# *Quantifying the Vancouver Biotech Cluster*[1]


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## Introduction

In order to have a meaningful discussion about any industrial cluster, it is necessary to be able to place bounds upon the cluster and to quantify the inputs to it, its outputs and its impact on the global industry of which it is a part. This paper addresses indicators of the performance of the Vancouver human heath biotechnology cluster. Separating input and output indicators is fairly easy in the case of the biotech industry. The main inputs for the cluster are federal (and somewhat provincial) R&D funding going to universities, associated teaching hospitals, and research centres, and highly qualified human resources (as opposed to inputs of materials and labour as in the case of most manufacturing industries). Output indicators from R&D activities are also easy to identify: scientific publications and patents. But there are other outcomes that include the commercialization of research (via licensing) and the creation of new companies (start-ups).

## Biotechnology policy in Canada

The federal government of Canada does not have a formal, written, science and technology policy. However, since the mid-1990s its S&T policy has been remarkable consistent. This unwritten S&T policy can be summarized as follows:

- direct support of basic and early stage applied research in the university sector

- creation of specialized, decentralized, stakeholder operated granting agencies for university-based research (e.g. Networks of Centres of Excellence)

- shift from direct support for industrial S&T and innovation to indirect methods (e.g. Scientific Research and Experimental Development tax credit program)

- reduction of direct R&D spending in government labs, and a consequent focus on mission-oriented research

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[1] This paper relies heavily on the work of many people. It is based on a paper presented by Monica Salazar and the author at the CSIIC Colloquium “Measuring the Impacts of Science”, Montreal, 2004, entitled “ In search of Impact and Outcome Indicators based on Vancouver Biotechnology Cluster Studies”. The current paper was presented at a colloquium in Anyang , Korea, in 2004, sponsored by the Korean Research Institute for Human Settlements.

- active recruitment of S&T HQP through repatriation of Canadian emigrants and encouragement of immigrants

- participation in international consortia for big science projects such as NASA programs, the Canada-France-Hawaii telescope, etc.

The federal government's policy on biotechnology and related industries is circumscribed by constitutional limitations in that health (as with all other social programs, such as education) is the responsibility of the provincial governments[2]. This does not stop the federal government from supporting biotechnology: The federal government circumvents this largely political issue by, on the one hand, providing research grants directly to academic researchers through granting agencies such as the Canadian Institutes of Health Research (CIHR) and the Natural Sciences and Engineering research Council (NSERC), and secondly by setting up 'arm's length" research networks, such as the Networks of Centres of Excellence and Genome Canada, which actually administer and distribute research funding. The federal department of health, Health Canada, is not a major funder of external research, although it has a number of laboratories of its own that carry out work on infectious diseases and regulatory issues. It should be noted that biotechnology-related research funding is an order of magnitude greater than government investment in ICTs.[3]

The federal government generally provides direct funding for research; industrial research in biotechnology (as well as other areas) is supported indirectly through tax credits. The tax credit programs provides direct funding rebates to small firms, which are in pre-production (and Canadian-controlled) and tax credits against taxes payable on profits for larger, more established, firms.

There are two other policies of note. The first is to encourage the formation of strong, industry-led associations, such as Biotech BC and Biotech Canada, which act as exchanges for pre-competitive intelligence and personal networking, and the encouragement, through tax measures, of private, non-profit, associations dedicated to medical research. These associations provide the only way in which individual Canadians can direct their donations to specific biotechnological research – they represent a grass-roots research program that is not duplicated in other disciplines.

## The nature of regional innovation systems

A number of Canadian authors (see for example, Holbrook and Wolfe, 2005) have described how Canada, a large, geographically and culturally diverse federation, is composed of a number of regional systems of innovation. These regional systems have a number of systemic differences. P.Cooke (1998) has proposed a taxonomy that differentiates regional systems of innovation in a two dimensional matrix. This matrix has a governance dimension (how technology is transferred in the economy) and a

[2] This is equally true of other disciplines. Education, including post-secondary education, is a provincial responsibility, and thus research in post-secondary institutions has to be managed without direct funding transfers from the federal government to the provincial governments.

[3] See Holbrook and Clayman (2004). On the other hand, Canada has a well-developed ICT research capability through Nortel Ltd., which is based in Ottawa, and which grew out of federal research programs in that city.

dimension that describes the innovation process in the business sector (how firms see themselves and their innovative processes)[4].

The table below shows the regions originally chosen by Cooke as exemplifying his taxonomy, Canadian provinces chosen by Holbrook and Salazar (2006), with equivalent Korean regions chosen by Chang (2005):

[4] The reader should refer to Cooke's paper (1998) for a full description of this paradigm

Table 1: Regional Systems of Innovation

| Governance → Business Innovation ↓ | *Grassroots* | *Networked* | *Dirigiste* |
|---|---|---|---|
| *Localized* | Tuscany | Denmark<br>*Pohang City* | Tohuku (Japan)<br>*Jinju City* |
| *Interactive* | Catalonia<br>*Saskatchewan*<br>*Manitoba* | Baden-Wurtemburg<br>*Alberta*<br>*British Columbia*<br>*Seoul City* | Quebec<br>*Daejon City* |
| *Globalized* | California<br>Ontario | North-Rhine<br>*Gyonggi Province* | Singapore |

Note: Regions in italics are from either Salazar and Holbrook or Chang. Those in regular font are from Cooke.

In the case of British Columbia, the geographic region in question really the Greater Vancouver Regional District, which is a geographic areas surrounded by the sea and by mountains. Vancouver is a well-defined economic region which hosts a number of high-tech industrial clusters, which beside biotechnology, includes wireless, fuel cells, and new media. All of these have the common feature that Vancouver does little actual manufacturing; rather it develops the intellectual property required for innovative products, while the actual products are manufactured elsewhere (often in lower wage-rate venues, closer to the final consumers).

**The Innovation Systems Research Network project: the Vancouver biotechnology cluster**

Why choose Vancouver[5] biotech cluster as a case study? Because, on the one hand, biotech is clearly a research-based industry, therefore university research and public R&D funding play a key role in the development of a cluster. On the other hand, Vancouver seems to be very successful according to different studies and indicators, such as number of bio-scientists , the number of spin-off companies from universities and the survival rate of these companies , the commercialization of R&D , and the ability to retain and attract talent.

The Innovation Systems Research Network (ISRN) is a cross-disciplinary, national network of researchers drawn from five regional nodes based in Atlantic Canada, Québec, Ontario, and Western Canada. In 2001 ISRN launched the five-year project "*Innovation Systems and Economic Development: The Role of Local and Regional Clusters in Canada"* funded mainly by the Social Science and Humanities Research Council

[5] This paper refers to Vancouver, but for cluster indicator purposes it is really the Lower Mainland of BC, which includes Vancouver, Burnaby, Richmond, Delta, North Vancouver, New Westminster, Abbotsford, and Langley, among other smaller cities. More than 50% of the firms are located in the city of Vancouver, followed by Burnaby with 15% of the enterprises. We purposely exclude Victoria taking into account that "no matter what method of transportation is used, it takes over two hours to travel from one city centre to the other (other than by scheduled helicopter service). Two hours is often taken as the outer boundary for travel time across the geographic area of a cluster" .

(SSHRC), with some additional support from other federal and provincial agencies. This project is investigating how local networks or clusters of firms and supporting infrastructure of institutions, businesses and people in communities across Canada interact to spark economic growth[6]. Research is focused on 27 clusters –of which Vancouver biotech is one - across the five regions in Canada in newly emerging knowledge-intensive areas as well as in more traditional sectors. It covers large metropolitan settings located near research-intensive universities as well as rural settings. One of the objectives of the ISRN study is to develop a methodology to examine regional innovation systems and their constituent features, and to define the necessary and sufficient conditions for the continued existence of the clusters in the regional innovation systems.

Finally, through the analysis of this data we may be able to identify the necessary and sufficient conditions are for a cluster to survive in the longer term. Up to now ISRN researchers have identified some of the necessary conditions, like a world-class research university and a cosmopolitan community . Yes the questions remains, what are the sufficient conditions for continued existence? It is the intent of this paper to identify outcome indicators that can assist in answering the above question. The paper is organized in four main sections, starting with an overview of the Vancouver biotech industry. In the second section we will present the main inputs to the cluster, followed by the presentation of some of its outcomes. Finally, we will draw some conclusions and set up the next step of this on-going research project.

### Sources of information

Results presented in this paper will make reference to different quantitative and qualitative studies. Quantitative information will mainly make reference to Statistics Canada, especially the 2001 Biotechnology Use and Development Survey. The other studies are: the Innovation Systems Research Network (ISRN) cluster project, the Vancouver Economic Development Commission (VEDC) report "Vancouver: A North American Biotechnology Centre" of 2002, a series of reports made for the Canadian Foundation for Innovation (CFI) regarding cluster development, and three reports commissioned by the Canadian Biotechnology Strategy.

The VEDC, BC Biotech Association, and Discovery Parks (DPI) undertook a study using the methodology of the 2002 Brookings Institution report *Signs of life: The growth of biotechnology centers in the U.S.*[7]. BC Biotech and DPI provided the data and VEDC did the analysis of the information. The set of indicators used to determine the relative success of the biotechnology industry were organized around two main areas: research activity (funding from CIHR[8] and CFI, and number of patents issued 1990-1999), and commercialization (venture capital funding to biopharmaceuticals 1995-2001, value of R&D partnerships with pharmaceuticals 1996-2001, number of biotechnology companies

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[6] To date, four books have been published with proceedings of the ISRN annual conferences, which include interim reports of the project, as well as contributions from national and international scholars . More information on the project can be found in www.utoronto.ca/isrn.

[7] See http://www.brook.edu.

[8] The Canadian Institutes for Health Research (CIHR) is one of the four Canadian granting agencies.

with 100 or more employees in 2001, and number of start-up companies 1991-2001) . The third group of reports used for this paper, is a couple of studies on clusters, looking at the role of spin-offs and R&D funding .

Finally, in 2003 the Canadian Biotechnology Strategy commissioned three studies related to: i) alliances between firms within and between clusters; ii) scientific publications and collaborations (a bibliometric study conducted by the Canadian Science and Innovation Indicators Consortium); and iii) a survey on eleven biotech firms from across the country (conducted by Strategic Health Alliances). These reports were later summarized by the National Research Council (NRC).

The Statistics Canada "*Biotechnology Use and Development Survey, 2001*" was undertaken in two phases. First a short survey to identify firms actually involved in biotech was sent to 11262 firms. Later the full survey was sent to 900 firms, with an 84% rate of response. Not-for-profit organization, universities, hospitals, government laboratories, and contract research organizations were excluded, as well as firms with less than 5 employees and less than $100,000 in R&D expenditures.

For the ISRN project, the research team designed a set of interview guides (for companies, research institutes, government agencies, financial institutions, and civic associations), based on the OECD Oslo Manual and Statistics Canada innovation surveys. For the Vancouver biotech cluster study 50 interviews were conducted in two rounds, during the Summers of 2002 and 2003, comprising 23 biotech/biomed firms, 7 government agencies, 7 contract research and manufacturing organizations, 5 venture capital companies (VCC), 5 law and consultancy firms, 2 research institutes, and 1 civic association.

**What is "biotech**"?

Before we go any further it is crucial to state what we mean by "biotechnology industry". Generally, this industry makes reference to small and medium-sized companies specialized or dedicated just to biotechnology[9], excluding multinational pharmaceutical firms. For the purpose of the ISRN study, we used the OECD definition of biotechnology, which is the same one that Statistics Canada used for its biotech survey:

"*Biotechnology is the application of S&T to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*".

The OECD uses as an indicative, but not exhaustive list of biotechnology techniques and applications as an interpretative guide, which includes:

> *DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering.*

[9] Some authors refer to these companies as "specialized biotechnology firms" (SBFs) or "dedicated biotechnology firms" (DBFs). For the purpose of this study we will use the term biotech firms, understanding these specialized SMEs.

*Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein glyco-engineering, proteomics, hormones, and growth factors, cell receptors/signalling/pheromones.*

*Cell and tissue culture and engineering: cell/tissue culture, tissue engineering, hybridisation, cellular fusion, vaccine/immune stimulants, embryo manipulation.*

*Process biotechnologies: Bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, biodesulphurization, bioremediation, and biofiltration.*

*Sub-cellular organisms: gene therapy, viral vectors.*

Some of the differences on the data presented below can be attributed to definitional issues, since some institutions talk about biotech industry, others about life sciences (especially institutions with various stakeholders), a broader concept, encompassing other industries such as medical devices. In addition, we differentiate between human health care biotech and other applications, such as agriculture, aquaculture, environment, etc.

### Characteristics of the Vancouver biotech cluster

BC Biotech states[10] that the biotech industry in the province is comprised of 90 privately owned firms, 12 contract research organization (CROs), 3 contract manufacturing organizations (CMOs), 6 clinical trial organizations, 7 venture capitalists, 8 government organizations, 3 not-for-profit organizations, 3 research institutes. Most of these located in the Lower Mainland and few in the Greater Victoria area. Some of these organizations perform more than one function.

Information from another source  provides a broader picture of the life sciences cluster in BC, which comprises: 43 private firms that develop pharmaceutical, therapeutics and genomic products for human health care, and more than 100 enterprises that develop medical devices, bioinformatics, nutraceuticals, diagnostics, agriculture and aquaculture products.

BC life sciences industry is mainly oriented to human health care - 60% of firms are oriented to biopharmaceutical and biomedical applications – with few agrobiotech firms in the province.

For making comparisons more meaningful between Canadian cities/clusters – due to large differences in size - we have to determine a normalizing factor. We have different options: population, highly qualified personnel, or number of biotech innovative firms. NRC uses population, Clayman and Holbrook use highly qualified personnel, and we propose number of innovative firms. Depending on the case, a different normalization variable will be used, the one that makes more sense.

[10] See web page (industry backgrounders) http://www.bcbiotech.ca.

Compared to Montréal and Toronto biotech clusters[11], Vancouver is smaller in number of firms, employment, revenues, and amount of capital raised, but invests more money in R&D and has more bio-scientists[12] (see table 1). Queenton and Niosi suggest that bio-scientists play a major role in the location and growth of biotechnology firms . This statement gives a promising future to Vancouver's biotech industry.

The biotech industry in the Lower Mainland is composed mainly of young and small firms[13], inspired by QLT - created in 1981 – which is the largest (around 300 employees) privately owned and highly successful biotech firm, which can be considered the star firm of the cluster - but not an anchor firm. At present there are more medium sized companies, and some are following the successful path of QLT (see table 2 for size distribution of biotech innovative firms).

Here it is important to introduce an issue that refers to the way statistics are presented in Canada, which hinder somewhat cluster studies based on official data. Statistics Canada generally doesn't provide data at the metropolitan level because of confidentiality concerns[14]. During the process of doing this research and writing the paper Industry Canada made available to the ISRN research team selected data for biotechnology companies at the city level, which allowed for more meaningful comparisons between clusters. However, Holbrook and Clayman's claim is still relevant:

> *"In Canada, given its geography, 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 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"* ).

In the table below some basic indicators are presented for the three major human health biotech clusters, although the data refers to all biotech firms.

**Table 1 Comparison of Canadian biotech clusters**

[11] Other Canadian cities claim to have a biotech cluster, but according to the NRC, Montréal, Toronto and Vancouver are really the major human health clusters in the country, Edmonton would be the fourth one to consider . For the purposes of this study we will just make reference to the first three.

[12] They established four categories of bio-scientists: bio-superstar, bio-star, bio-collaborator type A, and bio-collaborator type B. Differences between them refer to the number of patents granted and annual publications .

[13] See in Biotechnology in BC 2004, the official magazine of BC Biotech Association a list of the core BC Biotech member companies classified by stage of development, fields of study, tools and diseases. It can also be found in its web page.

[14] For instance, in a recent study by Statistics Canada on the emerging geography of new economy analysis is done at the provincial and urban level, but the data presented at the city level is aggregated by city size, that means that large cities (population greater than one million) are grouped in one category, then medium-sized cities, etc.

| Cluster | Number of biotech innovative firms | Biotech Revenues (millions of dollars) | Biotech business R&D expenditures (millions of dollars) | Number of employees in biotech-related responsibilities | Number of bio-scientists (1) |
|---|---|---|---|---|---|
| **Montréal** | 80.0 | 1017.0 | 113.0 | 2935.0 | 70.0 |
| **Toronto** | 55.0 | 1094.0 | 85.0 | 2661.0 | 47.0 |
| **Vancouver*** | 48.0 | NA | 258.0 | 1701.0 | 80.0 |
| **Subtotal major clusters** | 183.0 | 2111.0 | 456.0 | 7297.0 | 197.0 |
| **Total Canada** | 375.0 | 3569.0 | 1337.0 | 11897.0 | 430.0 |

Source: Statistics Canada Biotechnology Use and Development Survey - 2001; provided by Industry Canada; (1) Qeenton and Niosi, 2003.
Note: * Vancouver R&D expenditures do not include large firms because of confidentiality requirements.

The youth of Vancouver biotech firms can also be appreciated in the low revenues and high R&D spending, and their size can be measured by the number of employees. Vancouver has a bigger proportion (36 out of 48) of small firms (less than 50 employees) compared to Montréal and Toronto; Montréal has the largest share of large companies (more than 150 employees).

**Table 2 Size distribution of innovative firms in major biotech clusters**

| City | Small | % | Medium | % | Large | % | Total | % |
|---|---|---|---|---|---|---|---|---|
| **Montréal** | 49 | 41.2 | 15 | 38.5 | 16 | 64.0 | 80 | 43.7 |
| **Toronto** | 34 | 28.6 | 15 | 38.5 | 6 | 24.0 | 55 | 30.1 |
| **Vancouver** | 36 | 30.3 | 9 | 23.1 | 3 | 12.0 | 48 | 26.2 |
| **Total major clusters** | 119 | 100 | 39 | 100 | 25 | 100 | 183 | 100 |

Source: Statistics Canada Biotechnology Use and Development Survey - 2001; provided by Industry Canada

**Key Features of the Cluster**

Vancouver's biotech cluster has some very distinct characteristics[15]. The first question to ask is if firms consider themselves to be part of a network of related firms in the region (ie: a cluster): 59% of firms recognize there is a cluster even if loosely connected, and 33% say that they are not part of it, even if they usually acknowledge its existence. When we look at the cluster networking patterns and interactions between firms and various actors, we found no vertical integration (suppliers are from all over the world), and little horizontal integration or competition among local firms. In respect of suppliers, it is

[15] The data presented below is taken from the ISRN data base, making reference to 27 firms, biomed firms and contract research organizations.

important to mention that few firms in the Lower Mainland actually manufacture their main outcome is intellectual property as such. The few firms that have products in the market have manufacturing agreements with companies from outside the region. Therefore, suppliers are not key actors in the biotech cluster (70% of firms affirm that suppliers do not play a role in the growth of the company – see table 3). In relation to competition, each biotech company works in a very specific niche of technologies or products[16], knowledge comes mainly from research results of local scientists, so there is little technological competition among firms. In addition, the local biotech firms have little commercial relations among themselves. They neither compete for local talent – we will explore this issue later in the paper - nor for market (which is global), they just compete for venture capital funding, which is scarce locally. And that is changing too, since local companies have been successful in getting funding from American, European and Asian VCC[17]. Finally, in relation to collaborations and alliances, there are few companies that have some kind of association with other local firms, but strategic partnerships with non-local firms - especially big pharmaceuticals – are quite important; 55.6% of companies affirm that they have alliances with multi-nationals, which could be at different phases: drug development, clinical trials, production, or marketing.

The role of location and lifestyle are clearly a contributing factor to the development of the biotech cluster in Vancouver, based on the responses obtained in three different questions. First, we asked why they were located in the region: 85% of firms say that their location is due to founders being from Vancouver who have close relationships with university labs and R&D institutions; in addition 18.5% affirm that it is a nice place to live. Second, we asked about the advantages of being in Vancouver: 48% of the interviewees said that the advantages are due to the 'cluster' existence and the facilities associated with it (R&D labs, VC, etc.), and 22% said that the city is nice, which makes it easier to attract people to live here. And finally, when we asked about contributing factors for the growth of the firm and the cluster, co-location with other firms was important, but most important, was the existence of specialized research institutes and universities, and the accompanying factor of supply of workers with particular skills responses (see table 3 below).

**Table 3 Most important factors in the local/regional economy that contribute to or inhibit the growth of Vancouver biotech firms**

| **Factors** | **Not applicable** | **Inhibit** | **Contribute** |
|---|---|---|---|
| Co-location with other firms in the same industry | 8 | 1 | 18 |
| Supply of workers with particular skills | 2 | 4 | 21 |
| Physical, transportation or communication infrastructures | 12 | 4 | 11 |
| Availability of financing | 6 | 6 | 15 |
| Specialized research institutions and universities | 3 | 0 | 24 |

[16] See BC Biotech list of core member companies by fields of study, tools and diseases, available in its 2004 magazine and its web page.
[17] According to *Biotechnology in BC* (pg. 52) –the official magazine of BC Biotech Association - life sciences public and private companies raised $1.03 billion companies in 2003, via different mechanisms, VC, IPOs, equity financing; Vancouver biotech companies received around 92% of that money.

| | | | |
|---|---|---|---|
| Specialized training or educational institutions | 8 | 1 | 18 |
| Presence of key suppliers and/or customers | 19 | 3 | 5 |
| Government policies or programs | 5 | 7 | 15 |
| Other | 20 | 2 | 5 |

Source: ISRN data base

**Role of universities and research centres: Inputs and outputs**

As mentioned before, the biotechnology industry is heavily dependent upon scientific research, therefore the role of universities, research hospitals and R&D institutions, and the availability of R&D funding are crucial. However, the impact of universities cannot be traced easily regarding cluster creation and development. A recent report about universities and industrial clusters in selected US states, affirms that:

> *"Regional efforts to develop industry cluster increasingly include universities as central assets. Unfortunately, little is understood about how universities impact the development of regional industry clusters. […] The characteristics of the cluster are as important as the characteristics of the university if there is to be any regional impact. Universities cannot defy the forces of the market. The university can produce the seeds of new firms and industries, but the region must offer a fertile climate for them to flourish"* .

The NRC report identifies few metrics to measure cluster activity, starting with the size of the population, followed by the concentration of public funded research . We propose three different measures (one input and two outputs): public R&D funding, patents, and scientific publications.

**R&D funding**

In Canada, as in most countries, granting agency expenditure data is not usually des-aggregated or classified by industrial sectors or clusters, but is normally presented by subject or discipline, which makes it difficult to analyze the impact of R&D funding in the promotion of regional clusters and industries. Data can be classified by province or city according to the location of the receptor institution.

In relation to biotech R&D money, there are four different sources in Canada: the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council (NSERC), the Canada Foundation for Innovation (CFI)[18], and Genome Canada; CIHR being the most important granting agency in the case of biotech[19]. From the table below we can observe that British Columbia receives a proportional share of

[18] The mandate for CFI is to fund research infrastructure.

[19] CIHR funding is divided in four categories: biomedical; clinical health systems and services; and social, cultural, environmental, population health. Most of the money is dedicated towards biomedical and clinical research, though for simplicity we will use all CIHR funding.

infrastructure funding from CFI (using population as the normalizing factor), but less than its proportional share of CIHR funding. In addition, the three provinces where the major human health biotech clusters are located (Ontario, Quebec and British Columbia) account for over 90% of the R&D funding for health.

**Table 4 Provincial share of R&D funding for health-related research**

| Province | Share of CIHR funding 1999-2001 (average per year) % | Share of CFI health sector allocations 1997-2002 % | Share of population % |
|---|---|---|---|
| **Ontario** | 41.7 | 39.1 | 37.8 |
| **Quebec** | 30.3 | 29.9 | 24.1 |
| **British Columbia** | 8.4 | 14.5 | 13.2 |
| **Subtotal** | 92.8 | 96.9 | 84.8 |

Source: VEDC, 2002; based on data provided by CFI and CIHR.

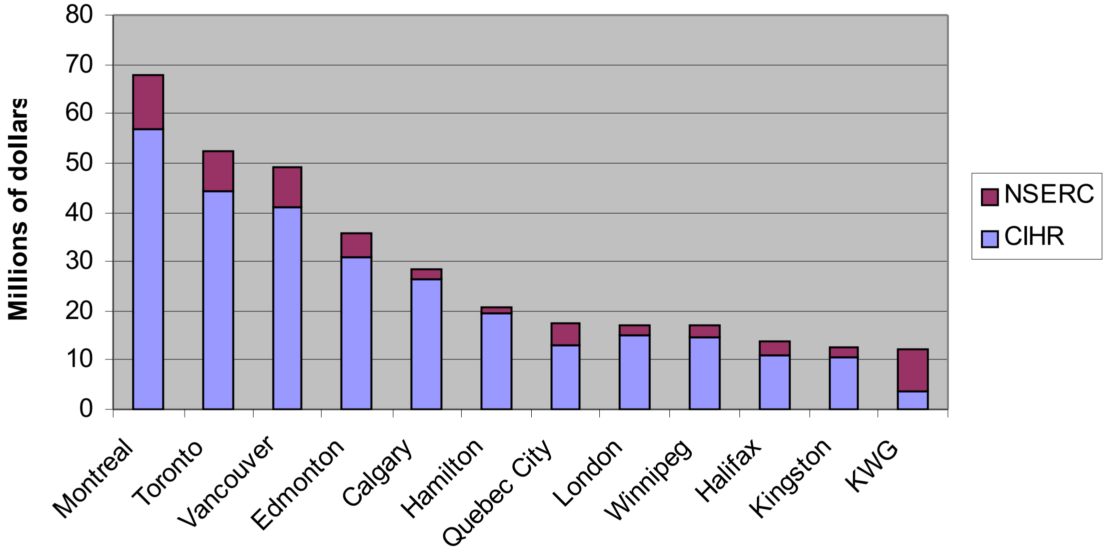
Using a different source, figure 1 shows the expenditures on biotech (in this case CIHR and NSERC) for major Canadian cities. Again we can clearly appreciate that Montréal, Toronto and Vancouver are the major recipients of those funds. What is interesting from that table is the distribution of NSERC biology funding, much less concentrated in the three major biotech clusters.

Holbrook and Clayman proposed several tests to qualify and characterize the impact of R&D funding on cluster creation and development. The first test is to determine R&D intensity (normalization of granting agency expenditures by population), which show the degree of R&D activity of a city. This data can be refined by HQP intensity, which is the ratio of HQP[20] to total labour force. In their own words:

> "*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 (HQP) in the population, which is a good measure of its receptor capacity*" .

[20] According to Statistics Canada 2001 Census Data HQP is defined as persons between 25 and 64 with at least a Bachelors degree.

Figure 1 - R&D funding for biotech (CIHR and NSERC biology) 2001

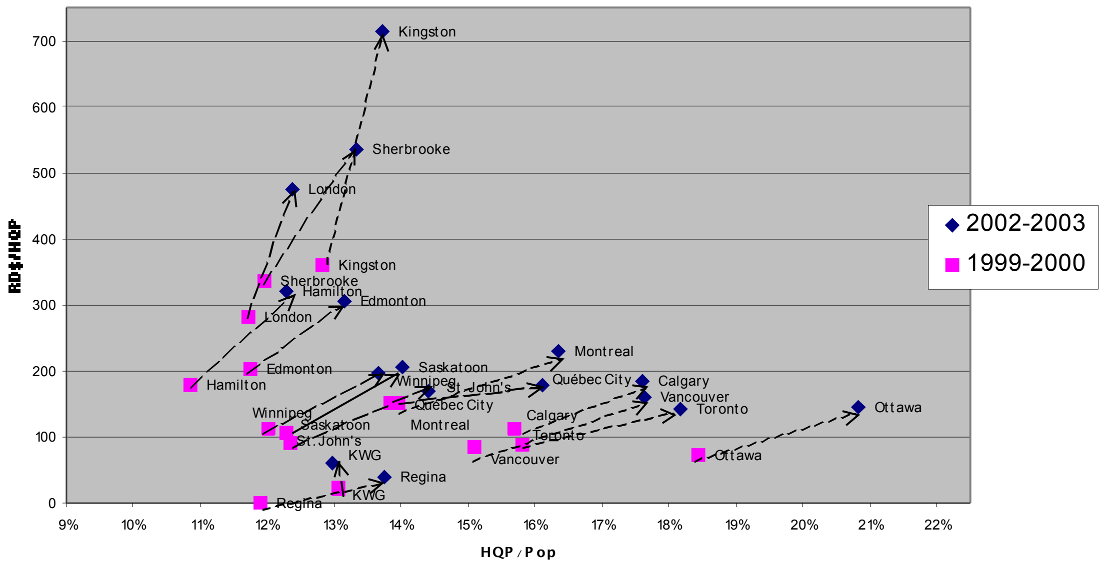



Source: Holbrook and Clayman 2004.
Note: KWG stands for Kitchener, Waterloo and Guelph, the only cities from the group that do not have medical schools.

Following Holbrook and Clayman analysis, the combination by city of R&D intensity and HQP intensity give us an estimative of the response of how the city is actually making use of R&D expenditures, if it is providing more or less qualified personnel to make an adequate use of that money. We encounter different situations in the Canadian case, two worth mentioning (see example of CIHR funding below), are:

- 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, which yield non-extreme levels of R&D intensity; and
- "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" .

**Year-to-Year Changes in CIHR R&D Intensity for 15 Major Cities**




Source: Holbrook & Clayman, 2004.

From the figure above it can be easily appreciated that Canada is keeping the pace in R&D funding for health research in relation to the increase in the highly qualified personnel; R&D spending is increasing at a higher rate than the increase in HQP. Different results were obtained for NSERC funding – flat arrows or slight increase– which could somewhat show the implicit S&T policy in Canada (i.e. health research is a priority).

### Patenting activity

Patents as said before are an important output of scientific and technological activity. Because of the close relationships between the biotech industry and universities and R&D institutions, it is important to study those relations through patents (i.e. licensing of university technology, or shared patents between companies and researchers). By studying patents we are also able to illustrate the involvement of scientists in the creation of biotech start-ups. This is also a measure of knowledge spill-over occurring within clusters. According to Queenton and Niosi's study on bio-scientists, a high proportion of Canadian university researchers are related to biotech companies through patents. In their own words:

> *"Contrary to our first assumptions on the importance of discoveries of genetic sequences, we found that for Canadian biotech firms what matters the most is the number and quality of patents that bio-scientists of different categories bring to those enterprises. Thus, the innovation output represented by patents and by patent citation constituted a real factor on employment growth"* .

Regarding patenting activity in Vancouver we have found interesting data (see table 5). Companies and UBC are the major patent holders, with similar numbers of patents granted. Interestingly, but not surprising, Vancouver organizations are not interested in patenting nationally (with the Canadian Intellectual Property Office); their target is basically the US. However it could be said that drugs are developed for a global market attended by multinational pharmaceuticals.

**Table 5 Patenting activity in Vancouver 1990-1999**

| Organization | US Patent and Trademark Office | Patent Cooperation Treaty | Canadian Intellectual Property Office | European Patent Office | Total patents by organization | Share % |
|---|---|---|---|---|---|---|
| **Vancouver companies** | 67 | 51 | | 69 | 187 | 52.8 |
| **SFU** | 10 | 5 | | 1 | 16 | 4.5 |
| **UBC** | 43 | 90 | 11 | 7 | 151 | 42.7 |
| **Total patents by office** | 120 | 146 | 11 | 77 | 354 | 100.0 |

Source: PATSCAN; taken from VEDC, 2002.

Queenton and Niosi affirm that the interaction between scientists and firms are much more than knowledge transfer, there are also market/monetary interests involved. In their own words:

> *"The analysis of the presence of star scientists in biotechnology firms and the identification of the roles they played in the formation and the survival of those firms will give us good indicators about the dynamic interaction between different types of activities in biotechnology. Scientists in university departments and in public research centres increasingly become full economic actors"* .

Following this argument, Queenton has further studied the kind of relationships that bio-scientists have with firms and what kind of role they perform. In the case of Vancouver, more half of researchers (57%) keep the link to the company through the patent, 36.5% have a seat on the board of directors, and fewer (6.1%) have the double connection. In relation to roles, few of Vancouver researchers (10.4%) act as founders of the company (10.4%), a relative high number (42.6%) have an specific function within the company, while a third of them keep both affiliations (to the firm and the university or R&D institution) .

### Scientific publications

Due to the close connection of the biotechnology industry to university research, it is important to analyze the patterns and trends of scientific publications. As an example, the Canadian Science and Innovation Indicators Consortium prepared for the Canadian Biotechnology Strategy a bibliometric study that tries to identify research clusters in biotechnology in Canada. Looking at this document and the summary report by NRC, there is nothing out of the ordinary; the number of publications per city/cluster follows the pattern of research funding .

**Table 6 Scientific publications in biotechnology 1996-2000**

| **Cluster** | **Number of publications** | **Share by city/cluster %** | **Provincial share %** |
|---|---|---|---|
| Montréal | 1432 | 21.2 | 28.7 |
| Toronto | 1337 | 22.7 | 40.9 |
| Vancouver | 787 | 12.5 | 13.7 |
| Total | 6305 | | 100.0 |

Source: .
Note: The provincial share is obtained based on larger number of publications.

Apart from only looking at the number of papers published, we can see how productive the scientists are by comparing the number of publications with the R&D funding they receive (table 7). Some authors affirm that for doing this kind of measurement one should consider a time lag of 5 to 7 years, after the funding occurs. Of course this is not a perfect match (person by person, or institution by institution), since it is aggregated, in this case at the city level. Different reports give various results on this issue. It seems that there are several factors which may affect these results: i) the categorization of scientific publications; ii) the granting agencies included; and iii) the time period considered, both for publications and R&D funding. Table 7 below present some data based on two different studies, and without taking into account the time lag suggested, showing a high rate of publication for Toronto, and a quite low rate for Vancouver. One possible explanation why Vancouver scientists publish less is because of their closer connections to biotech spin-offs firms, which discourages publication; the opposite would be applicable to Toronto.

**Table 7 Biotech scientific publications and public R&D funding for biotech**

| Cluster | Number of Publications 1999 (1) | Number of Publications 2000 (1) | R&D funding for biotech 2001 (2) | Publications (2000) per million dollars invested (2001) |
|---|---|---|---|---|
| **Montréal** | 284 | 291 | 67,996,641 | 4.3 |
| **Toronto** | 253 | 279 | 52,234,867 | 5.4 |
| **Vancouver** | 177 | 165 | 49,018,171 | 3.4 |
| **Subtotal major clusters** | 714 | 735 | 169,249,679 | 4.3 |
| **Canada *** | 1283 | 1291 | 391,648,9590 | 4.9 |

Source: (1) Godin et al (2003); (2) Holbrook & Clayman (2004).
Note: Total publications for Canada include only 14 major clusters. R&D funding includes CIHR and NSERC (biology) funding for 28 cities.

As a way of concluding this section, we can quote the VEDC report "*Vancouver: A North American Biotechnology Centre",* which affirms that "we do more with less", which means that despite the low level of research activity (funding and patenting) Vancouver rates high in the commercialization index . Comparing Vancouver[21] results with the average of 52 American metropolitan centres, Vancouver's research index is 0.34, and commercialization index is 2.50 (see overall results of the study in table 8).

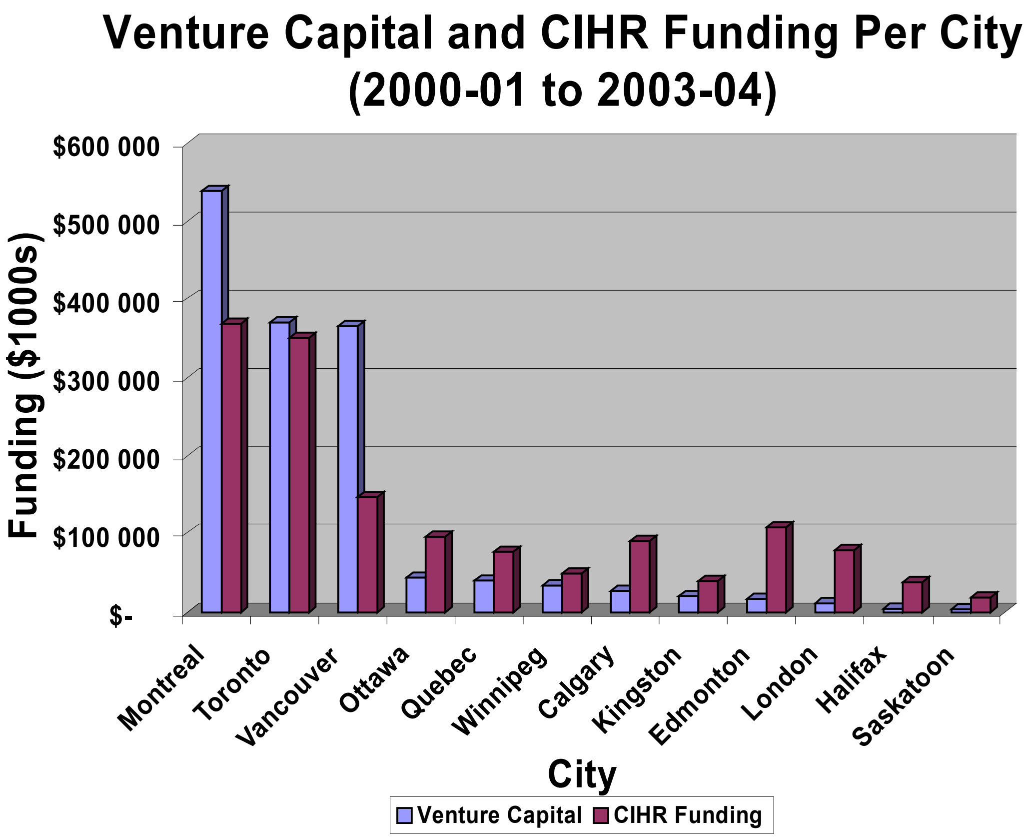
[21] VEDC did not have data available at the city level therefore they used provincial data, which for the case of BC is not too problematic since approximately 87% of biotech firms are located in the Lower Mainland (Vancouver for short).

**Table 8 Measures of biotechnology activity in metropolitan centres**

| | **Lower Mainland/Southern Vancouver Island** | **52 US cities average** |
|---|---|---|
| **Biomedical research capacity and activity** | | |
| CIHR/CFI funding 2000 | US$34.5 millions | US$225.5 millions |
| Patents files at US Patent Office 1990-1999 | 354 | 676 |
| **Research Index** | **0.34** | **1.0** |
| | | |
| **Biotechnology commercialization** | | |
| Venture capital 1998-2001 | US$204.1 millions | US$191.3 millions |
| Value of R&D alliances | US$290.0 millions | US$203.0 millions |
| Biotechnology firms with 100 or more employees | 6 | 6 |
| New biotechnology firms 1991-2001 | 60 | 9 |
| **Commercialization Index** | **2.50** | **1.0** |

Source: VEDC, 2002

These results were confirmed by NRC, which on a per capita basis they found Vancouver has a better record in firm generation, venture capital funding, than either Montréal and Toronto, but fall behind in CIHR funding .




Source: Griller and Viger, 2004.

**Outcomes of R&D funding**

What comes next is the more interesting story about the cluster. From the university point of view an outcome of its scientific and technological activity will be the commercialization of research, via licensing and spin-offs[22]. Some universities actually support and encourage this while others do not. Intellectual property rights (IPR) practices across Canadian universities are very diverse; there is no such thing as the Bayh-Dole act in the country. In the case of Vancouver, while the University of British Columbia (UBC) and Simon Fraser University (SFU) have different IPR policies, both encourage commercialization of R&D. In addition to licensing, there are spin-off companies, which can also be considered as an outcome indicator of R&D funding. Turning into private sector firms, established companies or newly created start-ups which license technology from universities (input), have as outputs of their innovative activities new technological products/services and processes[23]. There are some other

[22] Statistics Canada defines a spin-off as “a new firm created to transfer and commercialize inventions and technology developed in universities, firms and laboratories”, 1999 Biotechnology Use and Development Survey.
[23] It is important to note that Vancouver’s biotech firms produce mainly intellectual property rather than products as such .

consequences[24] of their activities: in the medium-term to create employment, to attract talent to the region; and in the longer-term to improve the quality of life (e.g. improve diagnostic methods, find cures to diseases, decrease mortality rate). We will focus on the medium-term outcomes of R&D activity both from universities and firms.

### University Spin-offs

The majority of biotechnology companies in BC have been spun-off from the province's universities, affiliated teaching hospitals and public sector research institutions; UBC being the major source of new firms, basically because it has a medical school. Since the creation of the University-Industry Liaison Office (UILO) in 1984, UBC has spun off till March 2003 48 life sciences companies[25], of which 31 are still active in the region, 5 acquired or merged (just one of them not locally present). Taking into account the common yardstick of 5 years minimum of survival, 28 companies (out of 38) founded before 2000 are still active, that is a 74% survival rate. Clayman and Holbrook (2004) found that 23 biotech firms were created in Vancouver between 1995 and 2001 and 19 were still active in the summer of 2003 –that is how they defined the survival rate of the companies- 14 spun out of UBC, and 5 spun out of SFU.

Using spin-offs as an outcome indicator carries some methodological problems. On the one hand, to date no government systematically collects data on spin-offs. The more comprehensive data available is the survey of technology commercialization activities in North American Universities conducted by the Association of University Technology Managers. On the other hand, there is no accepted definition of "spin-offs". Furthermore each definition varies. For example, there is a general belief that spin-offs result from research done at universities and R&D centres and sometimes companies. However, companies consider themselves spin-offs only when there is a licensing agreement or shared patent. In contrast, universities hold having a university professor as a founder of a company is enough to be considered a university spin-off. Thus it is easy to understand the methodological difficulties encountered when using the term "spin-offs". For our purposes we will use the term from the firms' standpoint.

[24] Statistics Canada differentiates between outcome and impact indicators of science and technology activity in a useful way: outcomes are medium-term consequences of such activities, and impacts are longer-term consequences of activities, linkages and outcomes.

[25] http://www.uilo.ubc.ca/tech_transfer/spin_off/index.htm

**Table 9 Biotech spin-offs companies 1995-2001**

| Clusters | Active | Inactive | Total | Survival rate % | Active spin-offs per 100.000 HQP |
|---|---|---|---|---|---|
| **Montréal** | 31 | 13 | 46 | 67.4 | 6.0 |
| **Toronto** | 23 | 9 | 32 | 71.9 | 2.7 |
| **Vancouver** | 19 | 7 | 26 | 73.1 | 5.6 |

Source: Clayman and Holbrook, 2004

Note: Vancouver includes University of British Columbia and Simon Fraser University; Toronto refers only to University of Toronto, and Montréal includes the universities of McGill and Montréal.

What is important to keep in mind is that the overriding goal of university spin-off is not to provide further income to the universities, but to create well-paid new jobs in the region. For doing so, they need to survive, and hopefully to stay in the city where they were created, so they can contribute to the further development of the local cluster. It is important to note that the national survival rate is 73%, the same as Vancouver's survival rate; Montréal and Toronto have lower rates of survival . In their own words:

> *"Companies spun off from university research appear to be a particular way of effective means of technology transfer out of universities, leading to job creation and wealth creation. [But for] spin-off companies to contribute to economic growth they must survive and succeed*" .

**Venture capital**

The health care biotech industry requires large amount of money to go through the drug development and approval processes, which means that public R&D funding and research capacity – embedded in universities - are not enough to make a cluster flourish; it requires large amounts of risk capital. A good indicator of this capacity is the venture capital money raised by biotech companies.

Vancouver is home to eight venture capital companies (VCC). The city is not considered a major financial centre in Canada, local VCC have small amounts of money to invest compared to other Canadian or US VCC. What has been seen in recent years is that a number of firms have been able to attract money from other markets (principally the US). This is not to discount the role of the local VCC firms as they play an important role in the process. Even with limited amounts of cash, their money acts as a leverage, and more important, they can keep an eye on these firms, providing information to foreign investors.

Looking just at Vancouver's data, we can appreciate that local biotech companies have substantially improved its performance in this respect. According to table 10, the amount of venture capital financing, the number of transactions, and the average investment per transaction have all increased between1998 and 2001. This trend is very important because biotech spin-offs do not have a bright future if they cannot access money to finance the costly and lengthy process of drug development. But when compared with the other two major clusters (see table 11), we see that Vancouver companies raise less money than their Montréal and Toronto counterparts, in absolute terms, and also less by innovative firm.

**Table 10 Vancouver Venture Capital Financing 1998-2001**

| Year | Venture capital investment (US$ millions) | Number of financings per year | Average investment per transaction (US$ millions) |
|---|---|---|---|
| 1998 | 16.6 | 11 | 1.5 |
| 1999 | 35.6 | 15 | 2.4 |
| 2000 | 45.1 | 13 | 4.1 |
| 2001 | 106.5 | 11 | 9.7 |
| Total | 204.1 | | |

Source: Macdonald and Associates

Comparing the major biotech clusters, it is not surprising that Montréal has attracted the most venture capital, but what is of interest is that Toronto does not get a bigger share of that money considering the infrastructure it has, and in the case of Vancouver, even if it is not a financial centre, still receives a significant amount of those funds. These results maybe related to distinct IP university practices.

**Table 11 Table Venture capital – life sciences industry**

| Cluster | VC $000s 2002 | VC $000s 2003 | VC (2002) per innovative firm (2001) |
|---|---|---|---|
| **Montreal** | 167.7 | 152.9 | 2.1 |
| **Toronto** | 100.6 | 74.5 | 1.8 |
| **Vancouver** | 71.9 | 43.1 | 1.5 |
| **Subtotal major clusters** | 340.2 | 270.5 | 1.9 |
| **Total Canada** | 479.0 | 392.0 | 1.3 |

Source: Macdonald & Associates[26]

### Human resources, talent, and employment

From the science and technology indicators point of view, the role of human resources, especially of highly qualified personnel (HQP), can be seen from two different angles. On the one hand, HQP is an input to R&D activities. On the other hand, from a broader perspective (cluster development), HQP is both an input to economic activity but also an outcome of the success of the local economy attracting and retaining personnel. However,

[26] Data obtained from their web site: http:// www.canadavc.com, on May 2004.

from either perspective, it is clear is that we need to analyse in greater detail the role that HQP (or talent using Richard Florida's wording), and the quality of life of places play in cluster emergence and development. In this respect, Gertler and associates have noted:

> *"To be successful in this emerging creative age, regions must develop, attract and retain talented and creative people who generate innovations, develop technology-intensive industries and power economic growth. Such talented people are not spread equally across nations or places, but tend to concentrate within particular city-regions. The most successful city-regions are the ones that have a social environment that is open to creativity and diversity of all sorts"* .

From a cluster perspective, recent studies have proposed that industrial agglomeration is due to much more than solely economic reasons. Richard Florida has stated that cities attract talent through two interrelated mechanisms: market forces (ie. industries and firms than create the demand for talent) and non-market forces, which can be referred as set of place-based characteristics, such as amenities, lifestyle options, types of people and the like. He states:

> *"People with high levels of human capital tend to co-locate to realize gains in productivity. Put another way, the basic mechanisms of city formation, growth and structure turn on the process of productive agents selecting locations that reinforce productivity. This is very different from the cost-minimization and firm linkage theories of clustering that dominate much of the economic geography*" .

Empirical studies, with the objective of testing the above statements, were conducted for some American and Canadian cities , and in both cases was found that social and cultural factors affect agglomeration.

For Canada the findings were similar to the US but stronger relationships were found. Vibrant local population and openness to diversity attract highly qualified people to Canada. The conclusions of the report say:

> *"There appears to be a strong set of linkages between creativity, diversity, talent and technology-intensive activity that are driving the economies of Canada's city-regions"* .

The American report about the role of universities on cluster development states that one of the key variables to study the relation between the two is through employment. They used two measures: employment change 1975-2000 – they used a long-range perspective to avoid short-term changes - and, location quotient – to determine the significance of regional share in particular industries .

Some analysts claim that for measuring the real growth of the cluster we should use the number of employees in biotech-related activities, not total employment in those firms, since there are a large proportion of personnel dedicated to other activities. Employment data show us interesting patterns for the major biotech clusters: they have 33% of the population, 30% of general employment, 47% of HQP, and 61.4% of biotech employment. Therefore, the concentration of biotech activity is clearly represented in these three cities. Additionally, the last column shows that Toronto innovative companies employ more people than Montreal and Vancouver, which share similar averages.

**Table 12 Human resources data**

| Cluster | Population (1) | Employment (1) | Highly qualified personnel (2) | Number of employees in biotech-related responsibilities (3) | Share of biotech employment | Average of employees per innovative firm |
|---|---|---|---|---|---|---|
| **Montréal** | 3,507,200 | 1,679,000 | 514,560 | 2935 | 24.7 | 36.7 |
| **Toronto** | 4,882,500 | 2,413,000 | 866,840 | 2661 | 22.4 | 48.4 |
| **Vancouver** | 2,076,100 | 995,320 | 340,215 | 1701 | 14.3 | 35.4 |
| **Subtotal** | 10,465,800 | 5,087,320 | 1,721,615 | 7297 | 61.4 | 39.9 |
| **Canada** | 31,021,300 | 17,046,800 | 3,676,630 | 11897 | 100.0 | 31.7 |

Source: (1) Statistics Canada web site; (2) Clayman & Holbrook, 2004; Statistics Canada Biotechnology Use and Development Survey – 2001, provided by Industry Canada.

Since biotechnology is a research-intensive sector, it is logical that it is also a heavy user of highly skilled labour. From table 13 we can appreciate that 59.5% of the jobs in major clusters are scientific research/direction and technician categories, and the national average is 49% . The table below also identifies some interesting facts about the employment structure of biotech companies**.**

Vancouver has more scientific personnel, Toronto more people in finance/marketing (big difference) and regulatory/clinical affairs, and Montréal more production personnel. The concentration of employees in the scientific research/direction and technician categories for Vancouver (67.4) is much higher than the national average, but also when compared to Montreal and Toronto. This structure of employment clearly shows the stage of the companies (early stage versus mature company) but also their emphasis (research/innovation versus production).

What we have observed in Vancouver biotech cluster in relation to the local talent pool, is that senior management is scarce locally (CEOs and regulatory/drug development experts especially), and technical and scientific personnel is available (graduating from local universities and technical institutions). It seems that mobility at higher positions is high, but there is not much mobility at the scientific and technical level, but certainly people stay in the region. The lack of specialized management expertise in Vancouver is due to the absence of pharmaceutical companies in the region. Analyses based on data collected through the Statistics Canada biotech survey, small companies tend to recruit personnel directly from universities, but as they grow they turn to other companies to look for new workers . What may happen in the future in Vancouver, as biotech jobs shift from small to medium-sized firms, is that we will see more mobility among companies, which is not happening at present.

**Table 13 Distribution of biotechnology employees in innovative SMEs**

| | Montré al | % | Toronto | % | Vancouver | % | General % |
|---|---|---|---|---|---|---|---|
| **Scientific research & direction** | 509 | 35.3 | 354 | 27.7 | 416 | 41.4 | 34.4 |
| **Technicians** | 400 | 27.7 | 274 | 21.5 | 261 | 26.0 | 25.1 |
| **Regulatory /Clinical affairs** | 52 | 3.6 | 109 | 8.5 | 28 | 2.8 | 5.1 |
| **Production** | 154 | 10.7 | 51 | 4.0 | 60 | 6.0 | 7.1 |
| **Finance/ Marketing** | 125 | 8.7 | 336 | 26.3 | 54 | 5.4 | 13.8 |
| **Management** | 189 | 13.1 | 135 | 10.6 | 120 | 11.9 | 11.9 |
| **Other** | 13 | 0.9 | 17 | 1.3 | 66 | 6.6 | 2.6 |
| **Total major clusters** | **1442** | **100** | **1276** | **100** | **1005** | **100** | **100** |

Source: Statistics Canada Biotechnology Use and Development Survey - 2001; provided by Industry Canada

Additionally, while conducting the ISRN interviews the research team noticed that in various biotech firms there were a number of key personnel who moved from various Canadian provinces, the US, and European countries[27]. Therefore, we undertook a simple Internet-based research, looking at companies' web sites, which provided academic information on their top management personnel. We surveyed 44 firms, of which 30 reported on their HQP. Results are presented in Table 12. Approximately 30% of people have a Ph.D. degree from a local university, while 70% in-migrate from other Canadian provinces or other countries[28].

**Table 14 Academic background of top management personnel (PhD level)**

| **Origin** | **Number of employees with PhD degree** | **Share%** |
|---|---|---|
| SFU | 3 | 4.8 |
| UBC | 16 | 25.4 |
| Rest of Canada | 9 | 14.3 |
| US | 16 | 25.4 |
| UK | 11 | 17.5 |
| Rest of the world | 8 | 12.7 |
| **Total** | 63 | 100.0 |

Source: CPROST – SFU

[27] See in the official magazine of BC Biotech Association "Biotechnology in BC 2004", the article by Rachana Raizada telling the story of Jeffrey Baccha, Inimex CEO who moved from San Francisco to Vancouver.

[28] At present we are re-doing this work, checking the information on the web sites and interviewing firms, gathering more information about management teams of all biotech firms in Vancouver.

Based on the ISRN interviews, the quality of life Vancouver offers is a major reason for companies and people to choose it, thus it can be said it is a contributing factor to the development of the cluster. It looks as though large firms and a larger pool of companies – that allow more mobility among firms- are not necessarily a prerequisite to attract employees as could be the case of Montréal and Toronto. The success of Vancouver could be due to the fertile ground that universities, R&D centres, and firms provide for highly qualified people to develop their careers and have a satisfying lifestyle. As Florida noted for US cities:

> "*The ability to attract talent is the fundamental dimension of city and regional growth. This contrasts with the preoccupation in much of the academic literature and in economic development practice that emphasizes the attraction of firms and the formation of industrial clusters. It is talent that orients the location decisions of firms and which underpins the formation of industrial clusters*" .

**Conclusions**

Several factors and conditions can be attributed to the creation and success of regional clusters, such as the existence of strong university research-oriented, availability of funding by public granting agencies, an entrepreneurial spirit, and a favourable location and environment so that talented people are attracted to those places. Research capacity is a necessary but not sufficient condition. As Griller and Viger (2004) pointed out: "*to succeed, increased research capacity, has to be overlapped with venture capital, and an entrepreneurial culture"*.

Vancouver seems to fulfill all those requirements. Once people come to Vancouver they tend to stay there (sticky labour). UBC research is the driving force behind the biotech industry in the city. R&D funding has not been as important as one would have expected, considering the growth of the cluster, but that has been replaced with an entrepreneurial force and availability of high risk capital[29].

Do the indicators tell us that Vancouver is significantly different in structure, not just size, from Toronto and Montréal? Is the Vancouver biotech industry an emergent or a research-based cluster? We could affirm that the structure is different and that Vancouver is really an R&D-based cluster: local firms invest more on R&D, there is a large pool of bio-scientists -who are highly productive (especially in terms of patents)-, employ more scientific and technical personnel, and do little manufacturing. These numbers were high in absolute terms and when normalized either by innovative firms or HQP. Additionally, S&T indicators show an interesting picture of Vancouver biotech cluster; we do not perform particularly well in terms of inputs and outputs (exception of patents), but we do

[29] Queenton (2004) has analyzed the various biotech clusters in Canada in terms of "stars", researchers who have significant numbers of papers and patents. By this measure Vancouver, with 80, comes slightly ahead of Montreal (70) and well ahead of Toronto (40). Other Canadian centres fall well behind these three cities.

in terms of outcomes (venture capital, attraction of talent, university spin-offs). Why is that? Are we missing any measures, particularly inputs? Maybe we have to broaden the way we study (measure performance) science, technology and innovation systems; we need to analyze especially the role of highly qualified personnel –their mobility and where and how they agglomerate.

Do the indicators tell us that Vancouver is a viable cluster? It looks as though the model of being an IP producer cluster works, that is, it seems that we do not need a manufacturing facility or pharmaceutical company to further develop the cluster. If the largest company of the region relocates or disappears, we do not believe that the integrity of the existing cluster would be jeopardized. In addition, as previously mentioned, Vancouver outperforms in attracting people, money and having an entrepreneurial capacity. New ideas, new firms, new people will come.

What policy advice could we derive from the indicators? The environment (city life and facilities) is key to developing the cluster. Richard Florida's conclusion certainly applies to Vancouver:

> *"People are attracted to real places. Cities and regions that facilitate the co-location of people that results in resource mobilization, new knowledge generation, and new ideas, reduces the costs associated with generating and transmitting ideas and knowledge"*

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