The Competencies of Regions Canada's Clusters in Biotechnology

Les compétences des grappes régionales des biotechnologies au Canada

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Résumé

Les industries intensives en connaissance tendent à se concentrer géographiquement, suite aux nombreuses externalités qu'elles génèrent. Ainsi, les firmes de biotechnologie s'établissent le plus souvent dans des régions qui sont déjà les hôtes d'autres firmes innovantes, de laboratoires gouvernementaux et d'universités qui les attirent (Swan, Prevezer et Stout, 1998). Dans ce texte, nous essayons de connaître plusieurs des caractéristiques des grappes canadiennes de biotechnologie, leurs régions principales, leur poids relatif, et les principales firmes et laboratoires gouvernementaux qui attirent de nouvelles entreprises. Aussi, nous développons le concept des régions comme des noeuds de compétences, une notion déjà établie pour les entreprises, mais qui peut être utile pour les régions à l'intérieur des nations, et à plus long terme pour les nations aussi. Les compétences (ou capacités) viennent avant, et expliquent, les externalités de connaissances. Les capacités des organisations et des régions varient de l'une à l'autre, et une étude approfondie des capacités organisationnelles et régionales, précède l'analyse des externalités de connaissance.

La méthodologie que nous utilisons pour cette étude est fondée sur les brevets, avec les brevets pris aux États-Unis comme source principale. Nous avons trouvé que Toronto était le premier centre de la biotechnologie canadienne, suivie de Montréal, et de Vancouver. La population totale des aires métropolitaines explique la taille, la localisation et les caractéristiques des principaux clusters, suivie de la recherche universitaire.

Abstract

Knowledge-intensive industries tend to concentrate geographically, because of the many spillovers that they generate. Thus new biotechnology firms often set up in regions that have innovative firms, government laboratories and universities, which attract them to enter (Swan, Prevezer, and Stout, 1998). In this paper we try to unveil some of the characteristics of Canadian clusters in biotechnology: the key regions, their relative weights, and the main firms and government laboratories that attract new entrants. Also, we develop the concept of regions as nexus of competencies, a notion already put forward for firms, but that may be relevant to regions within nations and, ultimately, to nations as well. Competencies (or capabilities) come before, and explain, knowledge spillovers. Capabilities of organizations and regions vary, and a thorough study of organizational and regional capabilities should precede the analysis of knowledge spillovers.

The methodology that we use for this purpose is based on patents, with the U.S. patent database as our main source. We found that Toronto is the main center of biotechnology in Canada, followed by Montreal, and Vancouver. Total population of the metropolitan area explains the size, location and characteristics of most Canadian clusters, followed by university research.

Keywords : Innovation clusters, firm competencies, biotechnology, regions' capabilities.
Mots clés : Grappes d'innovation, compétences de la firme, biotechnologie, capacités régionales.

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Within nations, scientific and technical competencies vary strongly among regions. Some regions within countries concentrate a disproportionate share of the capabilities of all developed and developing nations. Also, regions tend to concentrate their competencies on a few domains of expertise. This is what the literature calls "agglomeration effects": companies active in the same field of technology tend to cluster together geographically. They do so in order to share a common labor pool, and to obtain ready access to research institutions, such as government laboratories and universities, or to key markets and customers, such as large assemblers or government facilities (Feldman et al., 1999). The specialized literature calls these institutions and key markets/customers "entry attractors" (Swan et al., 1998)

In many types of science-based industries (SBIs), such as biotechnology, information technology and advanced materials, the major attractors are universities and government laboratories. In a few, more mature SBIs, including aerospace and aircraft, large assemblers tend to naturally attract smaller producers of parts, components and specialized software.

Canada is similar, in this respect, to other nations (Niosi, forthcoming). Its competencies cluster around a few large and medium-sized urban agglomerations, such as Toronto, Montreal, Vancouver, Ottawa, Edmonton, and Calgary. Specialized clusters have also developed around smaller cities. This study builds a theory of the competencies of regions using biotechnology as a case study. Government laboratories, as well as universities and a few large firms, attract entry. The goal of the paper is to examine -- using quantitative data –- the relative competencies of regions in biotechnology, and the role of NRC laboratories and university research[1].

CONTEXT

Clusters in biotechnology

Comparative analysis suggests that biotechnology tends to cluster regionally (Prevezer, 1998; Shohet, 1998). In both the United States and the United Kingdom, a few states or metropolitan areas concentrate a majority of the firms. Factors leading to this strong clustering include access to university and public sector research, and to venture capital and large markets in major cities. American biotechnology clusters developed around the US science base. Strong clusters exist in California (in Los Angeles and San Francisco), Maryland and Washington DC, Massachusetts (Boston), New Jersey (Princeton), New York City, North Carolina (the Triangle Research Park), Pennsylvania and Texas. These agglomerations undertake almost two-thirds of US biotechnology activity. Conversely, British clusters are closer to industrial agglomerations and concentrations of graduates. Analysts also consider the hypothesis that in Britain, the size of the biotechnology cluster varies with population: the triangle region delimited by London, Oxford and Cambridge has 50 per cent of British dedicated biotechnology firms (DBFs) (Shohet, 1998: 218). Greater London has the biggest agglomeration. However, no variable was highly significant in the United Kingdom to explain biotechnology clustering.

Knowledge spillovers, or externalities, are responsible for the geographical clustering of biotechnology firms. Innovative organizations generate knowledge, some of which "leaks" towards other organizations. As much of this knowledge is tacit –- particularly in new activities such as biotechnology –- geographical proximity is key for those absorbing such externalities. However, most of the literature assumes that all

[1] The NRC laboratories are the five biotechnology units in Halifax, Montreal, Ottawa, Saskatoon and Winnipeg.

organizations (firms, government laboratories and universities) are equally innovative. We challenge this assumption and inquire about their differential capabilities in this area. Also, we analyse the relationship between those capabilities and the clustering success of entry attractors. For this purpose, we extend the discussion of competencies from business administration to cluster theory.

A Theory of the Competencies of Regions

The resource-based theory of the firm explains the differential performance of firms by their different endowment of factors (Hamel and Prahalad, 1994; Foss, 1997). Firms develop internally or secure externally these resources to become more competitive than others in the field. Thus some firms get superior rents and maintain these idiosyncratic advantages through time (Williams, 1994). Differential performance may arise both from divergent endowment of resources, and from their novel organization of resources. The competence theory of the firm thus goes one step beyond the resource-based theory, recognizing that superior routines and organization may yield better performance (Foss and Knudsen, 1996; Durand, 1998). Competitors do not immediately imitate these performances because routines can not be observed easily, and because there is always some level of causal ambiguity about the causes of that superior attainment.

The competence theory for regions has identical assumptions to that for firms. Like firms, regions may be understood as sets of competencies and resources both tangible (physical infrastructure, corporate physical assets, research and development [R&D] laboratories...) and intangible (skills and human capital, routines, institutions). Not only resources are important for regions, but also the capacity to use them to produce superior results. In the evolutionary theory of the firm (Winter, 1987; Dosi and Marengo, 1995; Foss and Knudsen, 1996), as well as in the capabilities and competence approach (Teece, Pisano and Shuen, 1997), " organizational forms do matter because information flows, and behaviours differ according to the particular 'institutional architecture' of each system. In particular, if each system's performance rests on specific learning dynamics by individuals or groups of them (such as firms), the institutional architecture affects the scope at which such learning can occur." (Dosi and Marengo, 1995, p.158). Universities, of course, enhance regional capabilities by producing knowledge that facilitates wealth creation and the quality of life.

Similarly, regions within nations, like firms within industries, differ persistently in resources, behaviour, and performance. Thus their different outcomes and growth rates may be affected by some hidden variable, such as competencies, particularly core competencies. These variations in outcome suggest unequal resource endowments particularly in skills, information, and preferences, different attitudes towards risk and contrasted institutions related to technology and innovation (such as government laboratories and universities), learning routines, and financial institutions (such as venture capital firms).

Core competencies of regions include those that create economic value for markets outside the region, are co-specialized, and are difficult to imitate (Durand, 1998). In traditional industrial districts, as well as in the Perroux poles (Perroux, 1982), regional competencies consist of, first and foremost, those of the region's firms, including their capacity to cooperate with each other. Core competencies usually transcend those of firms: in science-based agglomerations and technological districts, with many SBIs, they include the propensity and capacity to cooperate with, and learn from, other institutions in the regional system of innovation (RSI), such as local universities, government laboratories, and venture capital firms.

Competencies, like knowledge in general, increase with use and decline if not used. Being closely related to and made of knowledge, they increase with practice, usually procuring sustained advantage to regions as well as firms.

Much knowledge is produced in an interactive way (Lundvall, 1992). Some authors have suggested that the density of the interactions between economic agents within a region also influences knowledge creation and thus performance (Héraud et al, 1997). According to some writers, a region such as Alsace -- where firms interact very little among themselves and with local universities and public laboratories, and where many of the firms are branch plants operating within an international network -- does not constitute a regional system of innovation. Of course, the question remains open as to how much local cooperation and how many local spillovers constitute a local or regional system of innovation.

Finally, as in business organizations, the explanation of a region's results is not always evident. There is much causal ambiguity as to what factors, and or combination thereof, explain the performances of regions. Thus economic actors, as well as governments, act under assumptions of bounded rationality. In an opaque, murky environment, they invest and operate without precise knowledge of future results. We see below that some government laboratories and university research efforts generate few economic spillovers in certain regions.

CANADIAN BIOTECHNOLOGY

Canadian biotechnology first started some years after their American competitors, but is comparable proportionately to the US field. By 1997, Canada had 282 domestic biotechnology DBFs, seventy-one of them public. The total market capitalization of these seventy-one firms was about C$ 12,9 billion by the end of May 1999, two-thirds of it in the four largest. Forty-two other firms had a market value under C$ 50 million each, and ten of these less than C$ 10 million. Also, the window of opportunity seemed to be closing for biotechnology initial public offerings (IPOs): in the first six months of 1999 only one new firm reached the market, with an offer that collected C$ 22 million.

Among the 282 DBFs existing in 1997, some 129 were in human health (46 per cent), 62 in agricultural biotechnology, thirty-two in environment, twenty in food products and thirty-nine in all other areas. They employed 9800 people. Human health had over two-thirds of employees, with an average size of eighty-one per firm, against forty-two in agricultural biotechnology, twenty-two in environment, twenty in food production and forty-three in other areas. DBFs had total annual revenues of C$ 11.2 billion, including exports worth C$ 4,9 billion.

The Canadian venture capital market has developed very rapidly in the last ten years. By the end of 1998, the total pool was estimated at C$ 10 billion, and that year more than C$ 1.66 billion was invested in some 1200 companies, sixty of them active in biotechnology. Seed money was the most frequent type of investment in DBFs, the average investment being around C$ 1 million. With some 210 firms outside the capital market, it is apparent that many demands for venture capital have not been accepted. In other words, even if the Canadian venture capital market is sizable, it cannot accommodate all the demands from domestic DBFs.

THE RESEARCH DESIGN

Methodology

We base this paper on an empirical analysis of technical competencies of DBFs, as indicated on the number of biotechnology of patents granted in the United States to Canadian corporations, to Canadian government laboratories and to Canadian universities[2]. Patents are uniquely revealing to study competencies, pointing not simply to resources (such as R&D personnel or laboratories), but to the ability to use resources to produce valuable results. Patents are thus the output of those resources. Thus they represent a more useful indicator of competencies than do R&D inputs.

In order to study technical competencies, we chose the U.S. patent database, instead of the Canadian one, for several reasons. First, all major inventions are patented in the United States, as most Canadian companies, government laboratories and universities seek to protect intellectual property of their most valuable knowledge assets in the largest, most inventive, and most affluent nation in the world. Second, the U.S. patent database, unlike the Canadian one, indicates the geographical location (country, city, and state or province) where the invention has been made, thus allowing precise identification of the region of the competence that has produced the invention. Third, more Canadian firms patent their novelties in the United States than in Canada. For instance, between 1980 and 1999 sixty-two Canadian biotechnology enterprises sought patents in the United States, and only thirty-seven in Canada.

Biotechnology presents a major methodological problem: it has no precise classification code -- be it a patent code, an industrial (or SIC) code, or a trade code – because it is a "generic technology," used across a variety of industries. We thus decided to identify DBFs (through the 1998 BIOTECanada Biotechnology Directory). We examined the patents of those companies, and ascribed them to biotechnologies, unless they were totally unrelated. The presence of a set of keywords in the patents' names and abstracts decided for us whether the patent was biotechnological or not. These key words included terms such as "DNA," "monoclonal antibodies," and "genetic material". We decided that DBFs produce biotechnology patents, but we checked for supplementary proof of capabilities in the specific areas by examining patent descriptions.

An additional problem for studies using patents, is the propensity to patent products rather than processes (Winter, 1989). Thus, we may have missed some process capabilities in biotechnology.

Government Laboratories

We examined government laboratories and all Canadian universities as to their role in attracting or nurturing private firms' competency. We found six public laboratories (five with the National Research Council of Canada (NRC), and one provincial unit) with Canadian patents. A brief description of these laboratories is presented here.

The NRC launched five institutes for biotechnology in Canada after the passing of Canada's biotechnology strategy in 1983. Some of these institutes started from scratch while others benefited from the experience and assets of pre-existing NRC laboratories. They are the Biotechnology Research Institute

[2] We based this work on the study by Antonelli (1986) on Italian industrial districts, though Antonelli used the Italian patent database, and had other research goals.

(BRI), the Institute for Biodiagnostics (IBD), the Institute for Biological Sciences (IBD), the Institute for Marine Biosciences (IMB) and the Plant Biotechnology Institute (PBI).

The Biotechnology Research Institute of Montreal was opened in 1987 from scratch and employs nearly 200 scientists, plus another 200 guest researchers in pharmaceutical, environmental and bio-processing industries. The most recent (1992) Institute for Biodiagnostics in Winnipeg is concentrated in developing technologies for disease diagnostic. The Institute for Biological Sciences in Ottawa, one of the oldest of NRC (1916) focuses on immunochemistry. the Institute for Marine Biosciences, originally established in 1952, works on marine biotechnology, including plants, shellfish toxins, and natural chemistry. In 1948, NRC created an institute for plant biology in Saskatoon, known as the Prairie Region Laboratory; under the new strategy, it became the Plant Biotechnology Institute in 1985, hosting some 45 staff and 70 guest researchers.

Each institute has been an “entry attractor” for new DBFs in its respective technology and region. As Canada had few DBFs in 1983, the NRC labs have antedated the founding of most of them. However, as all these institutes were created on or near university campuses, which already had departments or faculties of medicine, biology and biochemistry.

The Alberta Research Council set up laboratories in Edmonton in 1936 and created biotechnology facilities in the late 1970s and the 1980s. In terms of patents, ARC is the most active public laboratory in Canadian biotechnology.

Universities

Several Canadian universities have produced patents in biotechnology. The metropolitan areas of Montreal, Toronto, Saskatoon and Vancouver are among the most important centers of university research in biotechnology. We examined the competencies of a university via the patents held under its name, whatever the department or faculty having invented the product or process. Canadian universities have requested and obtained biotechnology patents since 1976, but most of them in the 1980s and 1990s. Research universities with a proved track record in medicine, plant and/or human biology include the Universities of British Columbia, Laval, McGill, McMaster, Montreal, Saskatchewan, and Toronto.

PATENTS THE EVIDENCE AND ITS SIGNIFICANCE

We collected patent data, as well as foundation dates, for the largest Canadian census metropolitan areas: Toronto, Montreal, Vancouver, Ottawa, Edmonton, Calgary, Winnipeg, Halifax, Quebec City, and Saskatoon. Only a few are hosts to public laboratories, but all have research universities. We present the results in Tables 1 to 8.

The number of DBFs, patents and patenting firms indicate that Toronto is the centre of Canada’s biotechnology with nearly 50 per cent of the patents granted to Canadian DBFs by the United States Patent Office since 1989. Despite creation of the BRI, Montreal remains a distant second (See tables 1 to 3 in the Appendix).

The two most inventive DBFs in terms of U.S. patents are Toronto’s Connaught and Allelix, followed by BioChem Pharma of Montreal. Two other Toronto firms come fourth and fifth: Visible Genetics and

Spectral Diagnostics. Also, one major DBF dominates invention capability in Montreal (BioChem Pharma), and one each in Edmonton (Biomira), Vancouver (QLT Phototherapeutics), and Saskatoon (Biostar). Each firm has between 38 and 75 percent of the privately held patents in its region. Toronto appears more economically decentralized in terms of technological competencies in biotechnology (Tables 4 and 5): several firms own a large portfolio of patents.

Table 4: Biotechnology. Economic concentration ratios of total patents of Canadian firms (1989-1999)

Ratio	Number of total patents	Percent Of Patents
CR4 (4 firms with most patents)	180	43
CR8 (8 firms with most patents)	238	57
CR12 (12 firms with most patents)	279	67
CR20 (20 firms with most patents)	330	79
Total	418	100

NB: Only private firms.
Source: US Patent Office: US Patent Database.

Table 5: Biotechnology. Regional concentration of US patents of Canadian firms (1989-99)

Region	Number of patents	Percentage
Toronto	178	61
Montreal	51	17
Vancouver	21	7
Saskatoon	12	4
Edmonton	11	4
Calgary	7	2
Ottawa	7	2
Quebec City	4	1
Winnipeg	3	1
Other	2	1
	292	100

Source: US Patent Office: US Patent Database.
NB: Only private firms

As for public laboratories, IBS in Ottawa remains the most productive of the NRC's five (in terms of patents), but the Alberta Research Council in Edmonton is the most productive public inventor of biotechnology. Some of the public labs are not strong in terms of patented novelty and so probably have less spillover potential in knowledge.

As for firm creation, BRI (Montreal) and PBI (Saskatoon) seem to have been major entry attractors: substantially more companies were created or attracted to the after their creation. The other large NRC institutes in Ottawa, Halifax or Winnipeg did not have as much impact. Also, regions with major research universities, such as Toronto, Vancouver and Quebec City (Ste-Foy) seem to bring in many DBFs even without the help of government units. Research universities seem to be as important magnets as government laboratories, which possess some of the largest concentrations of R&D resources and competencies in all the regions where they are present.

University labs

When it comes to universities, the regions rank differently (See table 9 in the Appendix). The University of Saskatchewan owns by far most patents, followed by the University of British Columbia in Vancouver, McGill University and the University of Montreal (both in Montreal), and the University of Alberta in Edmonton[3]. By urban agglomeration, Montreal and Saskatchewan share the first place in university patents, with thirty each, followed by Vancouver with twenty-two patents, and Toronto with thirteen patents (including those of the University of Toronto, with the universities of McMaster and Waterloo).

[3] One has to bear in mind the different intellectual property regimes of Canadian universities. UBC requires all professors and researchers on the campus to grant ownership of inventions to the University, while Toronto does not. Existing figures probably underestimate the importance of such universities as Toronto and Calgary where the owners of the patents may or may not be the University.

Table 6: Biotechnology. Regional concentration of patents of Canadian firms, universities and main government laboratories (1989-99)

Region	Number of patents	Percentage
Toronto	191	37
Montreal	96	18
Edmonton	59	11
Saskatoon	50	10
Vancouver	44	8
Ottawa	37	7
Winnipeg	9	2
Calgary	8	2
Quebec City	7	1
Other	19	4
	519	100

Source: US Patent Office: US Patent Database.

Table 7: NRC patents by institute (1989-99)*

Year	IBS (Ottawa)	BRI (Montreal)	PBI (Saskatoon)	IBD (Winnipeg)	IMB (Halifax)
1989	0	0	0	NA	0
1990	1	0	0	NA	0
1991	3 1/2	3	0	NA	0
1992	1/2	0	0	0	0
1993	0	0	1	0	1
1994	2	2	0	0	0
1995	3	2	0	1	0
1996	4	2	2	0	0
1997	2	2	1 1/2	1	0
1998	5	1	1	1	0
1999	3	3	2 1/2	1	0
Totals	24	15	8	4	1

Source: US Patent Office: US Patent Database, NRC Web site; personal communication with the Institutes
*:half patents design patents where NRC is one of two co-assignees.
NA: The IBD was founded in 1992.

Table 8: Biotechnology patents by university: 1989-99

University	Total number of patents assigned (A)	Number of patents in biotechnology (B)	Patents in biotechnology as % of total (B*100/A)
University of British Columbia	214	22	10%
Queen's University	77	8	10%
McGill University	68	16	24%
University of Alberta	61	9	15%
University of Waterloo	50	1	2%
University of Toronto	47	4	9%
University of Saskatchewan	45	30	67%
Université Laval	43	3	7%
Université de Montréal	42	13	31%
Victoria University	33	3	9%
University of Manitoba	31	2	6%
Simon Fraser University	24	1	4%
University of Ottawa	23	6	26%
Université de Sherbrooke	22	3	14%
McMaster University	14	8	57%
Université du Québec à Montréal	14	1	7%
Carleton University	5	0	0
Concordia University	5	0	0
Dalhousie University	5	1	20%
University of Calgary	4	1	25%
University of Windsor	2	0	0
Memorial University of Nfld	1	0	0
University of Winnipeg	1	0	0
Totals	831	132	16%

Some agglomerations with attractors but they did not bring in DBFs (i.e. Kingston, Ontario, and Sherbrooke, Quebec). Conversely, Canada's larger city, Toronto, has only one attractor (its university), but it is the most important center for biotechnology in the country.

We thus proceeded to measure the precise weight of each factor (see table 10 in the Appendix). How important are public attractors (public laboratories and universities) to biotechnology clusters? Correlation analysis suggests that government labs are of little importance. In fact, government laboratories capabilities as measured by patents are correlated negatively with the three dependent variables: number of patents held by DBFs, number of DBFs, and the number of patenting DBFs.

Conversely, university research strongly correlates with two of the three dependent variables: number of DBFs and number of patenting DBFs. University research thus seems to attract DBFs and to contribute to enhance their competencies. However, university is not enough to entirely explain the location of firms.

The major overall attractor, however, is population. When we bring in the 1996 Census Metropolitan Areas (CMAs), the three dependent variables strongly correlate with their total population. In other words, activity in biotechnology clusters where most people live, and secondary, where Canadian universities do research. The proportion of a CMA's population with university degrees is barely relevant. Only the size of the CMA and the scale of its university research matters.

Normalized correlation, holding population constant, confirms the significance of university research, at least for both total patents by DBFs, and number of patenting DBFs (see table 11 in the Appendix). We calculated three ratios, dividing the three values of the dependent variables by the population for each CMA. Government patenting still has little impact – or even a negative one – on the dependent variables.

Finally, we conducted cluster analyses combining the patent productivity of DBFs, and of universities and government laboratories. The analysis uncovered three types of regions (Table 12). The first type, consisting of Toronto, Montreal, Vancouver and Saskatoon, strong DBF and university patenting, combined with moderate government patenting. The second type, formed by Edmonton and Ottawa, has strong government patenting associated with weak DBF and academic patenting. The third group, has weak DBF and public patenting, innovative dynamism is low. This group includes Calgary, Halifax, Kingston, Quebec City and Winnipeg.

CONCLUSIONS AND POLICY IMPLICATIONS

In biotechnology, economic concentration of competencies goes hand in hand with regional concentration: only twelve firms hold over two thirds of the patents. Six of them are in Toronto, two in Montreal, and one each in Edmonton, Ottawa, Saskatoon and Vancouver.

Toronto enjoys indisputable leadership as Canada's top biotechnology cluster, by number of DBFs, number of patenting DBFs, and patents. Montreal follows, Vancouver appears in the third rank. In other words, the three main Canadian biotechnology clusters are located in the three largest cities; all of them have at least one major research university.

With regard to theory, this analysis brings credibility to the competency theory of the region. Knowledge spillovers depend not only on the (variable) amount of industrially useful knowledge produced by firms, universities and government laboratories, but also, on the size of the market and other related characteristics of the urban agglomeration. Relevant characteristics may include availability of venture capital (probably much more readily obtainable in larger cities such as Montreal, Toronto and Vancouver than in smaller ones such as Edmonton or Saskatoon, whatever the quality of their university research and government facilities). "Star scientists", as most researchers and university graduates in the health sciences, may also prefer larger cities.

Because of causal ambiguity, government laboratories have only marginally countered the market forces that tend to concentrate biotechnology activities in a few large cities with strong university environments. This analysis suggests that governments might reinforce Canadian biotechnology clusters if they relocated their laboratories and research universities in the largest metropolitan areas. Canada's citizenry and cities may not be large enough to bear the dispersion of efforts in ten or more urban regions.

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Table 1. Biotechnology. Year of foundation of patenting firms existing in 1998

Year	Toronto	Montreal	Vancouver	Ottawa	Saskatoon	Quebec City	Winnipeg	Edmonton	Calgary	Other	Canada
Before 1980	4	2	0	**IBS** 3	1	1	1	0	0	**IMB**	12
1980	1	0	0	0	0	0	0	0	0	0	1
1981	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	0	0	1
1984	1	1	0	0	0	0	0	0	0	0	2
1985	1	0	0	0	**PBI** 0	0	0	2	0	0	3
1986	2	1	0	0	0	1	0	0	0	0	4
1987	1	BRI /0	0	0	0	0	0	0	0	0	1
1988	1	1	0	0	0	0	0	0	0	0	2
1989	0	2	1	0	0	0	0	0	0	0	3
1990	0	1	1	0	0	0	0	0	0	0	2
1991	2	0	2	0	0	0	0	0	0	0	4
1992	1	3	2	0	0	0	**IBD** 0	0	1	0	7
1993	1	2	1	1	0	0	0	0	0	0	5
1994	2	1	2	0	2	1	0	0	2	1	11
1995	0	0	1	0	0	1	0	1	0	0	3
1996	0	0	1	0	0	0	0	0	0	0	1
1997	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0
Total	17	14	11	4	4	4	1	3	3	1	62

NB: Firms with either Canadian or US Patents.
Sources: Canadian Patent Office: Canadian Patent Database, and US Patent Office: US Patent Database

Table 2. Biotechnology. Year of foundation of firms existing in 1998

Year	Toronto	Montreal	Vancouver	Ottawa	Saskatoon	Quebec City	Winnipeg	Edmonton	Calgary	Halifax	Other	Canada
Before 1980	34	25	8	**IBS/4**	3	6	2	4	1	**IMB/4**	10	101
1980	5	1	1	0	1	0	0	0	0	0	2	10
1981	1	1	7	0	0	0	0	0	1	1	0	11
1982	2	0	1	0	0	0	0	0	1	0	0	4
1983	4	1	3	0	1	0	2	0	0	1	1	13
1984	5	1	1	0	0	0	0	1	1	0	2	11
1985	4	3	2	0	**PBI** 1	1	0	4	0	0	1	16
1986	5	4	5	0	1	2	0	1	1	1	3	23
1987	3	**BRI/0**	3	0	4	1	0	1	2	1	2	17
1988	6	4	2	1	1	3	0	0	0	1	3	21
1989	6	4	3	1	2	0	0	1	1	0	4	22
1990	5	5	6	0	0	0	0	0	1	0	4	21
1991	5	5	5	0	2	2	2	0	0	1	0	22
1992	5	6	8	0	2	0	**IBD** 1	1	1	2	2	28
1993	5	3	6	0	1	2	0	0	0	1	2	20
1994	4	4	2	0	2	5	0	2	2	1	5	27
1995	1	5	4	2	0	3	0	4	0	1	2	22
1996	1	2	3	0	0	0	0	0	0	2	1	9
1997	3	1	1	0	0	0	0	0	0	0	0	5
1998	0	0	0	0	0	0	0	0	0	0	0	0
Total	104	75	71	8	21	25	7	19	12	17	38	400

Source: BioteCanada: Canadian Biotechnology Directory 1993, 1995 and 1998

Table 3: Biotechnology. US patents of Canadian companies and major government laboratories, granted between 1989 and 1999

Company	Toronto	Montreal	Edmonton	Vancouver	Calgary	Saskatoon	Ottawa	Quebec City	Winnipeg	Other
1	51	28	**39***	8	3	9	**24****	2	**4****	**1****
2	50	**15****	11	3	2	**8****	3	1	3	1
3	23	4		2	2	3	3	1		1
4	13	3		2			2			
5	12	3		2						
6	8	3		1						
7	5	3		1						
8	4	2		1						
9	3	2		1						
10	3	1								
11	3	1								
12	1	1								
13	1									
14	1									
Total	178	66	50	21	7	20	31	4	7	3

NB: *Alberta Research Council; ** NRC laboratories.
Source: US Patent Office: US Patent Database.

Table 9: University and government laboratories' patents by urban agglomeration (1989-99)

Urban agglomeration	University #1	University #2	University #3	Total university patents	Government laboratory	Total attractor patents	Total patents	Attractor patents as % of total
Edmonton	9	0	0	9	39	47	59	80
Montreal	16	13	1	30	15	45	96	47
Saskatoon	30	0	0	30	8	38	50	76
Ottawa	6	0	0	6	24	30	37	81
Vancouver	23	1	0	23	0	23	44	52
Toronto	8	4	1	13	0	13	191	7
Kingston	8	0	0	8	0	8	8	100
Winnipeg	2	0	0	2	4	6	9	67
Quebec City	3	0	0	3	0	3	7	43
Sherbrooke	3	0	0	3	0	3	3	100
Halifax	1	0	0	1	1	2	3	67
Calgary	1	0	0	1	0	1	8	13

Table 10: Correlation

	Privpat	Privcos	Patgcos	Univpat	Govpats	Attrapat	Popul96	
Privpat	1.000							
Privcos	0.8359**	1.000						
Patgcos	0.8821**	0.9707**	1.000					
Univpat	02513	0.5454	0.5924	1.000				
Govpat	-0.1459	-0.1588	-0.0614	0.1055	1.000			
Attrapat	0.0522	0.2268	0.3260	0.7005	0.7836	1.000		
Popul96	0.8875**	0.9297**	0.9542**	0.4005	-0.0193	0.2364	1.000	
Ungrad96	0.1908	0.0985	0.1718	-0.1564	-0.0948	-0.1658	0.1644	1.000

Note: Pearson coefficients; *significant at 0.05 level (2-tailed); **significant at 0.01 level (2-tailed).

Table 11: Normalized correlation

	Patgcos	Univpat	Govpat	Attract	Ratio1	Ratio2	Ratio3
Patgcos	1.000						
Univpat	0.592	1.000					
Govpat	-0.061	0.106	1.000				
Attract	0.326	0.701*	0.784*	1.000			
Ratio1	0.422	0.627*	-0.220	0.255	1.000		
Ratio2	0.002	0.493	-0.133	0.213	0.721*	1.000	
Ratio3	0.008	0.650*	0.030	0.427	0.822**	0.898**	1.000

Note: Pearson coefficients; *significant at 0.05 level (2-tailed); **significant at 0.01 level (2-tailed).