, R., "*The Rise of the Creative Class,*" Basic Books, New York, 2002
[8] Gertler, M.S., R. Florida, G. Gates, and T. Vinodrai, "*Competing on Creativity: Placing Ontario's Cities in North American Context,*" 2002 www.competeprosper.ca
[9] The Milken Index was originally developed by the Milken Institute for measuring high-technology output in US cities. It is a measure of factors such as R&D inputs, risk capital, entrepreneurial infrastructure, investment in human capital, and the S&T workforce. Gertler *et al. (op. cit.)* have adapted that index using Canadian data from Statistics Canada.

average, or against each other. To compensate for widely differing conditions – population, economic activity, etc. – the data should be normalized and the result presented as a ratio. For comparing R&D expenditures between nations or states, one traditional measure has been the ratio of R&D expenditures to economic activity, often the gross domestic product (GDP). In line with the arguments in the previous paragraph linking high-tech success to levels of human capital, the denominator should be some measure of human resources in the region. The most obvious measure is population in the region and we have performed normalization by population for each region under study.

Given the work of Florida (*op. cit.*) and Gertler (*op. cit.*), we believe another normalizing factor is also useful: the ratio of R&D expenditures to numbers of highly qualified personnel (HQP). HQP in a region/city can be viewed as the level of human capital available as an input to the R&D process. HQP is defined here as persons between 25 and 64 with at least a Bachelor's degree, according to Statistics Canada 2001 Census data.[10] Use of this normalization links the level of R&D expenditures to a broad measure of the receptor capacity of the city. We will refer to this ratio, R&D expenditures over HQP, as the "R&D intensity."

A "Region" or a "City"?

Studies of regional systems of innovation and studies of industrial clusters converge on individual cities or metropolitan areas. Industrial clusters can only exist in a limited geographical area – the human capital in each cluster should be able to interact on a face-to-face basis, not only to exchange information but also to build the relationships that will be part of their professional activities. In Canada, given its geography, this means that any cluster, existing or putative, is almost always linked to a single city or metropolitan area. Regardless of the means through which clusters are stimulated (e.g. by granting agency funding) they must be analyzed on a municipal basis. Thus in order to analyze federal research support at the cluster level, data on expenditures must be collected by city and regional municipalities and, where there is more than one university per urban entity, these university activities must also be aggregated.

For the most part Census Metropolitan Areas (CMA) and Census Agglomerations (CA), as defined by Statistics Canada, are singular economic areas in Canada. There are three major exceptions: the Greater Toronto area (the "GTA") which includes Barrie (CMA) and Oshawa (CA), the Lower Mainland of British Columbia which should include Abbotsford (CMA) in Vancouver, and the combination of Kitchener-Waterloo and Guelph (CA). In some cases, a CA may be considered to approximate a larger area – thus data for PEI could be attributed to Charlottetown even if the research does take place outside the city boundaries, with the resulting intellectual activity influencing the economic growth of the city. Thus, although the federal Government is developing its urban policy on the basis of a list of 32 CMAs and CAs (see Appendix A), we will use a slightly truncated version (Appendix B) which takes account of these exceptions (GTA includes Barrie and Oshawa, Vancouver includes Abbotsford, and Kitchener-Waterloo includes Guelph, hereafter referred to as KWG). We also note that the main campus of the University of New Brunswick is in Fredericton, whereas the larger population (CMA) is Saint John, which is included in our sample incorporating research expenditures for both

[10] Degrees in all disciplines are included since receptor capacity requires a much wider variety of skills than just S&T skills. This is consistent with Gertler *et al. (op. cit.).*

campuses. For the purposes of this paper we will refer to all of these areas as "cities" regardless of their actual political structure**.**

Each of these cities has at least one research university within its boundaries. We define "research university" as an institution that has at least one Canada Research Chair. Although Okanagan University College in Kelowna has one Chair, and that recently established; its research expenditures are small compared to the next largest university/city, and so it too is dropped from the comparisons herein.

Figures 1a and 1b show the distributions of population and HQP in major centres across Canada. All figures in this paper follow the appendices at the end of the text. It is worth noting that the subject cities comprise only 65.8% of the population but are home to 76.4% of the HQP.

Data, Clusters and Priorities

We start by looking at federal granting agency expenditures and industrial R&D expenditures by subject area across the cities. In order to determine granting agency spending by city and by subject area, data for fiscal year 2001/02 were sorted by date of award, institution and subject area or review committee. Not included were grants where there was more than one institution listed or where the institution was not clear, where the subject area was not clear, or where the total awards by committee were less than 0.5% of the total. Thus the totals for SSHRC and NSERC comprise approximately 75% and 85% respectively of the total awarded for that fiscal year. CIHR data by city are not assigned to CIHR's four "pillars" – the CIHR database was undergoing modification that prevented this; we were able to obtain the overall breakdown of expenditure by pillar. All CFI awards for 2001/02 are listed; we attributed awards for national facilities to the host institution.

Most granting agency expenditure data are not delineated by national "priority" areas or by industrial sectors and they are not classified according to a standard economic or social coding system, as are industrial data. Granting agency expenditures are subdivided by subject or discipline; the main ones are shown in the figures where the information is available. These categories may or may not correspond to an industrial sector or national priority area.

We needed to obtain data on industrial R&D from the Impact Group's Re$earch Infosource because Statistics Canada does not provide industrial R&D expenditure data by city. The Re$earch Infosource data are for the top 100 companies which publicly disclose their R&D expenditures and therefore underreport total industrial R&D expenditures in the cities and nationally. Current Statistics Canada data are based on information provided by corporate head offices and, while in aggregate they are undoubtedly more accurate, they do not give the regional distribution of this important economic activity across the country, in part because head office sites are not necessarily the sites of corporate R&D.

Results of this data gathering and subsequent analysis are presented in Figures 2 – 22, at the end of the text. Figures 2 – 7 show the magnitudes of federal granting agency and of industrial R&D expenditures by cities. The names of some of the cities are truncated due to space limitations. Figures 2a – 5a give the breakdown of total granting agency expenditures by major headings. It is important to note that CFI funding is strictly in support of research infrastructure and their grants tend to be much larger and much more variable, on a year-to-year and institution-to-institution basis, than those of the other three granting agencies. Therefore the data shown in Figure 5 should not be taken as wholly representative of an annual pattern of CFI funding and neither should the totals in Figure 6, since a large component of some of them is CFI expenditures. Figure 7 shows that industrial R&D activity is highly centralized in a relatively few cities and in a very few industrial sectors.

Normalizations of granting agency expenditures and industrial research expenditures by population are shown in Figures 8 – 13. This form of normalization is the most intuitive and gives a useful measure of the degree to which the city is an active R&D centre. The averages cited are the cumulative averages for all the subject cities, found by dividing total expenditures in all the cities by their total 2001 population.

Another useful measure of the capacity of a city to participate in the knowledge-based economy is the proportion of HQP in the population – the "HQP Intensity." These ratios are presented in Figure 14 for the subject cities, based on the 2001 Canadian census.

Clusters of R&D Activity and R&D Intensity

As previously noted, in order to get a measure of the intensity of knowledge production, data on R&D expenditures in a city should be normalized. Looking at R&D intensity as defined above reveals four situations:

- Large urban centres, such as Toronto and Vancouver, with high levels of absolute R&D expenditures and large numbers of HQP in non-R&D activities yield non-extreme levels of R&D intensity,
- "University towns" such as Kingston, where the university is a major factor in the local economy, have high R&D expenditures and low numbers of HQP, resulting in high R&D intensity which may not reflect to true state of the local economy,
- Ottawa and some of the provincial capitals which have low levels of granting agency R&D expenditures and large numbers of HQP in non-R&D, public service activities resulting in low R&D intensity, and
- Other cities where knowledge-based industries are not a large component of the economy have low R&D expenditures and low numbers of HQP, resulting in non-extreme R&D intensity.

The other factor (in addition to R&D intensity) influencing these characterizations is the HQP intensity, as defined above. The HQP intensity is indicative of the extent to which the economy of a city is knowledge-based, but is of course also subject to influence by large numbers of civil servants or management personnel who are not participants in R&D activities. HQP intensity can differentiate regions by their levels of potential high-tech capability and, as seen in Figure 14, ranges from just over 8% to almost 20%.

Thus a possible comparator of R&D investments in cities is a plot of R&D intensity in the city versus HQP intensity. A linear regression can be performed on the data – while the correlation coefficients may not be good, the regression line can give an estimate of the overall trend, so that cities that perform above or below the trend line can be identified. A plot of R&D intensity versus HQP intensity for total expenditures by all four of the granting agencies is presented in

Figure 15.[11] The regression line shows that, although there is a wide dispersion of values, R&D intensity over HQP intensity tends to be roughly constant over a wide range of HQP intensities.

Figure 16 shows the effects (for certain centres) of changes in NSERC expenditures from 1997/1998 to 2001/2002. From this figure we observe that NSERC R&D intensity has approximately kept up with, but not grown faster than HQP intensity. A similar analysis for SSHRC funding shows the same trend.

Publications arising from research can be viewed as a measure of intellectual output. This measure is imperfect, as publication practices vary widely across disciplines. However, it can be used as a broad measure of output, provided its limitations are recognized. Figure 17 shows the number of papers produced over a four-year period in the health sciences and in the natural sciences from each institution (modified by an "impact factor' for each publication) and aggregated by city.[12] R&D in health sciences is typically much more expensive than R&D in natural sciences, but we observe that intellectual outputs across the country (as measured by publications) in the natural sciences are of the same order of magnitude as in the health sciences. Although the classifications are not immediately transferable, a similar relationship might be expected when comparing intellectual output in Biotech with that in ICT. This is additional confirmation that R&D expenditures alone should not be used to indicate the existence of specific clusters.

Numbers of students, both undergraduate (Figure 18) and graduate (Figure 19), can be good indicators of both demand for and supply of HQP. Graduate enrolments, both full-time and part-time, are good indicators of R&D intellectual output. While numbers of students and degrees may not be directly linked to R&D activities or production of knowledge, they are indicators of the level of intellectual "attractiveness" of a city in much the same way as the Canada Council funding can associated with the level of artistic activity in a city. A confounding factor is the limited accessibility to universities in some regions caused by lack of capacity – here demand will be high but impossible to satisfy.

Referring to the data on student enrolments in Figures 18 and 19, we note that Florida (*op. cit.*) and Gertler (*op. cit.*) both confirm long-standing wisdom that the field of study of the HQP labour force should not matter – it appears that the presence of HQP, in all subject areas, is directly linked to the economic growth of a city/region. The number of part-time students is also interesting – it is an indicator of HQP who are also upgrading their skills. In case of graduate students, it is often difficult to differentiate between full-time and part-time study (except by the student's formal enrolment status, which may or may not reflect actual time commitments) or to determine accurately the level of R&D in the graduate work.

While enrolments are clearly related to such external factors as size of the city, they do represent the major input to the knowledge-based workforce in the near future. Again there are exceptions to this interpretation – there are several "university towns" in Canada (such as Kingston) where the majority of the students leave the city after graduation – they will show as anomalously large student enrolments in relation to the local level of R&D activity.

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[11] The slope of the line gives R&D spending /population. There is clearly room for further investigation of the inter-relationship of R&D intensity and R&D/population. Not all cities are labeled due to lack of space.
[12] From the Canadian Science and Innovation Indicators Consortium www.csiic.ca

Cluster Formation in Cities

Because of the large number of externalities that affect the creation and development of clusters it is difficult, from the data above, to draw specific conclusions about clusters within individual cities. Indeed, it can be difficult to link specific research areas supported by the granting agencies to areas of economic activity in the individual cities. However, the existence of several, globally competitive, clusters in Canada is well-documented. Clear linkages to university R&D have been traced through studies of the effectiveness of technology transfer from universities through their licensing and spin-off activities.[13] These studies show that Canadian universities overall are equal to, or superior to, their US counterparts by several important measures.

The Biotechnology (Biotech) and Information and Communication Technology (ICT) sectors are two areas where there appears to be a linkage between granting agency investment and industrial activity.[14] Biotech companies accounted for over half of university spin-off companies in the period 1995 – 2001[15] and ICT companies for over 25%. Neither of these classifications, "Biotech" or "ICT," corresponds directly to specific industrial statistical classifications, nor should they – there are frequent spill-overs from research in one field to economic and social benefits in another. Figure 20 shows the relative level of Biotech research (as approximated by total CIHR expenditures and by expenditures via NSERC biology-related committees) and ICT research (as approximated by NSERC ICT expenditures) supported in Canada. It should be noted that Biotech expenditures are much larger (by roughly a factor of 10) than ICT expenditures and also that R&D in Biotech is closely associated with research carried out in medical schools.

This concentration of research expenditures in specific cities and the Biotech/ICT ratio are consistent with evidence from Re$earch Infosource. They note that if R&D expenditures by Nortel Networks in Ottawa are removed from Canadian industrial R&D figures, Biotech, rather than ICT, becomes Canada's major industrial R&D activity. Indeed, with Nortel removed, the overall level of industrial R&D, instead of falling by 8.7%, actually rose 6.5% from 2001 to 2002. Figure 7 shows clearly the Biotech clusters in Canada (Montreal, Toronto, Edmonton and Vancouver) and the ICT clusters (Montreal, Ottawa, Toronto, KWG and Vancouver). In the case of Biotech, the existence of these clusters has been confirmed by the work of Queenton and Niosi[16] who have looked at concentrations of Biotech human capital (or "stars," as they refer to them).

International comparisons

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[13] Clayman, Bruce P. "*Technology Transfer at Canadian Universities: Fiscal Year 2001 Update*," and "*Addendum to Technology Transfer at Canadian Universities*," both reports to the Canada Foundation for Innovation, 2003. www.sfu.ca/vpresearch/vprreports.htm

[14] Note also that Biotech and ICT are two of the eight priorities identified by the European Union in their list of priorities for their next round of R&D funding.

[15] Clayman, B.P. and J. A. Holbrook, "*The Survival of University Spin-offs and Their Relevance to Regional Development*," CPROST report to the Canada Foundation for Innovation, 2003. www.sfu.ca/vpresearch/vprreports.htm

[16] Queenton, J. and J. Niosi, "*Bioscientists and biotechnology: A Canadian study,*" 3rd European Meeting on Applied Evolutionary Economics, Augsburg, Germany 2003 www.emaee.net

In order to place Canadian R&D indicators in context, it is useful to examine comparable data from selected member countries of the Organisation for Economic Co-operation and Development (OECD); see Figure 21. For compatibility with OECD data, we re-define HQP here as the persons in the labour force (not the entire population, as previously) who have a tertiary degree. Total Canadian R&D expenditures per population are at about average ($575) among the subset of OECD countries considered here, but R&D/HQP at $3,011 is well below their average ($5,511). R&D/HQP is also well below the levels of our principal trading partners (in particular, the US) and below the average for the OECD overall ($4,641).

Figure 22 shows that among OECD countries Canada has the largest fraction of its workforce with tertiary education – i.e. HQP as defined by the OECD. However, relatively low R&D funding prevents full utilization of this receptor capacity. This speaks again to the need to increase R&D expenditures at rate that exceeds the growth of HQP (or population) in order for Canada to become a more research-intensive, knowledge-based economy and society.

Similar charts could be prepared describing and comparing individual states of the United States, but comparability between states or with provinces of Canada is compromised by the presence, or absence, of large military R&D programs, which are often funneled through industrial research labs, universities, or university-managed research facilities.

The result – an innovative community?

Measured R&D expenditures have always been a proxy – an indicator – for the level of innovative activities. As the OECD has found over the years, R&D expenditures are a measure which provides some information on the level of innovation in a nation, but which does not necessarily capture all facets of innovation in the economy. For example, a resource-based economy may be very innovative and very efficient, but if we look solely at R&D expenditures it may appear to be backward, because the R&D expenditures that lead to efficiencies in production occurred in some other industrial sector (e.g. machinery) and/or in some other location.

Statistics Canada has pioneered the use of surveys of innovation[17] in the OECD community with its surveys of innovation in Canada. These surveys, of necessity, are not precise – they require interpretation and normalization. Table 1 shows some results obtained from Statistics Canada that were obtained via their Survey of Innovation, 1999. They are presented by city to give a view of the innovativeness of the firms in the cities to represent a possible interpretation of the "output" of granting agency and other investments in R&D. According to Statistics Canada's definition, "an innovative firm is one that has offered a new or significantly improved product or introduced a new or significantly improved production/manufacturing process during the last three years." The results in Table 1 are expressed in terms of whether firms in a city are collectively significantly above (+), below (-), or near to (o) the national average for that measure of innovativeness.[18]

[17] Statistics Canada Survey of Innovation, 1999. catalog number 88F0006XIE2002016 www.statcan.ca
[18] Statistics Canada defines "significant" as follows: "an estimate is significantly above or below the national estimate if its range, as defined by its coefficient of variation, is outside the range of the national estimate, which is defined as twice the coefficient of variation for the national estimate."

Table 1: Some Results from the Statistics Canada Survey of Innovation, 1999

City	Innovativeness of local firms	Firms engaged in R&D	Firms engaged in R&D that led to an innovation	Use of SREDs
Victoria	-	-	-	-
Vancouver	-	-	-	-
Calgary	-	-	-	-
Edmonton	-	-	-	-
Saskatoon	o	o	o	-
Regina	o	o	-	+
Winnipeg	-	o	-	-
Thunder Bay	+	o	o	o
Sudbury	o	o	o	o
Windsor	+	o	o	+
London	o	o	o	o
Kitchener	+	o	o	o
Hamilton	+	o	o	o
St. Catharines	o	o	+	o
Toronto	o	o	o	-
Kingston	o	+	o	o
Ottawa	+	+	o	o
Montreal	+	-	+	+
Sherbrooke	+	o	+	+
Trois-Rivieres	-	o	o	+
Quebec	+	o	+	+
Chicoutimi	-	+	o	+
Saint John	o	o	-	-
Moncton	+	+	+	o
Halifax	o	o	o	+
Charlottetown	-	+	+	+
St. John's	o	o	-	-

When one attempts to compare these measures of innovation in a city with previously cited R&D expenditures, R&D expenditures per population and/or R&D intensity, one must be aware of a number of confounding factors. For example, use of R&D tax credits can be heavily influenced by provincial R&D tax credit policies (such as those that were in effect in Quebec at the time of the survey). Another factor influencing the propensity to perform research in a particular city is the local economic structure, particularly if the economy is based on natural resources and natural resource products, since Canadian resource industries have historically been reluctant to invest in R&D or in innovative machinery or processes. For example, the forest industry in western Canada has been profitable through sale of low value-added products (such as raw logs) which require little in the way of innovative processes. There are also a number of methodological difficulties with such surveys related to the local contexts in which the firms were surveyed.[19]

[19] Holbrook, J. A. and L.P. Hughes, "*Comments on the use of the OECD Oslo Manual in non-manufacturing based economies,*" Science and Public Policy, Vol. 28, #2, 2001; Salazar, M. and J. A. Holbrook, " *A Debate on*

Conclusions

As noted in work cited above, research activities, particularly those carried out at universities, are necessary for the development of industrial clusters, but by no means are sufficient for their continued existence. R&D, regardless of the institution in which it is performed, provides the input of intellectual capital that clusters need to grow and thrive. Thus the ability to develop IP is as much an element of a city's infrastructure, as are good transportation links or a pleasant urban environment. While the data are incomplete and clearly would benefit from further analysis, a few salient points emerge:

- R&D expenditures by the granting agencies tend to scale with city size
- Industrial R&D expenditures are concentrated in a few centres; much better data disaggregated by industrial sector and by city are needed to understand fully the role of industrial R&D in the development of clusters
- There is a clear focus of granting agency expenditures on biotechnology and human health, with consequent benefits to Biotech clusters
- There are several "university towns" where there are relatively high levels of R&D activity per population and per HQP. Some of these towns could possibly be regarded as part of larger metropolitan areas (e.g. Kingston, with its proximity to Toronto, Montreal and Ottawa), but others (e.g. St. John's) tend to reflect the distribution of Canadian universities, which are often found in provincial capitals.

The results shown in Figure 16 imply that for many cities R&D intensities are increasing at the same rate as the city's economy becomes more knowledge-based, i.e. as HQP become a larger proportion of the total population. Arguably the increase in HQP intensity is as valuable a policy objective (or perhaps more so![20]) in terms increased competitiveness and social benefits as is increased R&D intensity. That graph suggests that, if the federal government intends to make Canada a more research-intensive country, it must increase levels of R&D expenditures at rates that <u>exceed</u> the rate of increase in HQP as a ratio of total population. As noted earlier, Canada already has the highest HQP intensity of any of the OECD countries – the challenge is for the country to increase its investment in R&D to levels commensurate this currently under-utilized capacity. Failure to do so would continue the present non-optimal return on its investment in human capital.

Neither direct R&D expenditures, nor student enrolments, nor papers published by sector forms a complete picture of the existence of clusters. It would be useful if Statistics Canada could add questions to its surveys of R&D expenditures to determine numbers of HQP in specific research subject areas, by city; these data could provide critical complementary evidence about the existence and strength of clusters.

Specific investments in R&D (or HQP) may, or may not, lead to the development of a specific cluster. For example, while the investment in ICT may well have led to the development of the ICT industry in KWG, the investment in TRIUMF in Vancouver has not led to the development

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Innovation Surveys," A conference in honour of Keith Pavitt: "*What do we know about innovation?*" SPRU, University of Sussex, 2003

[20] The federal *Innovation Strategy* contains a number of targets which are related to increasing the overall supply of HQP in Canada

of a major cluster of industries based on its use or its specific technologies, al though TRIUMF has contributed to the overall growth of the overall intellectual infrastructure of the city.

The existence of large, globally competitive high-tech clusters in Canada is evident. As mentioned above, the Biotech clusters in Montreal, Toronto and Vancouver stand out, as do the ICT clusters in Ottawa and KWG. There are clusters in the automotive sector and in technologies related to natural resource extraction in other cities. All these clusters are developing rapidly, often using IP generated within universities in the cities in which the clusters are located. Canadian universities overall are equal to, or superior to, their US counterparts by several important measures of technology transfer. An issue at hand is how to enhance these linkages in order to strengthen existing clusters and to develop nascent clusters, whose impact may not be evident in the short term.

Clusters develop when creative individuals "cluster" themselves and, as a group, provide the synergy to develop an economic and social entity that is greater than the sum of its parts. "If you build it, they will come" should be an approach to building the knowledge capacity of a city, but it does not guarantee that that economic and social development will follow the funded research activities. Investment in R&D, in itself, is <u>necessary</u> (but not sufficient) for a city to develop a knowledge-based economy.

Although it has not been possible, due to lack of definitive data, to demonstrate unambiguously that university research, funded by the granting agencies, leads to the creation and success of industrial clusters, we have presented a number of partially convergent indicators fully consistent with that conclusion. This supports other previously cited research that concludes that clusters are created when a number of favourable circumstances co-exist in a city and that research activity is one of them; without research, clusters cannot form or grow.

Acknowledgements

The authors would like to thank their research assistants Michelle Petrusevich and Glenda Shaw-Garlock for their assistance in reducing the data and preparing the graphs. Pauline O'Neill provided great help through her critical reading and editing of this text. We would also like to thank the Impact Group and Statistics Canada for help in providing data. Financial assistance from the Canada Foundation for Innovation is gratefully acknowledged.

Appendix A

Census Metropolitan Areas (CMAs) and Census Agglomerations (CAs) of Canada[21]

CMA or CA	Population (2001 Census)	Research Universities in the **CMA** or CA
Toronto	4,682,897	Toronto, York, Ryerson
Montreal	3,426,350	Concordia, McGill, HEC, Polytechnique, UQAM, INRS, École de technologie supérieure
Vancouver	1,986,965	UBC, SFU
Ottawa-Hull	1,063,664	Ottawa, Carleton, U de Q (Hull)
Calgary	951,395	Calgary
Edmonton	937,845	Alberta
Quebec	682,757	Laval
Winnipeg	671,274	Manitoba, Winnipeg
Hamilton	662,401	McMaster
London	432,451	Western
Kitchener-Waterloo	414,284	Waterloo, Wilfrid Laurier, Guelph
St. Catharines-Niagara	377,009	Brock
Halifax	359,183	Dalhousie
Victoria	311,902	Victoria
Windsor	307,877	Windsor
Oshawa	296,298	
Saskatoon	225,927	Saskatchewan
Regina	192,800	Regina
St. John's	172,918	Memorial
Sudbury	155,601	Laurentian
Chicoutimi-Jonquiere	154,938	U de Q (Chicoutimi)
Sherbrooke	153,811	Sherbrooke
Barrie*	148,480	
Kelowna *	147,739	Okanagan University College
Abbotsford *	147,370	
Kingston *	146,838	Queen's, Royal Military College
Trois-Rivieres	137,507	U de Q (Trois-Rivieres)
Saint John	122,678	UNB (also in Fredericton)
Thunder Bay	121,986	Lakehead
Moncton *	117,727	Moncton
Guelph *	117,344	Guelph
Charlottetown *	58,358	UPEI

* Not included in the study by Gertler *et al.*[8]

[21] CMAs are indicated in **bold type**.

Appendix B

Revised Census Metropolitan Areas (CMAs) and Census Agglomerations (CAs)[22]

CMA or CA	Population (2001 Census)	Research Universities in the **CMA** or CA
Toronto GTA	5,127,675	Toronto, York, Ryerson
Montreal	3,426,350	Concordia, McGill, HEC, Polytechnique, UQAM, INRS, École de technologie supérieure
Vancouver - Lower Mainland	2,134,335	UBC, SFU
Ottawa-Hull	1,063,664	Ottawa, Carleton, U de Q (Hull)
Calgary	951,395	Calgary
Edmonton	937,845	Alberta
Quebec	682,757	Laval
Winnipeg	671,274	Manitoba, Winnipeg
Hamilton	662,401	McMaster
Kitchener-Waterloo-Guelph	531,628	Waterloo, Wilfrid Laurier, Guelph
London	432,451	Western
St. Catharines-Niagara	377,009	Brock
Halifax	359,183	Dalhousie
Victoria	311,902	Victoria
Windsor	307,877	Windsor
Saskatoon	225,927	Saskatchewan
Regina	192,800	Regina
St. John's	172,918	Memorial
Sudbury	155,601	Laurentian
Chicoutimi-Jonquiere	154,938	U de Q (Chicoutimi)
Sherbrooke	153,811	Sherbrooke
Kingston	146,838	Queen's, Royal Military College
Kelowna	147,739	Okanagan University College
Trois-Rivieres	137,507	U de Q (Trois-Rivieres)
Saint John	122,678	UNB (also in Fredericton)
Thunder Bay	121,986	Lakehead
Moncton	117,727	Moncton
Charlottetown	58,358	UPEI

[22] CMAs are indicated in **bold type.**

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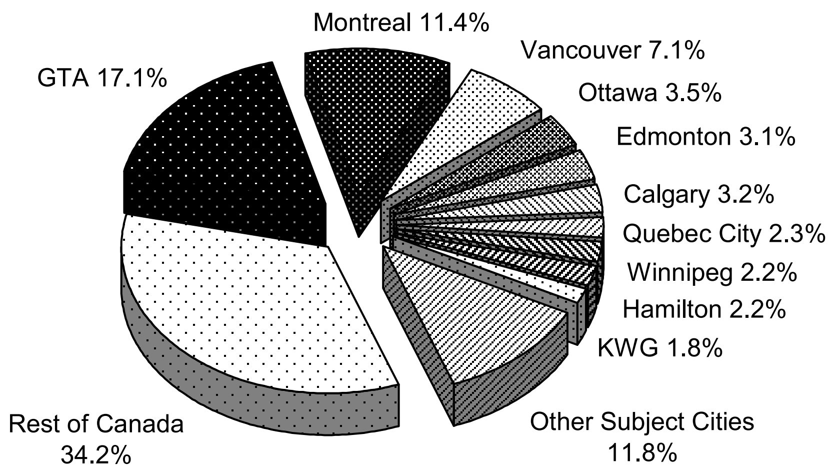
2001 Census



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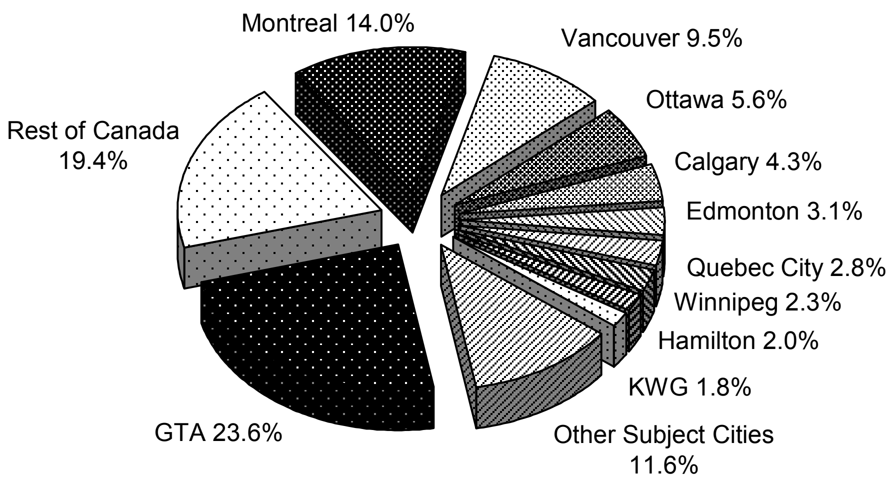

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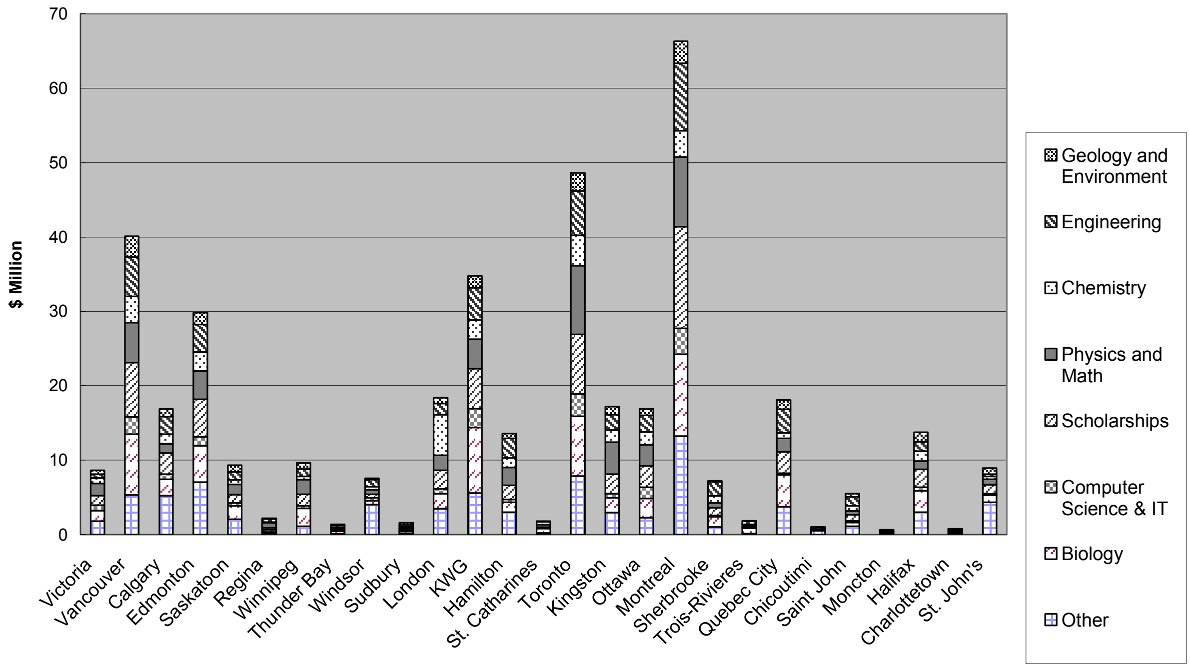

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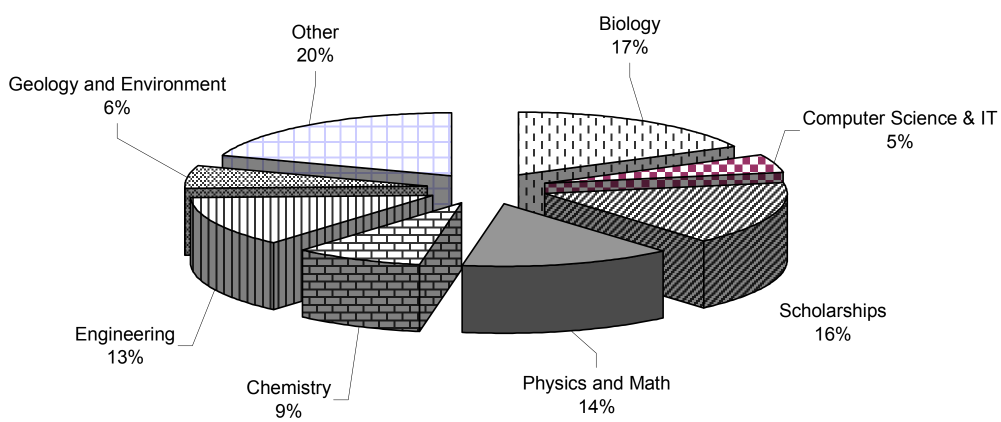

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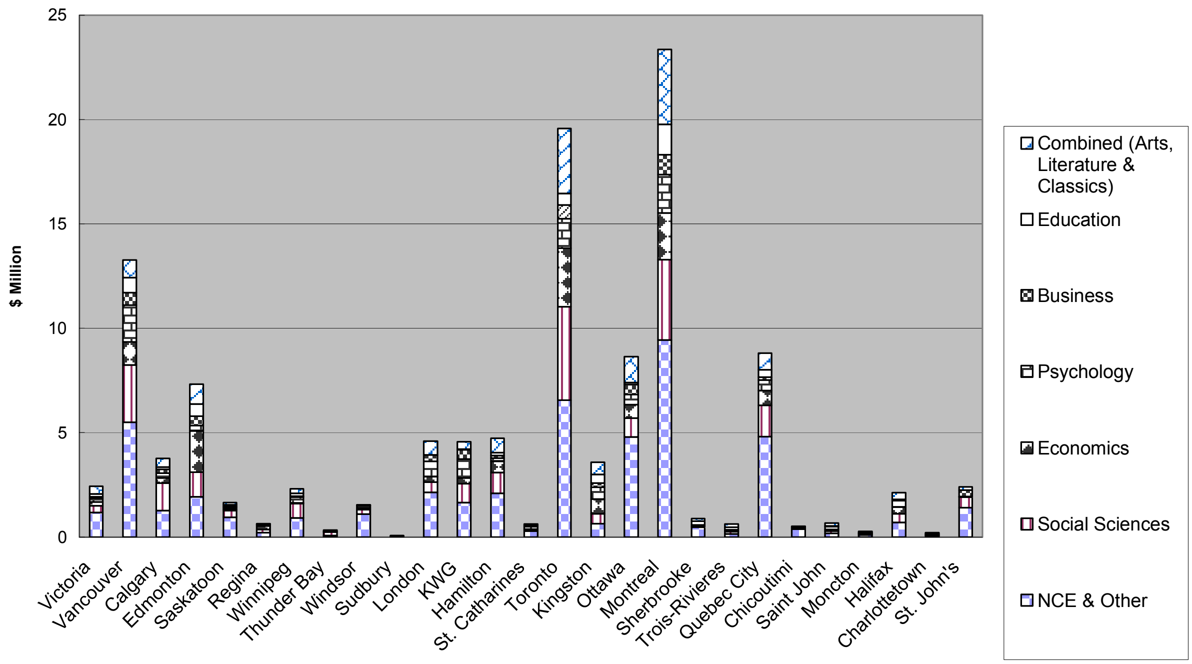

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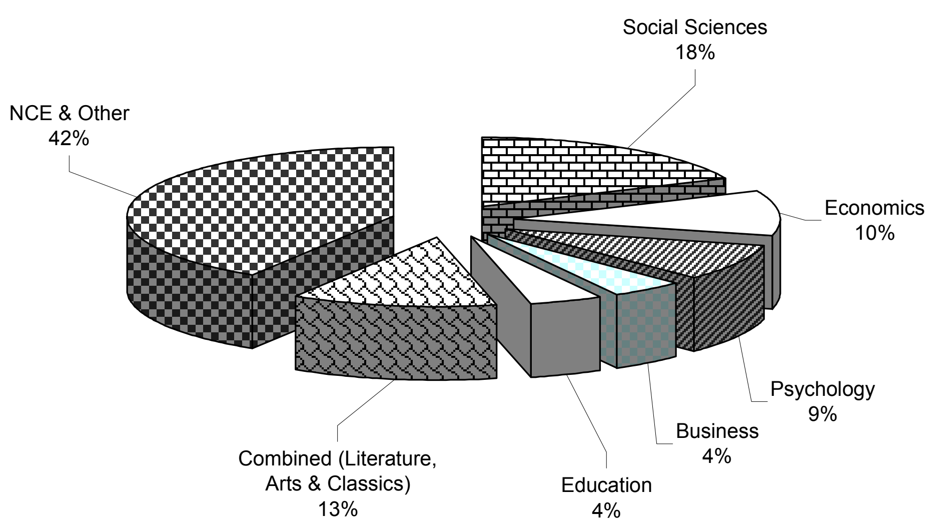

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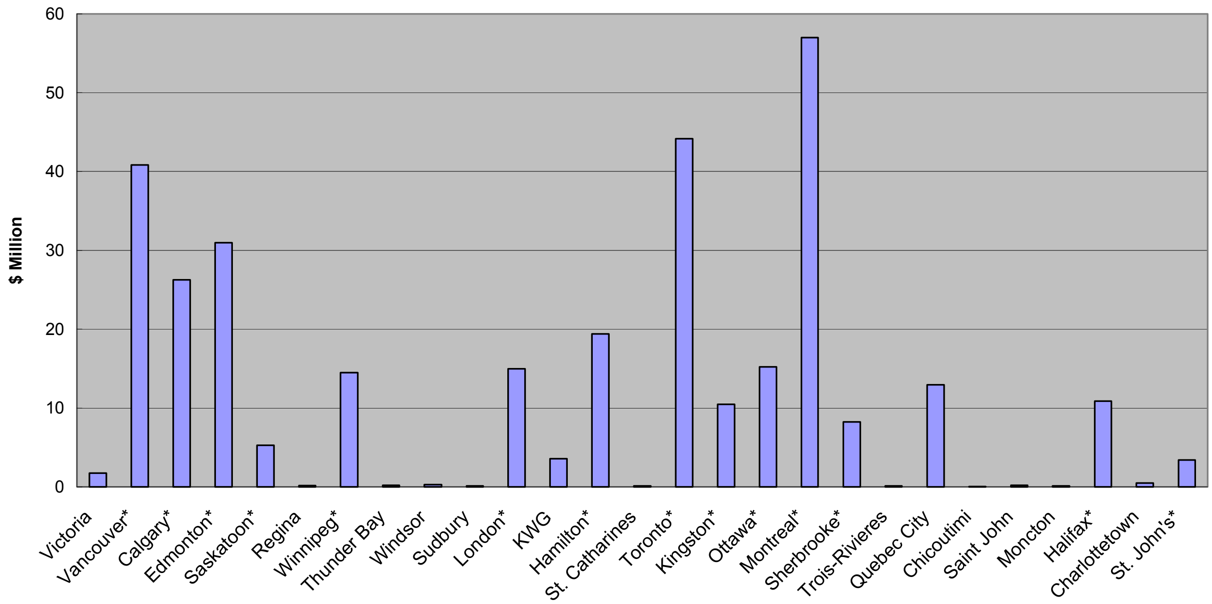
denotes presence of medical school(s)



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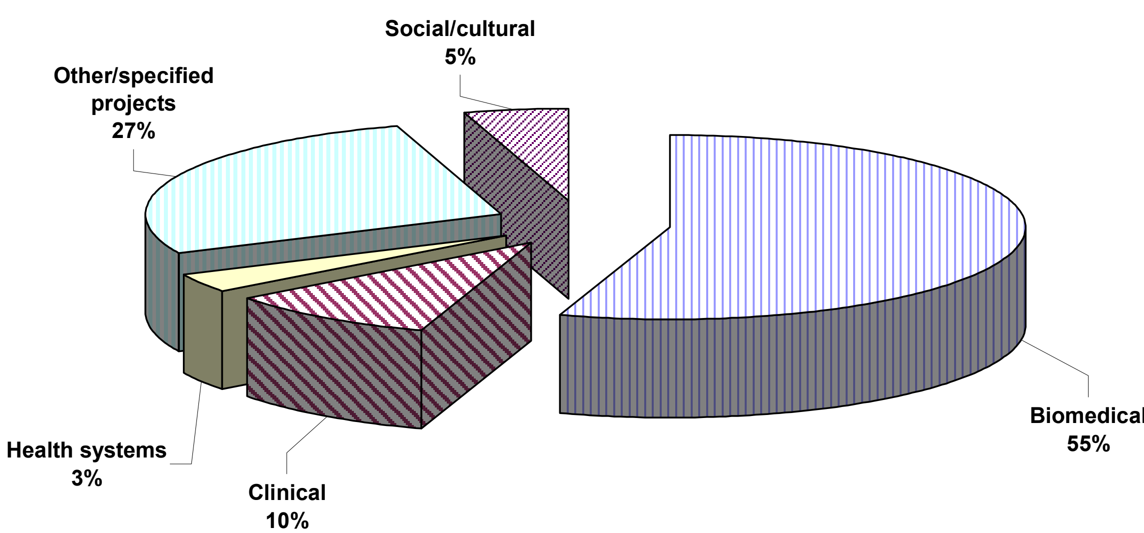

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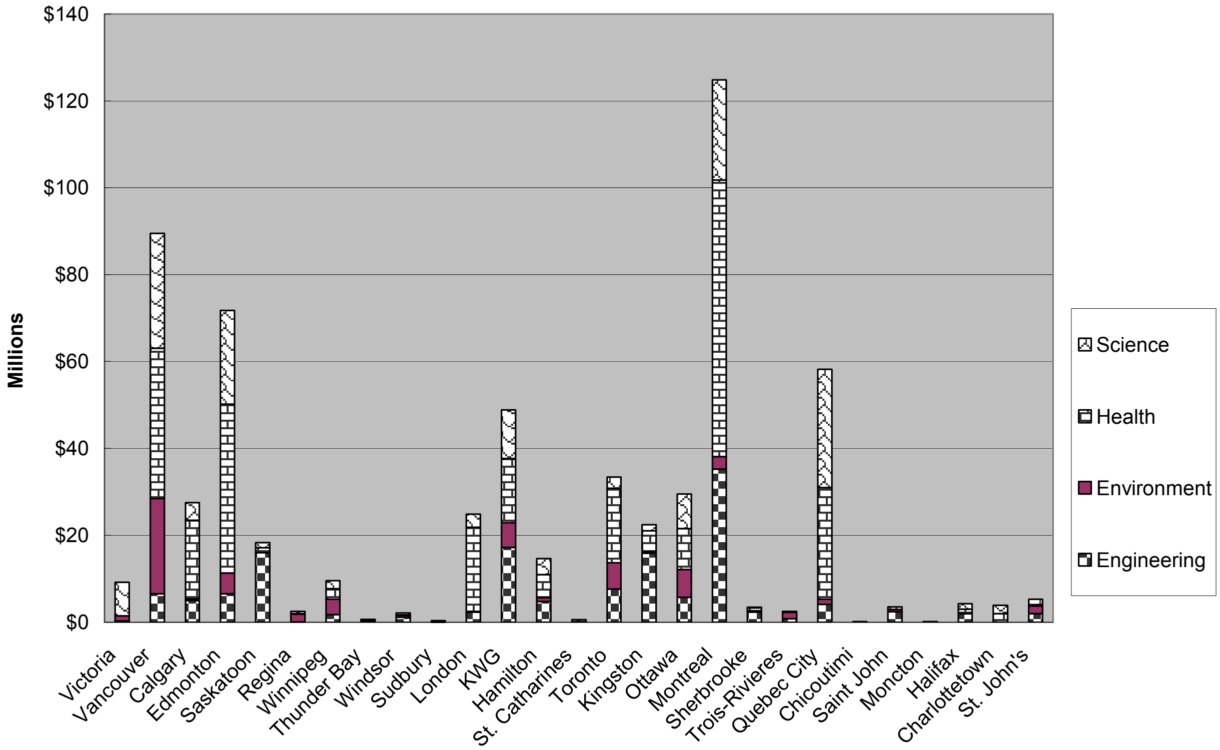

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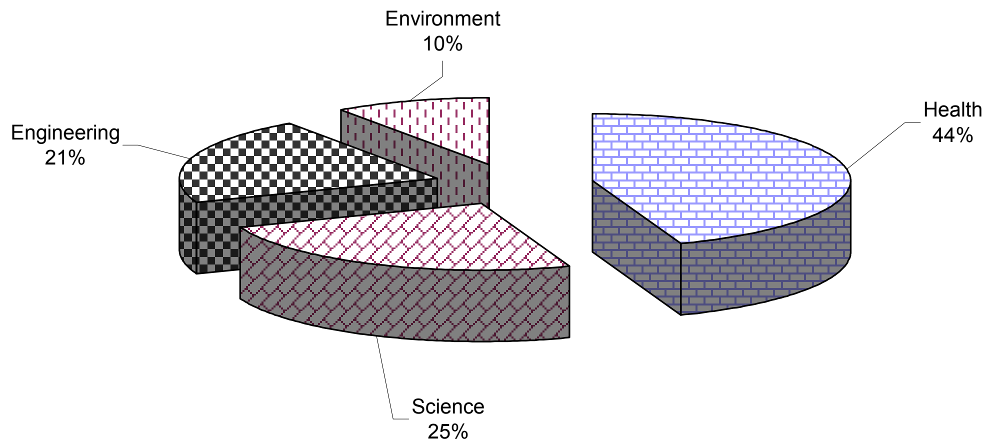

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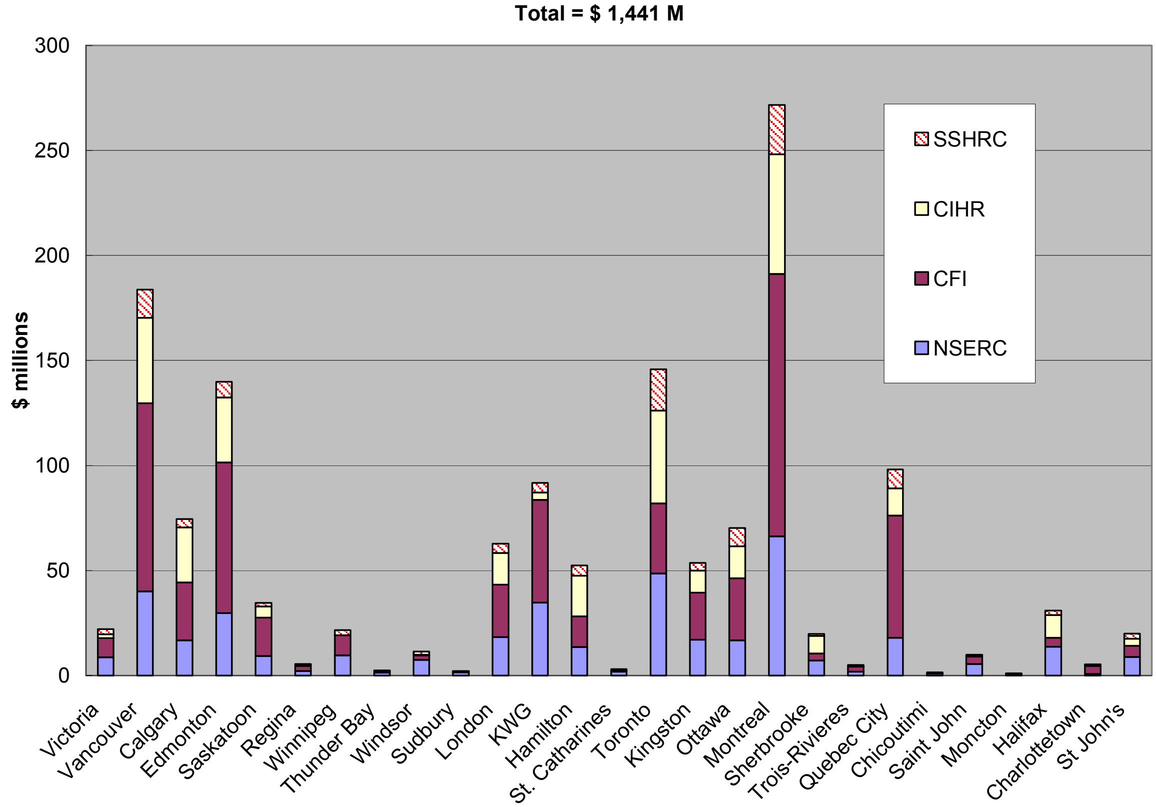

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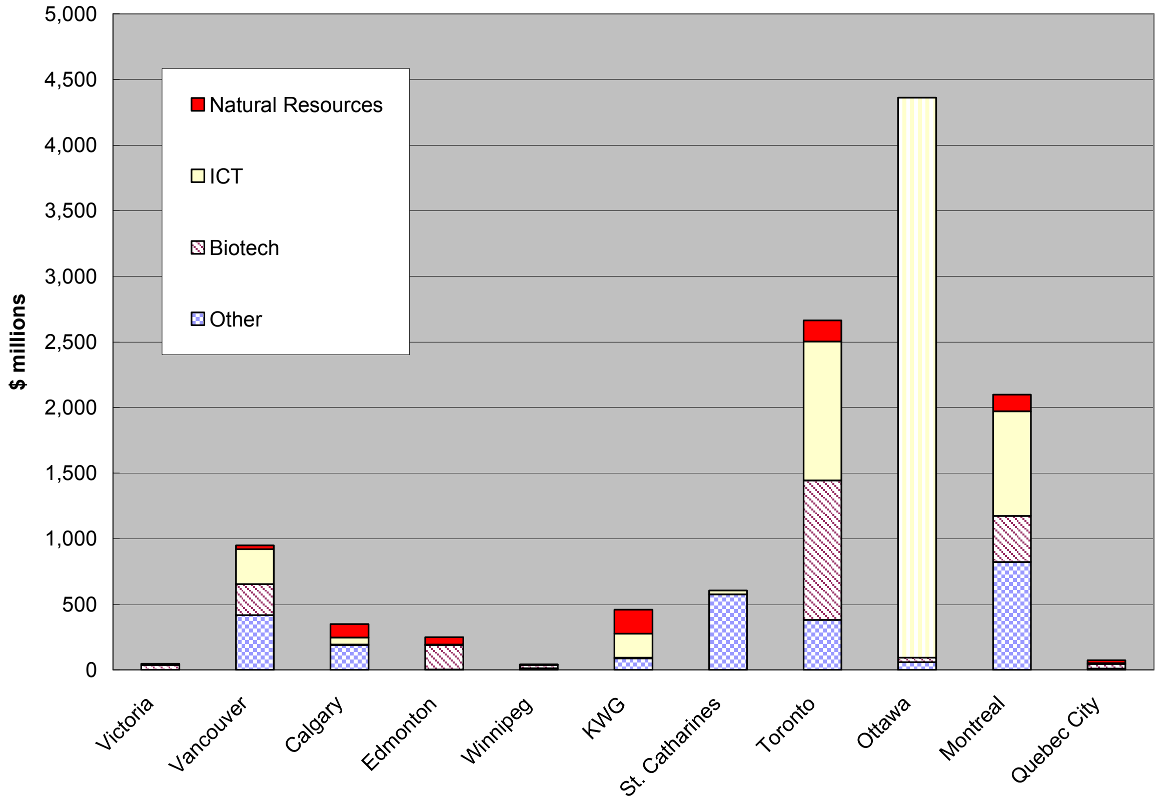

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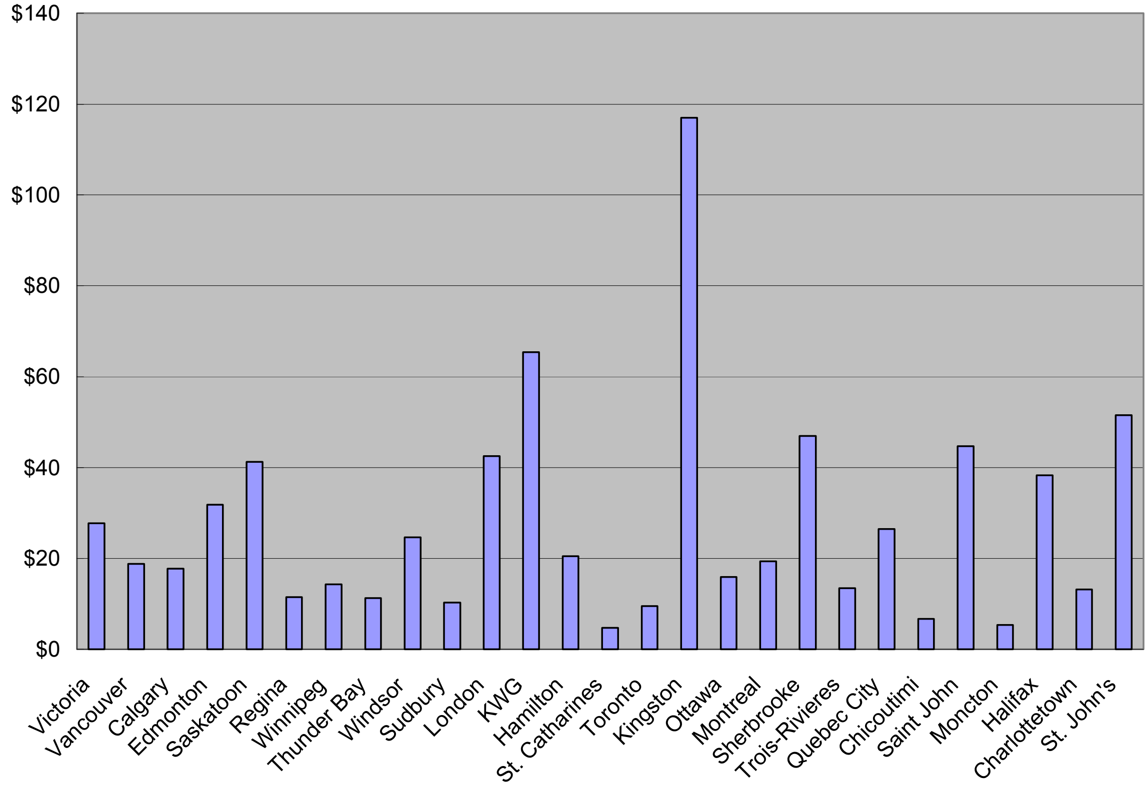

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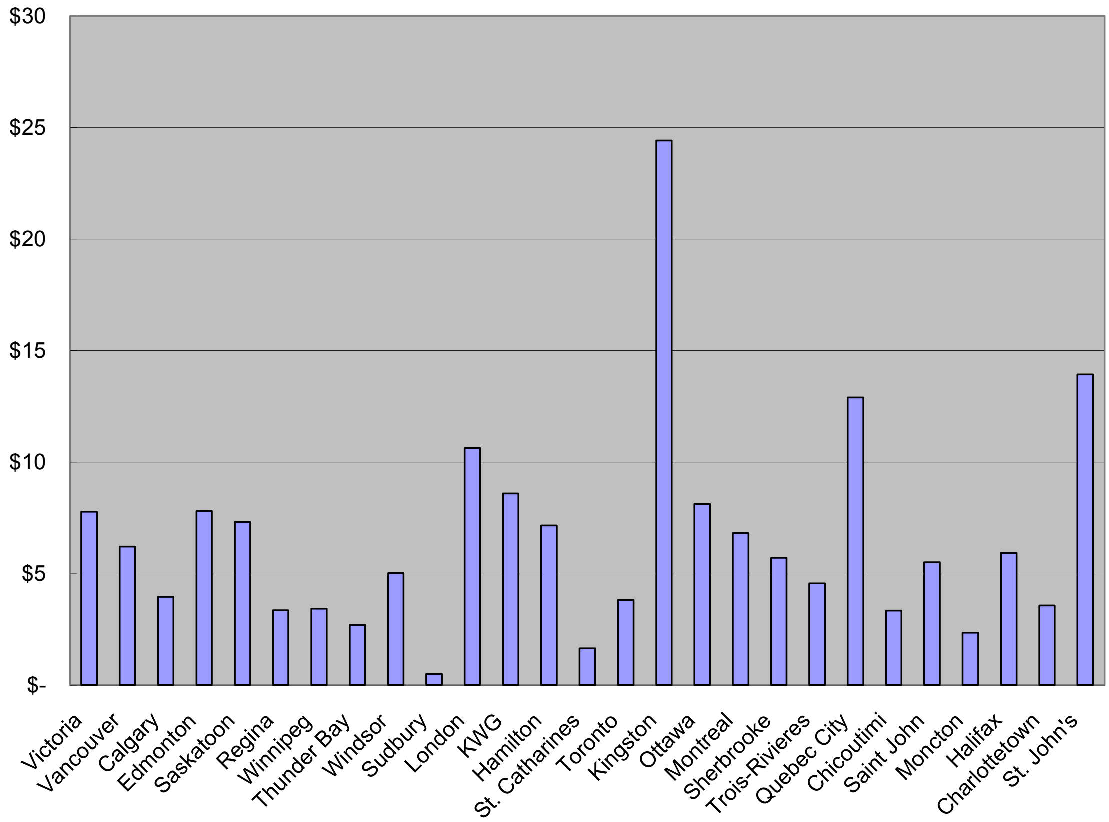

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Total CIHR Funding per Population 2001/2002
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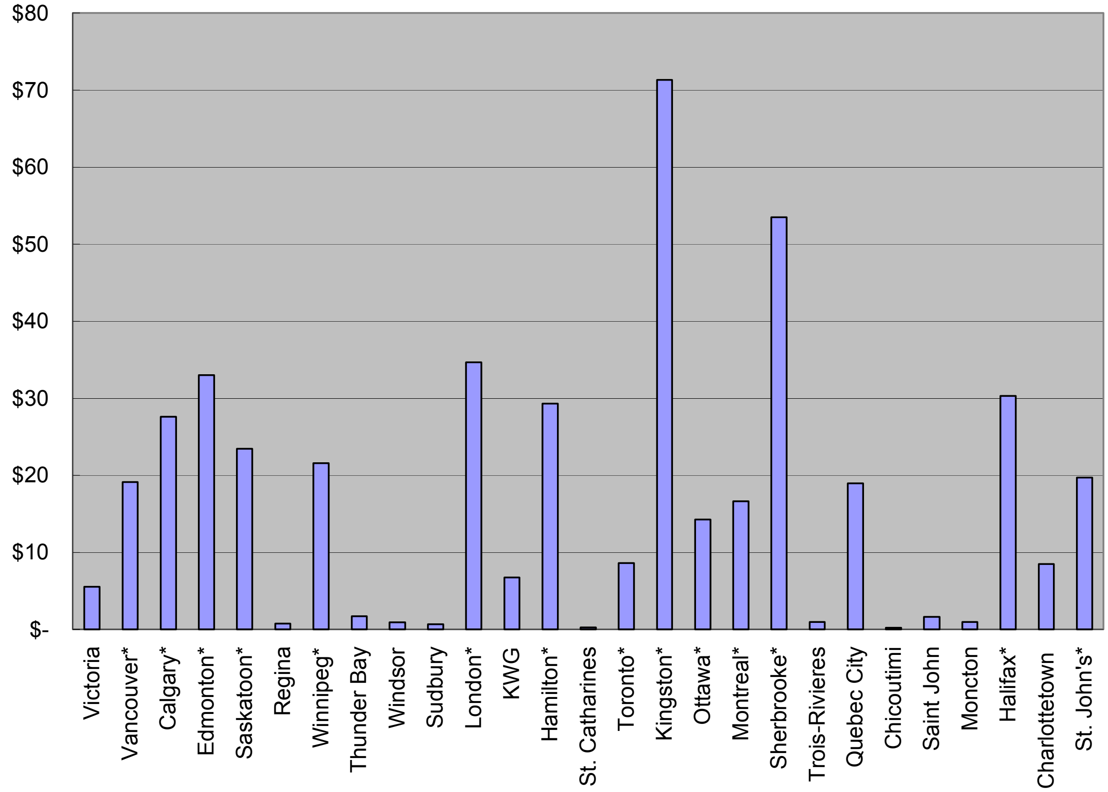
denotes presence of medical school(s)



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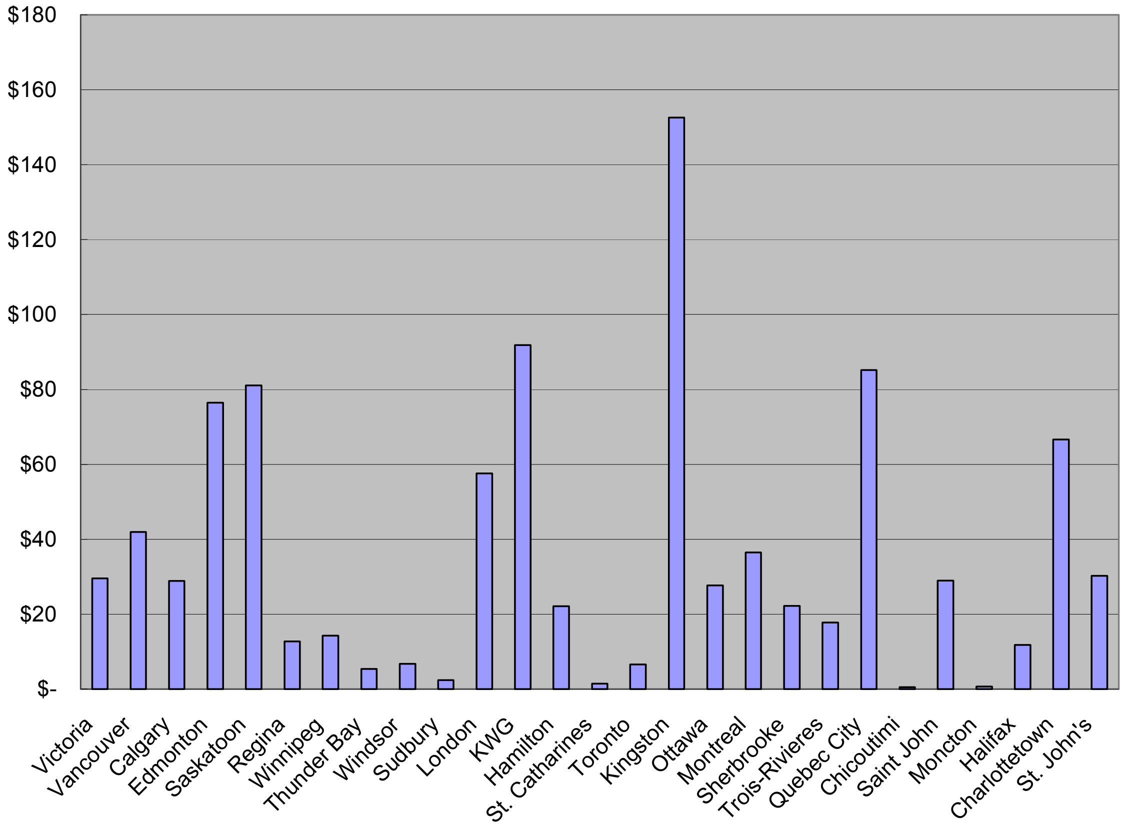

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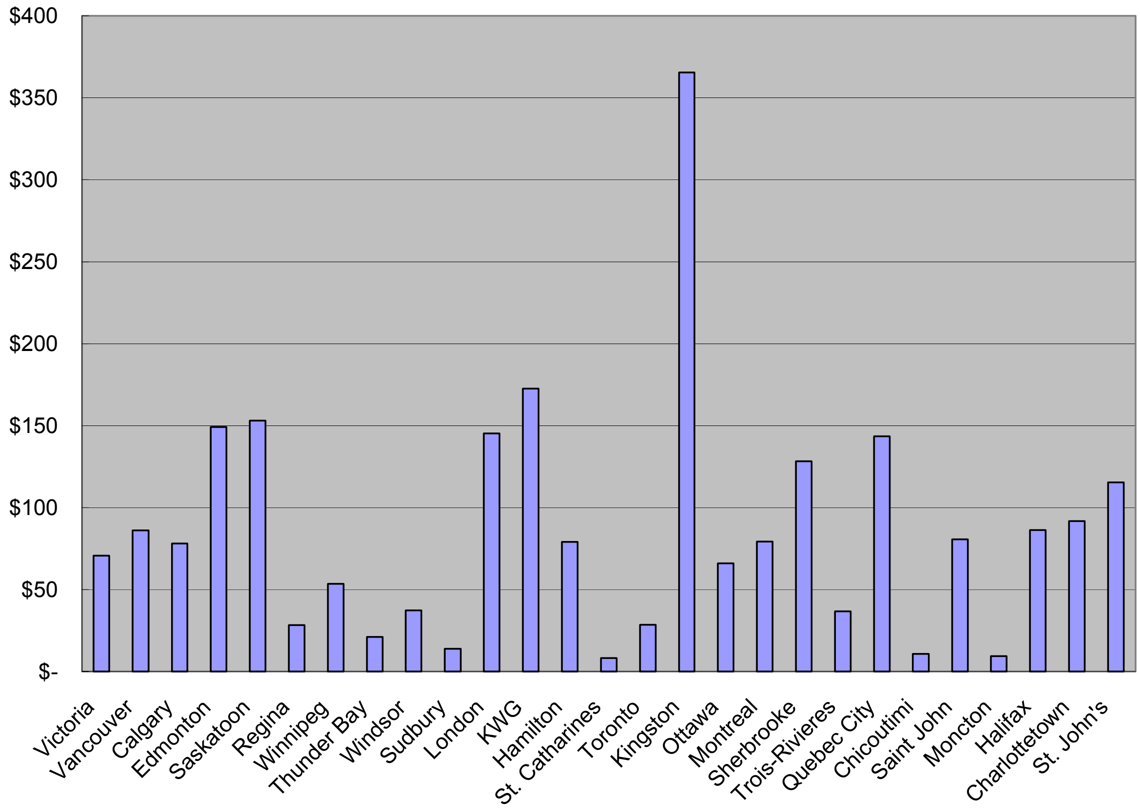

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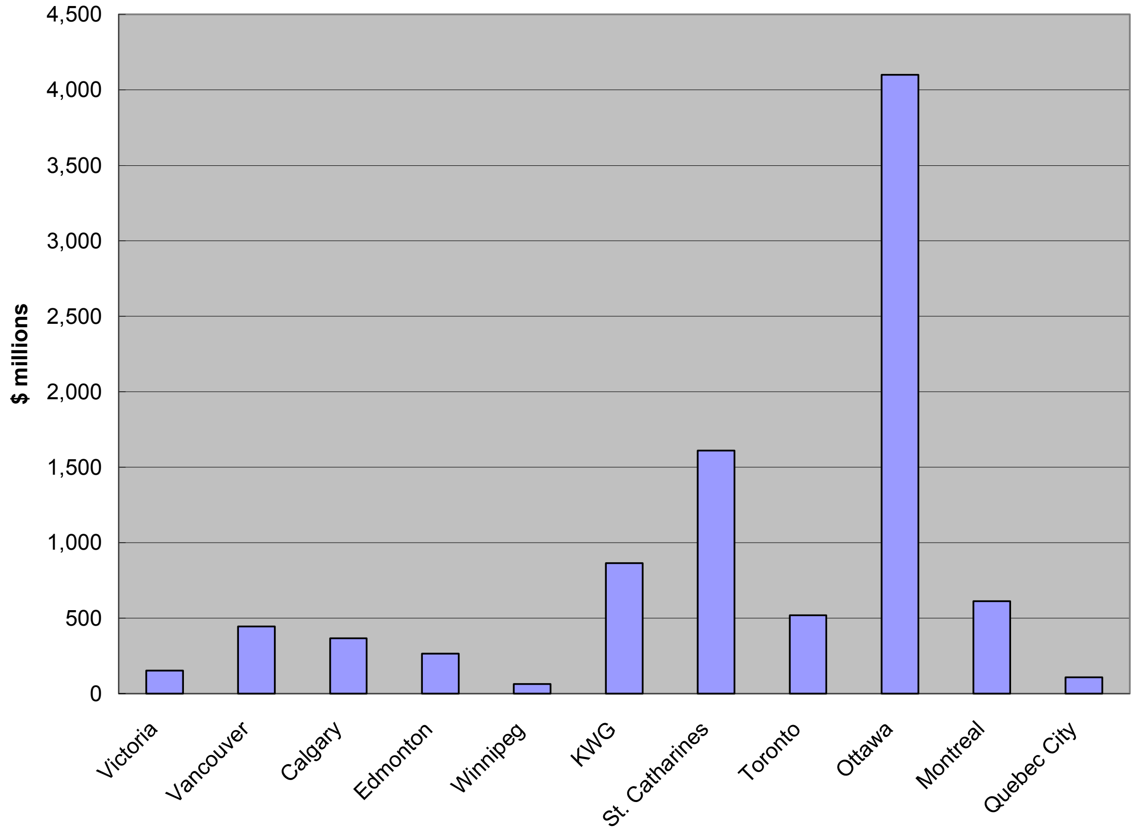
Average Accros Selected Cities = $ 734



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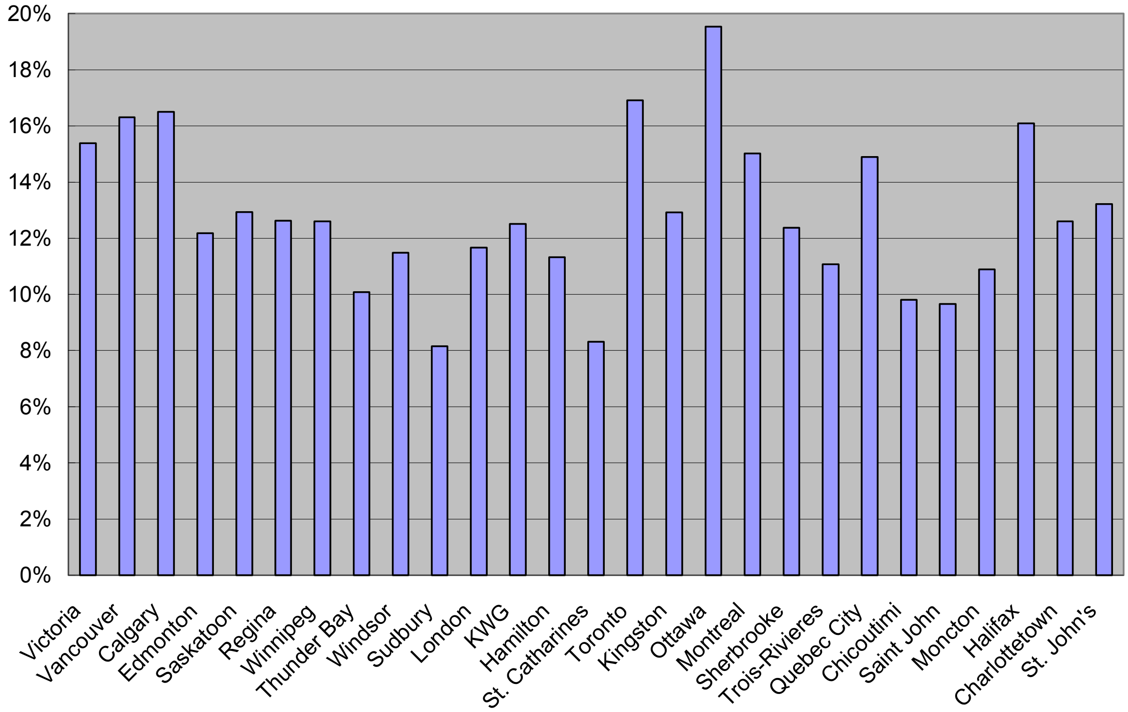

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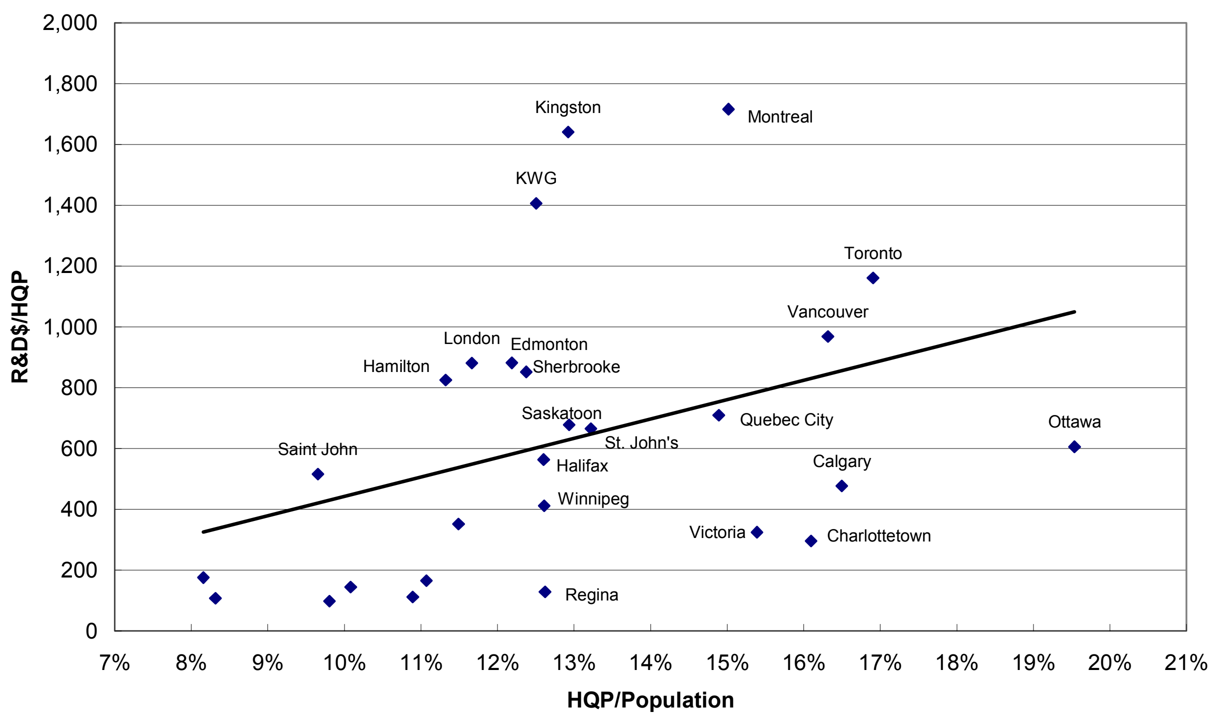

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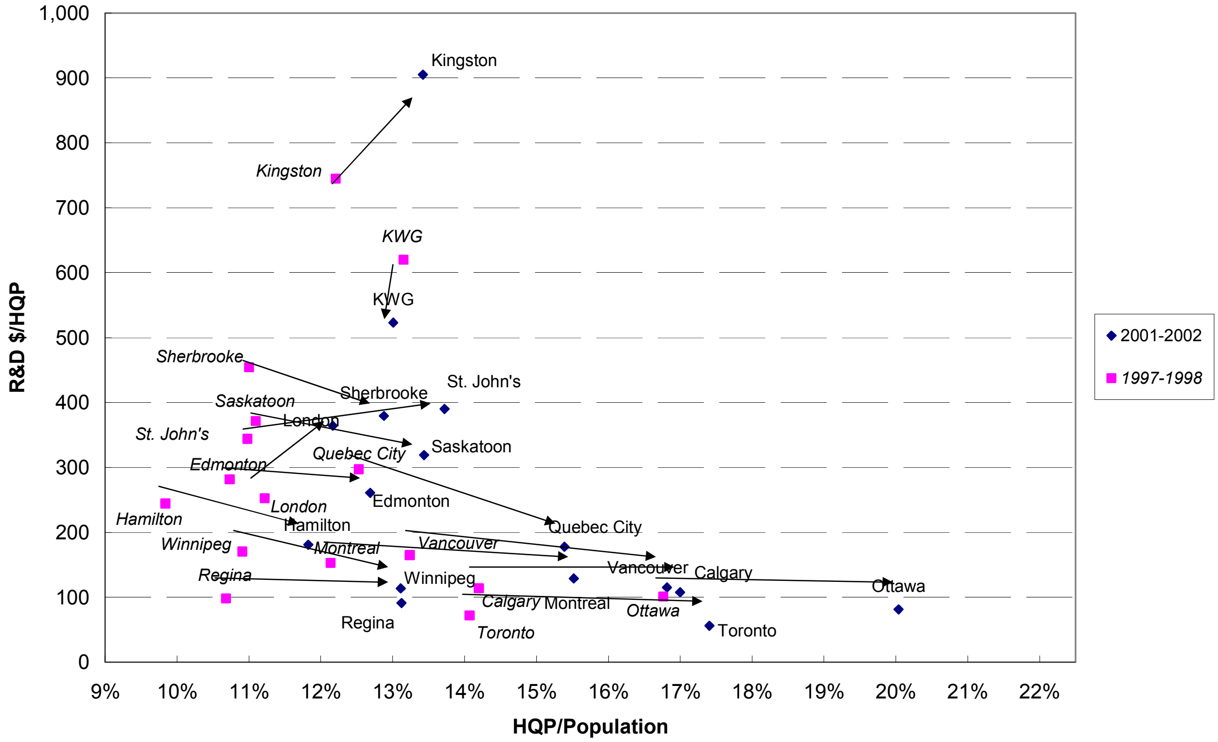

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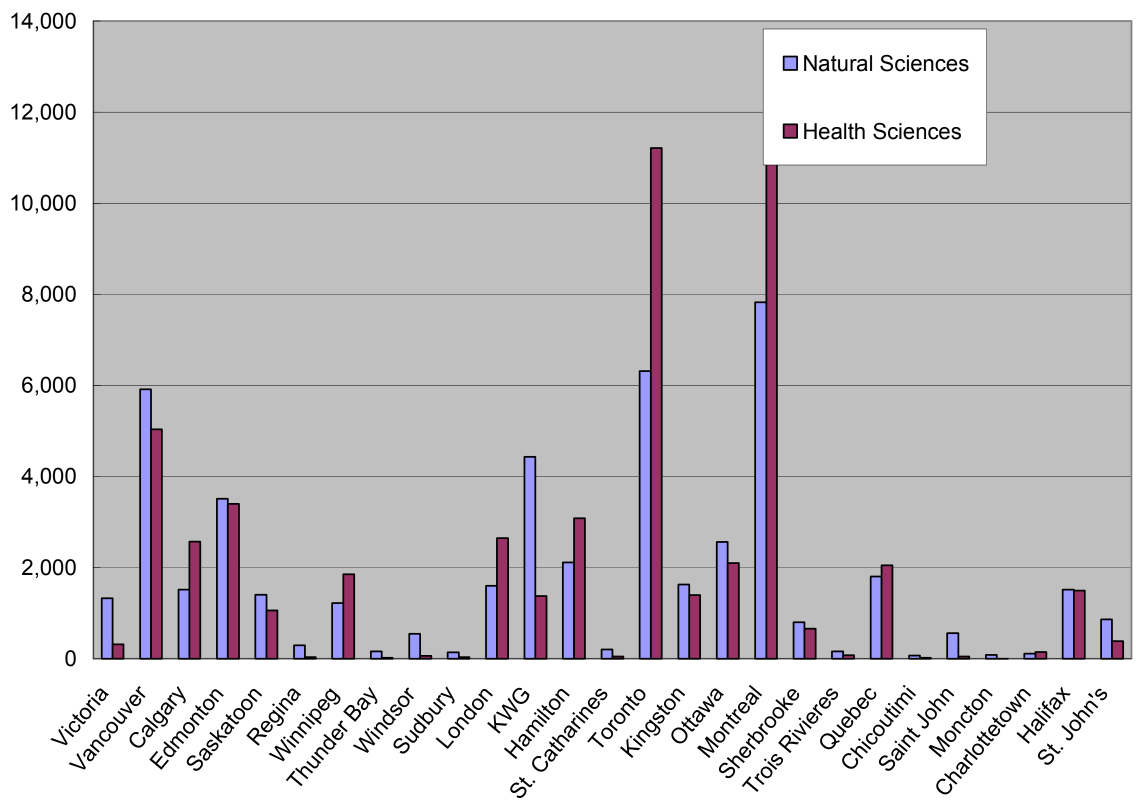

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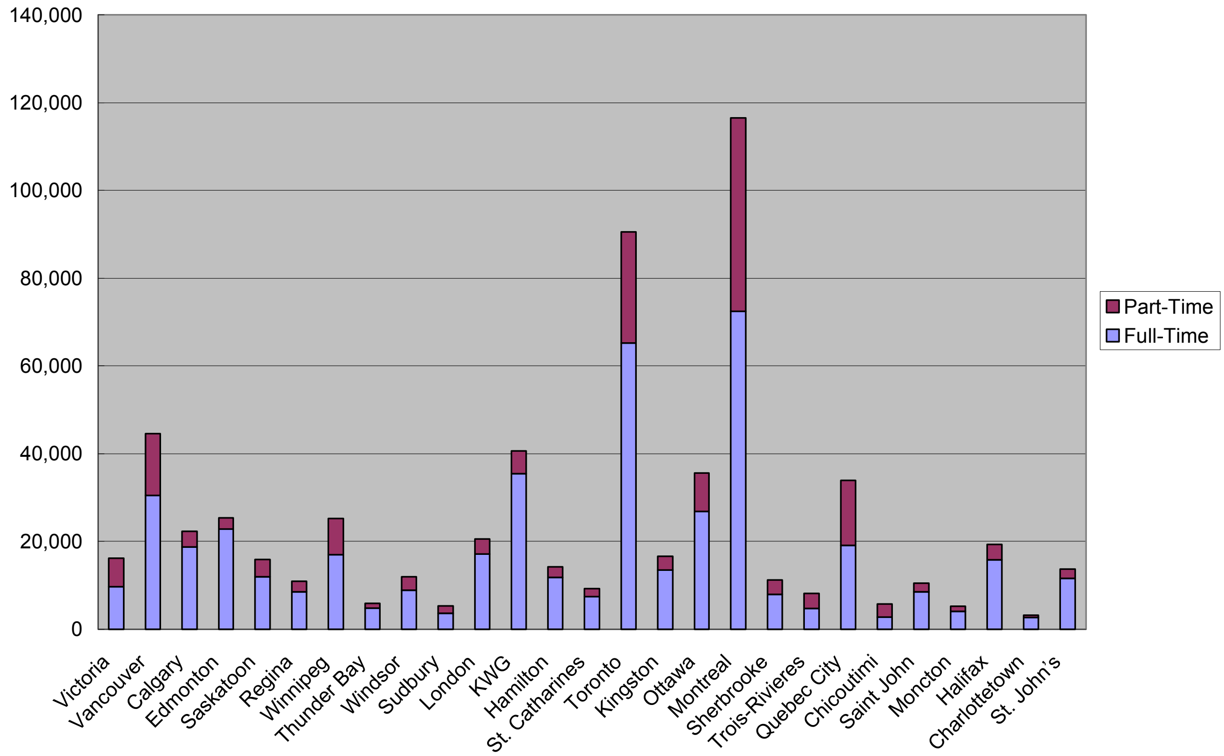

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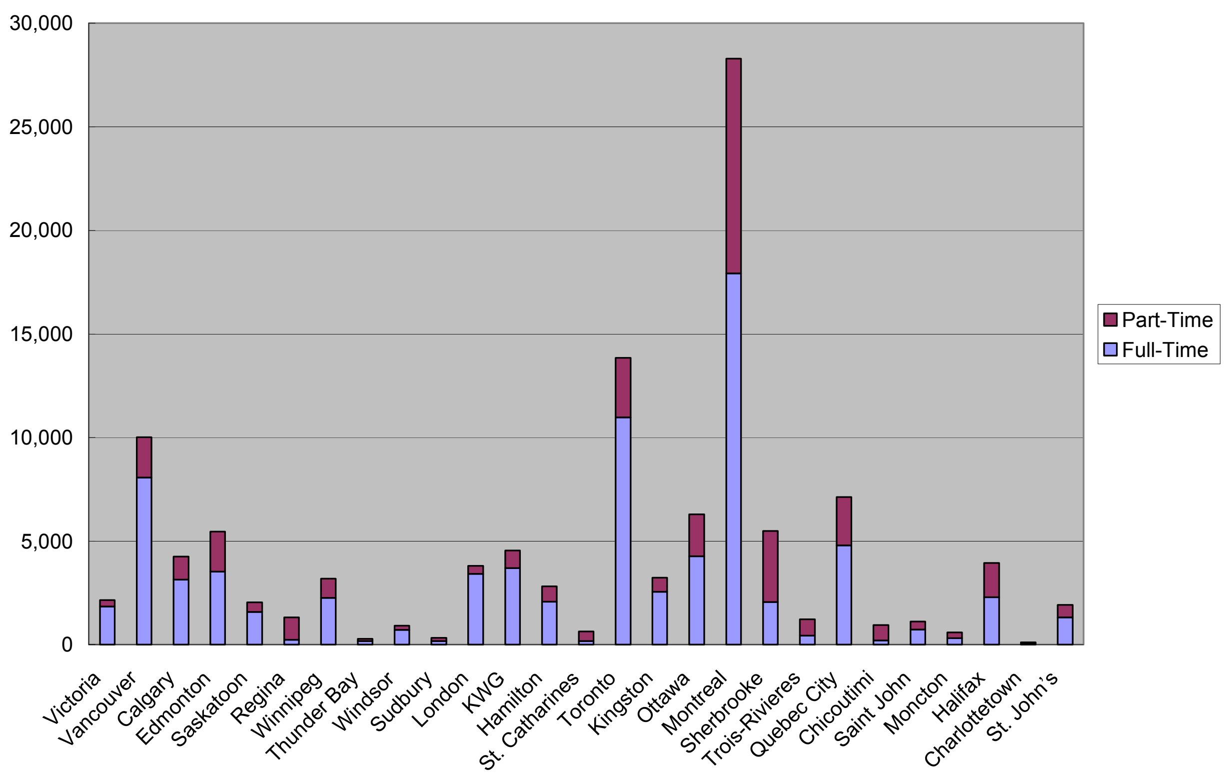

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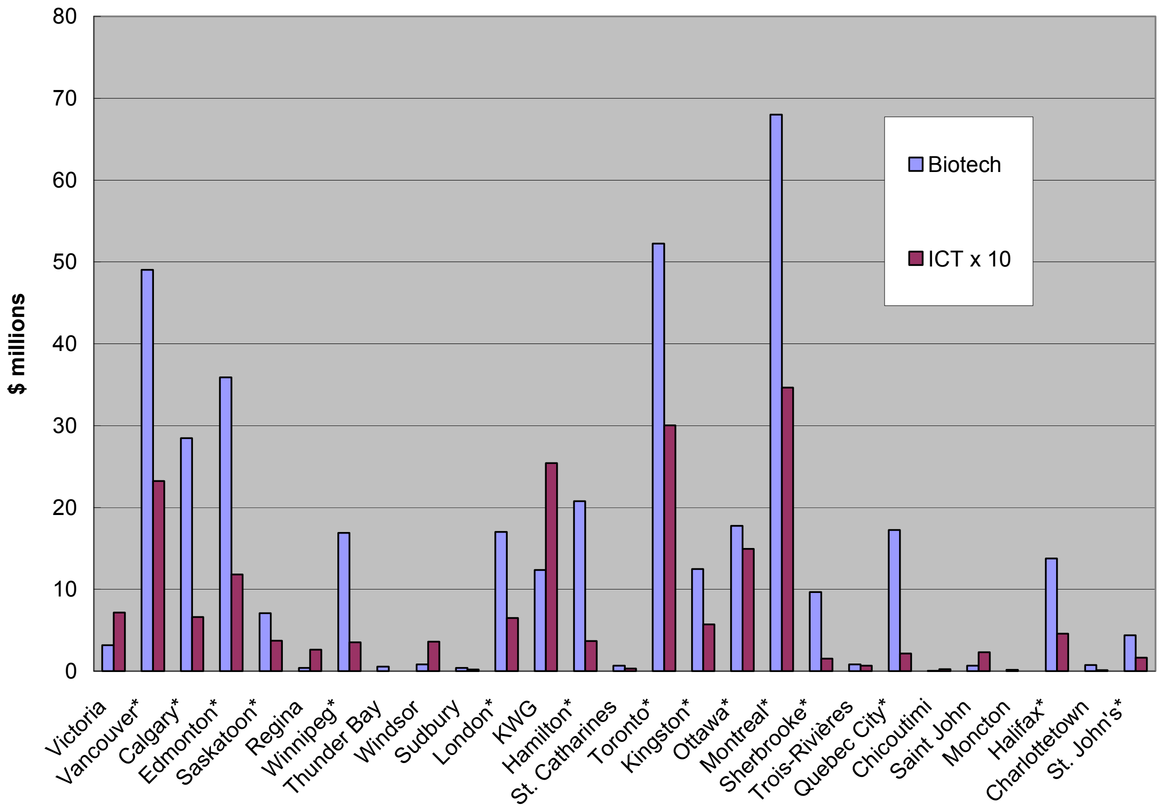

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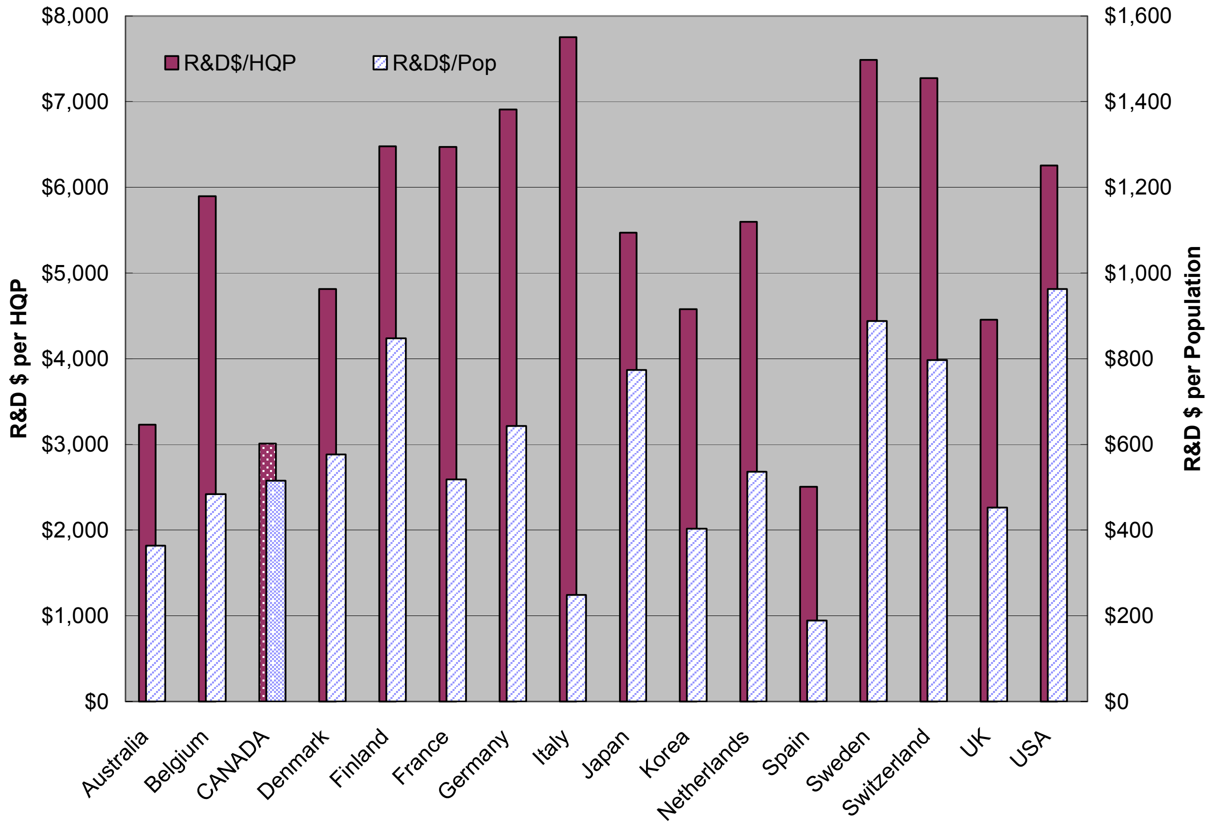

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