The competencies of regions and the role of NRC

By Jorge Niosi and Tomas G. Bas

ABSTRACT

Knowledge-intensive industries tend to be geographically concentrated, due to the many spillovers that they generate. Thus biotechnology, information technologies and new materials often appear clustered in regions with innovative firms, universities and government laboratories, the latter playing the role of entry attractors (Swan, Prezever and Stout, 1998). This paper tries to unveil some of the characteristics of Canadian clusters in the three above-mentioned technologies: what the key regions are, their relative weight, the main firms and government laboratories playing the role of attractors. Also, we want to develop the concept of regions as a nexus of competence, a notion that has already been put forward for firms, but that deserves to be extended to regions within nations and, ultimately, to nations as well.

The methodology used for this purpose is based on patents, using the US patent database as the main source. The US patent database (unlike the Canadian one) publishes the address of the inventor, thus allowing the geographical location of the patent. We found strong clustering in the three technologies. Also, Toronto is the main center of both biotechnology and materials, while the Ottawa region is the Canadian center of information technologies.

1. Introduction

Within nations, scientific and technical competencies vary strongly from one region to another. Some regions concentrate a disproportionate share of the capabilities of all developed and developing nations. Also, regions tend to concentrate their competencies on a reduced number of domains of expertise. This is what the literature calls agglomeration effects: companies active in the same technological areas tend to geographically cluster together. They do so in order to share the same labour pool, have easier access to some research institutions, such as universities and government laboratories, or to some key markets and customers, such as large assemblers or government facilities. (Feldman et al., 1999) These institutions and key markets/customers are called “entry attractors” in the specialized literature (Swan et al., 1998)

In many science-based industries (SBIs), such as biotechnology, information technologies 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 be the natural entry attractors of smaller producers of parts, components and specialized software.

Canada is not different from other large nations (Niosi, forthcoming). Its competencies are strongly clustered around a few large and medium-sized urban agglomerations, such as Toronto, Montreal, Vancouver, Edmonton, Ottawa and Calgary. Smaller clusters have also developed around Quebec City and Saskatoon. This study will illustrate a theory of the competencies of regions using biotechnology, information technology and industrial materials as case studies. In these three cases, government laboratories (as well as universities and a few large firms) act as entry attractors. The goal of the paper is to examine - using quantitative data – the relative competencies of the regions in these three areas of technology, and to draw some conclusions on the role of NRC laboratories[1].

2. A Theory of the Competencies of Regions

The resource-based theory of the firm explains the differential performance of firms by their different factor endowments (Hamel and Prahalad, 1990; Foss, 1997). Firms develop internally or secure externally these resources to obtain superior competitiveness over competitors. Thus some firms get superior rents and manage to maintain these idiosyncratic advantages over time (Williams, 1994). Differential performance may arise both from divergent resource endowment, but also from their capacity to organize resources in novel ways. The competency theory of the firm thus goes one step beyond the resource-based theory of the firm, as it recognizes that superior routines and organization may yield superior performance (Foss and Knudsen, 1996; Durand, 1998).

The competency theory of the regions has identical assumptions. Like firms, regions may be understood as sets of competencies and resources both tangible (physical infrastructure, corporate physical assets, R&D laboratories...) and intangible (skills and human capital, routines, institutions). The competency theory goes however, a step beyond the resource theory: not only resources are important for regions, but also the capacity to use them in such ways that produce superior results. That is what competencies or capabilities mean. In the evolutionary theory of the firm (Winter, 1987; Dosi and Marengo, 1995; Foss and Knudsen, 1996), as well as in the capabilities and competency approaches (Teece, et al., 1992), "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, contribute to the capabilities of regions by producing knowledge that has an impact on wealth creation and the quality of life.

Similarly, regions within nations, as firms within industries, persistently differ in their resource endowment, behaviour and performance. Thus their different outcomes and growth rates may be affected by some hidden variable, such as competencies, particularly core competencies. These differences in outcome suggest unequal endowments particularly in skills, information, and preferences including risk aversion and financial institutions related to technology and innovation, but also learning routines, and institutions.

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). The central - or core - competencies of the regions are, first and foremost, those of the firms that are located in the region. In the traditional industrial districts, as well as in the Perroux poles, the competencies of the regions are essentially those of the firms. They include the capacity of firms located within the region to cooperate among themselves. These core competencies usually go beyond the competencies of firms: in science-based agglomerations and technological districts, with many science-based industries, they include the propensity and capacity to cooperate with, and learn from, other institutions in the regional system of innovation, such as local universities, government laboratories, and venture capital firms.

Competencies as knowledge in general, increase with its use and decrease if not used. Thus competencies, being closely related and made of knowledge, increase with their practice, usually procuring sustained advantage to regions as well as firms.

Much knowledge is produced in an interactive way (Lundvall, 1992). In the same vein, some authors have suggested that the density of the interactions between economic agents within a region is also a factor influencing knowledge creation and thus performance (Héraud et al, in Hauteville et al, 1997). According to some authors, a region such as Alsace, where firms interact very little among themselves and with local universities and public laboratories, where much 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 local spillovers must occur for a region to be considered a local or regional system of innovation.

3. The research design

This chapter is based on an empirical analysis of technical competencies made on the basis of patents granted in the United States to Canadian corporations in three technological areas: biotechnology, industrial materials and information technologies[2]. In order to study technical competencies, we preferred the use of the US Patent Database (instead of the Canadian one) on several grounds. For one, all major inventions are patented in the United States, as most companies, government laboratories and universities tend to seek intellectual property protection of most of their best knowledge assets in the largest, most inventive and most affluent nation in the world. Second, the US Patent Database, unlike the Canadian one, gives a precise indication of the geographical location (country, city, state or province) where the invention has been made, thus allowing the precise identification of the region in which resides the competency that has produced the invention. Third, more Canadian firms patent their novelties in the United State than in Canada. For instance, we found that, between 1980 and 1999, sixty-two Canadian biotechnology enterprises patented in the United States and only thirty-seven in Canada.

These three technologies present a major problem: none of them has one precise classification code, be it a patent code, an industrial code (or SIC code) or a trade code. The reason for this particularity is that all three are “generic technologies”, used across a variety of industries. It was decided to identify specialized biotechnology firms (through the 1998 BIOTECanada *Biotechnology Directory*), industrial material firms (using several sources, including the CAIMAF Directory) and information technology firms using a set of SIC codes. The patents of those companies were examined and ascribed to these technologies, unless they were totally unrelated to these technologies. The presence of a set of keywords in the patents’ names and abstracts decided whether the patent would be classified in one of these three technologies or not. These key words included terms such as “materials”, “ceramics”, “alloys”, “superalloys”, or “ceramics” (in materials), “DNA”, “monoclonal antibodies” or “genetic material” (in biotechnology). In Information Technology (IT), SIC codes were taken as additional evidence of patenting competencies. Simply stated, we decided that specialized biotechnology firms produce biotechnology patents or that specialized information technology firms produce information technology patents, but checked for supplementary proof of capabilities in the specific areas through an examination of the patent abstracts.

An additional problem, which appears in all studies using patents as the main source, is that the propensity to patent processes is smaller than for products (Winter, 1989). Thus, some processes in the three technologies may have gone unnoticed.

4. NRC Laboratories

Five NRC laboratories were used as case studies of entry attractors and competency agglomerators. A brief survey of the five laboratories is presented here.

Five institutes for biotechnology in Canada under the aegis of NRC were launched after the passing of Canada's biotechnology strategy in 1983. They are the Plant Biotechnology Institute (PBI), the Biotechnology Research Institute (BRI), the Institute for Biological Sciences (IBD), the Institute for Biodiagnostics (IBD) and the Institute for Marine Biosciences (IMB). Some of these institutes started from scratch, while others benefited from the experience and assets of pre-existing NRC laboratories.

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. 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 Institute for Biological Sciences in Ottawa, one of the oldest of NRC (1916) focuses on immunochemistry. The most recent (1992) Institute for Biodiagnostics in Winnipeg concentrates on developing technologies for disease diagnostics. Finally, the Institute for Marine Biosciences, originally established in 1952, works on marine biotechnology, including plants, shellfish toxins, and natural chemistry. Each of these institutes has played the role of “entry attractor” for new biotechnology firms in their respective technologies and regions. As there were very few biotechnology companies in 1983, it is valid to say that NRC labs have accompanied or preceded the founding of most Canadian biotechnology firms. However, their role was shared with universities, as all of these institutes were created either on university campuses – where medicine, biology and biochemistry already existed - or close to them.

In the information technology sector, the Institute for Information Technology in Ottawa was created in 1990 on the basis of the Division of Electrical and Electronic Engineering (DEEE), one of the oldest institutes of NRC. Here, contrary to biotechnology, the information technology industry in Canada existed well before the conversion of the old DEEE into IIT. The Institute thus shared its role of attractor with large, medium-sized and small companies, as well as two research universities, already existing in the National Capital Region by 1990.

Finally, the Industrial Materials Institute was founded in Montreal in 1978. Again, its role as attractor was shared with companies of all sizes already active in the Montreal area, as well as with four research universities; we can not thus reach a final conclusion about the precise and definitive contribution of IMI to the development of the materials industry.

In all cases it is worth remembering that firms can precede NRC laboratories, but the goal of this paper is to investigate, through patent analysis, how technology has developed after the creation (or, more often, the upgrading) of the public laboratory, compared to the previous situation, before the existence or the upgrading the NRC facility.

4. The evidence

Patent data, as well as foundation dates data were collected for at least the four largest metropolitan areas on the three technologies: biotechnology, industrial materials and information technology. The metropolitan areas were Toronto, Montreal, Ottawa, Vancouver; in addition, due to the many biotechnology institutes in different locations, information was collected on the competencies of biotechnology organizations in Saskatoon, Edmonton, Calgary, Halifax, Quebec City and Winnipeg. As only a few of them are hosts to NRC laboratories, we expect that both in terms of the number of firms and/or the number of patents, NRC influence can be measured. The results are presented in Tables 1 to 14.

6. Biotechnology

When the number of patents and the number of patenting firms measure competencies, Toronto is the center of Canada's biotechnology. Ontario's capital concentrates nearly 50 per cent of the patents obtained by the Canadian biotechnology industry in the United States since 1989. In spite of the creation of BRI, Montreal remains a distant second in terms of competencies as measured by the number of patents (Tables 1 to 6).

(Tables 1 to 6 here)

IBS in Ottawa remains the most productive of NRC's biotechnology laboratories (in terms of patents), but Alberta Research Council biotechnology labs in Edmonton are among the most productive biotechnology inventors of the country. The relation seems weak, however, between the number of patents granted to government laboratories and the number of new firms in the area, as witnessed by the Ottawa and Edmonton cases, against Toronto or Vancouver.

The two most inventive Canadian biotechnology firms in terms of US patents are Toronto's Connaught and Allelix, followed by BioChem Pharma of Montreal. Two other Toronto firms occupy the fourth and fifth Canadian ranks in terms of patents: Visible Genetics and Spectral Diagnostics. Also, one major biotechnology firm dominates the invention capability landscape in Montreal (BioChem Pharma), Edmonton (Biomira), Vancouver (QLT) and Saskatoon (Biostar). In each case these firms represent between 38 and 75 percent of the privately held patents in the region. Toronto appears more economically decentralized in terms of technological competencies in biotechnology.

In terms of firm creation, BRI and PBI seem to have had a major impact as entry attractors: the number of companies created or attracted to the region has increased substantially after the foundation of the NRC institutes in Montreal and Saskatoon. The same effect does not appear to occur in either Ottawa, Halifax or Winnipeg where the other large NRC institutes are located (see Table 1). Also, regions with major research universities, such as Toronto, Vancouver and Quebec City (Ste-Foy) seem to be prolific locations of new biotechnology firms without the help of government laboratories. Research universities seem to be at least as important an attractor as government laboratories are. Conversely, government laboratories are among the largest concentrations of R&D resources and competencies in all the regions where they are present.

7. Information Technologies

In this set of industries, large companies with many patents have located their major R&D laboratories in Ottawa, including of course the three largest telecommunication equipment manufacturers: Nortel, Mitel and Newbridge, as well as some of the largest software producers under Canadian control. Ottawa thus represents the largest concentration of IT competencies in Canada, followed by Toronto, Montreal and Vancouver (see Tables 7 to 10)

(Tables 7 to 10 around here)

In the three largest Canadian IT regions, namely Ottawa, Toronto and Montreal, Nortel represents the largest core institutional technical competence. In Ottawa, Nortel holds 75% of the region's US patents, followed by Mitel, Mosaid and Newbridge. In Toronto and Montreal, Nortel's presence is less staggering than in the National Capital Region. In that city, the largest IT company other than Nortel, IBM Canada, has only a few patents, as it is mostly concentrated in software. In Montreal, some of the largest IT firms, such as Canadian Marconi and CAE also own few patents. In Vancouver there is a rising cluster growing with companies such as MDA, Glenayre and MacDonald Dettwiler.

In Ottawa, the overall impact of NRC's IIT, compared with such giants as Nortel, Mitel or Newbridge thus may be considered minor. However, IIT is active in both software and hardware. Its benefits have mostly been in the generation and transfer of technology to smaller firms, as well as in the implementation of IT research projects with local enterprises. The size of its total budget or its patent portfolio may thus underestimate its long-term regional impact.

8. Industrial materials

In Canada, industrial materials are dominated by large firms, both Canadian and foreign-controlled. They operate in primary metals, chemicals, pulp and paper and other forest products. A fringe of smaller firms specialized in composites, polymers, alloys and metal powders surrounds these large corporations. In this sense, industrial materials differ from the previous technological areas examined above: much of its major firms have been founded many decades ago, and they include several multinational corporations.

Toronto is the undisputed leader of industrial materials, followed by Montreal, Calgary, Edmonton, Ottawa and Vancouver (see Tables 10, 11 and 12). However, industrial materials companies are not necessarily concentrated in major cities, as their plants - and usually their laboratories as well - are located close to natural resources and energy sites. Thus places such as Arvida (Quebec), Trail (British Columbia) and Sarnia (Ontario) are major centers of materials research in Canada, although their strength is usually specialized and depends on just one or a few major corporations.

(Tables 10 to 13 here)

Other industrial materials corporations, however, have located their major R&D centers in large cities. Thus, three major materials producers dominate Toronto’s industrial materials landscape: DuPont Canada, Inco and Alcan. Noranda Technology Center in Pointe-Claire, Hydro-Quebec’s IREQ in Varennes, and Domtar R&D laboratory at Senneville dominate Montreal’s region. Calgary shares with Edmonton the main role in oil technology, with Calgary’s Imperial Oil R&D center as its major inventor. Edmonton is the second capital of oil technology, its forte including oil sands research. However, the largest materials inventor in that city (and in Alberta) is Westaim, producing advanced materials mostly for medical purposes. In Ottawa, Forintek was the largest materials inventor, before it moved to Quebec City.

Patents may not always be the best indicator of competencies in this technological area, as many small and medium-sized enterprises (SMEs) in the materials industries avoid patenting, because they are usually unable to discover counterfeiters, let alone defend their patents against imitators (Niosi, 1995). This strategy explains that well-known Canadian SMEs in advanced industrial materials have no American patents[3].

In the Montreal region, the Industrial Materials Institute (IMI), founded in 1978, operates mostly in established materials, and conducts cooperative research with both large and small firms. With twenty-eight patents obtained in the last ten years, and over one hundred in its entire history, IMI represents the second largest concentration of industrial materials expertise in the Montreal region, after Noranda Technology Center, and one of the largest in Canada.

In a speech to IMI, the former vice-president of Alcan, John Wilson, wondered about the feasibility of a “technology push” approach to materials:

> A special problem for materials developments is that domestic customers are too few, as suggested by the recent Porter report, they demand too little, to pull effectively on R&D upgrade the proposed materials that Canada offers to world markets. One result in our scientific establishments, in government and industry, is technology ‘push’ R&D, which might come close, but most often fails to hit the commercial target which is always best understood by the demanding customer and the end user. (Wilson, 1991)

In other words, Wilson suggested that, conversely to information technology, in which technology- and science-push are the norm, materials innovation is a case of demand pull: novelties arise from the demand of users such as the aerospace, automobile and energy industries. In Canada, the relative size of the aerospace industry (Canada has no military aerospace), foreign control of the car industry (conducting little R&D in Canada) and availability of traditional energy supplies, all reduce the demand for advanced materials and related innovation. Several large Canadian materials producers thus conduct advanced material research abroad (Niosi, 1997, 1999).

Except for oil in Calgary and Edmonton, the clustering of Canada's materials competencies is probably much less evident than in biotechnology or information technology, as some of the largest research facilities are located far from the largest urban communities and close to the resource-transformation plants. In this respect, it is important to recall that most industrial materials producers in Canada are specialized in extraction and primary transformation. Their research is centered on process, less so on product development. Few of them conduct R&D on new materials, either in Canada or abroad; this type of R&D is usually geographically concentrated in urban centers, close to the markets. Thus Canadian multinationals conduct advanced materials R&D in the United States, Western Europe and, marginally, in Japan more often than in Canada.

9. Conclusion

These three technologies have a major weight, though a very different one, in the Canadian innovation system. Information technologies have a major and decisive role in Canadian competencies (Table 14). Among the one-hundred largest industrial R&D spenders, thirty-nine corporations are operating in information technologies, and their total combined R&D expenditures in 1998 amounted to C$5.7 billion dollars. As to biotech and pharmaceuticals, twenty-seven corporations spent C$1.2 billion. Materials came a distant third, with fifteen corporations and almost C$500 million. Even if the giant Nortel (accounting for C$3.8 billion) is taken out of that total figure, the remaining thirty-eight IT firms outspent biotechnology and pharmaceuticals and materials combined.

(Table 14 here)

In biotechnology, economic concentration of competencies is paralleled by regional concentration: over two thirds of the patents are held by only twelve firms. Six of them are located in Toronto, two in Montreal, and one each in Vancouver, Edmonton, Ottawa, and Saskatoon.

Toronto enjoys an indisputable leadership as Canada's top biotechnology cluster, either by the total number of firms, the number of patenting firms, and the number of patents. Montreal follows, as a distant second. Vancouver appears in the third rank according to the total number of firms, the number of patenting firms, and the number of private-firm patents. Government laboratories have probably partially countered the market forces that tend to concentrate biotechnology activities in a few large cities with strong university environments.

In information technology, Ottawa deserves its label as "Silicon Valley North", as it concentrates more patents than Toronto, Montreal and Vancouver together. However, the relative importance of Canada's largest industrial R&D performer, Nortel, is much higher in Ottawa than elsewhere in Canada. NRC's IIT has contributed to reinforce some of the new emerging companies in the region, and thus its long-term contribution may be major.

Toronto appears also as the undisputed leader of Canadian industrial materials, followed by Montreal, Calgary and Edmonton. However, the Canadian landscape is probably much less concentrated, both geographically and economically, in industrial materials than it is biotechnology or information technology. This is due to the fact that most large Canadian materials corporations conduct process R&D in Canada, close to their main chemical, primary metals or pulp and paper plants, and advanced materials research abroad, close to large markets. IMI represents the second largest concentration of material research competencies in the Montreal region, and one of the largest in Canada.

NOTES

[1] NRC laboratories are the three biotechnology laboratories in Montreal, Ottawa and Saskatoon, the Industrial Materials Institutes of Montreal and the Institute of Information Technology in Ottawa.

[2] We based this work on the study by Antonelli (1986) of Italian industrial districts, though he used the Italian patent database.

[3] Out of over 50 firms Quebec, listed by the Conseil de la science et de la technologie du Québec (1992), supposedly conducting R&D in materials in only eight have obtained patents in the United States related to materials. They appear in tables 10 to 12.

REFERENCES

Amable, Bruno, R. Barré and R. Boyer (1997) *Les systèmes d'innovation à l'ère de la globalization*, Paris, Economica.

Antonelli, Cristiano (1986) *L'attività innovativa in un distretto tecnologico*, Turin, Fondazione Giovanni Agnelli.

Axelrod, Robert (1984) *The Evolution of Cooperation*, New York, Basic Books.

Conseil de la science et de la technologie du Québec (1992) *Les matériaux avancés*, Ste-Foy.

Dosi, Giovanni and Luigi Marengo (1995) “Some Elements of an Evolutionary Theory of Organizational Competencies,” in R.W. England (ed.) *Evolutionary Concepts in Contemporary Economics*, Ann Arbor, University of Michigan Press, pp. 157-178.

Durand, Thomas (1998) "The Alchemy of Competence," in G. Hamel et al. (eds.) *Strategic Flexibility*, New York, Wiley, pp.303-330.

Edquist, Charles (ed.)(1997) *Systems of Innovation*, London, Pinter.

Feldman, Maryann (1999) “The New Economics of Innovation, Spillover and Agglomeration: Review of Empirical Studies,” in *Economics of innovation and new technology*, 8:1-2: 5-25.

Foss, Nicolai and C. Knudsen (Eds.)(1996) *Towards a Competence Theory of the Firm*, London, Routledge.

Foss, Nicolai (Ed.)(1997) *Resources, Firms and Strategies*, New York, Oxford University Press.

Harhoff, Dietmar (1999) “Firm Formation and Regional Spillovers- Evidence from Germany,” in *Economics of innovation and new technology*, 8, 1-2: 27-55.

Hauteville, Bernard, J.A. Héraud and M. Humbert (Eds.)(1997) *Technologie et performances économiques*, Paris, Economica.

Héraud, Jean-A. et al.(1997) “Réseaux d’innovation et tissu industriel régional,” in Hauteville, Bernard, J.A. Héraud and M. Humbert (1997) *Technologie et performances économiques*, Paris, Economica, pp. 97-122.

Lundvall, Bengt-A.(ed.)(1992) *National Systems of Innovation*, London, Pinter.

Marshall, Alfred (1920) *Principles of Economics*, Eighth Edition (Reprint by Macmillan, London, 1986)

National Science Foundation (1998) *Science and Technology Indicators*, National Science Board, Washington.

Niosi, Jorge (forthcoming) *Canada’s National System of Innovation*, Montreal & Kingston, McGill Queen’s University Press (with the collaboration of André Manseau and Benoît Godin).

Niosi, Jorge and Godin, Benoît (1999) “Canadian R&D Abroad. Management Practices”, *Research Policy*, 28, 2-3: 215-230.

Niosi, Jorge (1997) “The Globalization of Canada’s R&D”, *Management International Review*, 37, 4: 387-404.

Niosi, Jorge (1995) *Flexible Innovation*, Montreal and Kingston, McGill-Queen's University Press.

Observatoire des sciences et des techniques (OST) (1998) *Science et technologie. Indicateurs 1998*, Paris, Economica.

Ottawa Economic Development Corporation (1998) *Ottawa Facts*.

Perroux, François (1982) *Dialogue des monopoles et des nations*, Grenoble, Presses de l'Université de Grenoble.

Perry, Martin (1999) *Small Firms and Networks Economies*, London, Routledge.

Saxenian, AnnaLee (1991) "The origins and dynamics of production networks in Silicon Valley", *Research Policy*, 20, 5: 423-438.

Storper, Michael (1993) "The Limits to Globalization: Technology Districts and International Trade", *Economic Geography*, 68, 1: 60-93.

Swan, G.M. Peter; M. Prevezer and D. Stout (Eds.)(1998) *The Dynamics of Industrial Clustering*, New York and Oxford, Oxford University Press.

Tatsumo, Sheridan (1986) *The Technopolis Strategy*, Englewood Cliffs, Prentice Hall.

Williams, Jeffrey (1994) "Strategy and the Search for rents: The Evolution of Diversity Among Firms", in R. P. Rumelt et al (Eds.): *Fundamental Issues in Strategy*, Boston, Harvard Business School Press, pp. 228-246.

Wilson, John (1991) *The Future of Materials Science: the Engineering Connection*, A presentation to IMI in occasion of the 75th anniversary of NRC, Montreal.

Winter, Sidney (1987) "Knowledge and competence as strategic assets" in D.J. Teece (Ed.) *The Competitive Challenge*, New York, Harper and Row, pp. 159-184.

----------- (1989): "Patents in Complex Contexts: Incentives and Effectiveness" in V. Weil and J. W. Snapper (eds.) *Owning Scientific and Technical Information*, New Brunswick and London, Rutgers University Press, pp. 41-60.

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

Year	Toronto	Montreal	Vancouver	Ottawa	Saskatoon	Quebec City	Winnipeg	Regina	Edmonton	C
Before 1980	4	2	0	**IBS** 3	1	1	1	0	0	
1980	1	0	0	0	0	0	0	0	0	
1981	0	0	0	0	0	0	0	0	0	
1982	0	0	0	0	0	0	0	0	0	
1983	0	0	0	0	1	0	0	0	0	
1984	1	1	0	0	0	0	0	0	0	
1985	1	0	0	0	**PBI** 0	0	0	0	2	
1986	2	1	0	0	0	1	0	0	0	
1987	1	BRI /0	0	0	0	0	0	0	0	
1988	1	1	0	0	0	0	0	0	0	
1989	0	2	1	0	0	0	0	0	0	
1990	0	1	1	0	0	0	0	0	0	

1991	2	0	2	0	0	0	0	0	0
1992	1	3	2	0	0	0	**IBD** 0	0	0
1993	1	2	1	1	0	0	0	0	0
1994	2	1	2	0	2	1	0	1	0
1995	0	0	1	0	0	1	0	0	1
1996	0	0	1	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0
Total	17	14	11	4	4	4	1	1	3

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	H
Before 1980	34	25	8	**IBS/4**	3	6	2	4	1	**IN**
1980	5	1	1	0	1	0	0	0	0	
1981	1	1	7	0	0	0	0	0	1	
1982	2	0	1	0	0	0	0	0	1	
1983	4	1	3	0	1	0	2	0	0	
1984	5	1	1	0	0	0	0	1	1	
1985	4	3	2	0	**PBI** 1	1	0	4	0	
1986	5	4	5	0	1	2	0	1	1	
1987	3	**BRI/0**	3	0	4	1	0	1	2	
1988	6	4	2	1	1	3	0	0	0	
1989	6	4	3	1	2	0	0	1	1	
1990	5	5	6	0	0	0	0	0	1	
1991	5	5	5	0	2	2	2	0	0	
1992	5	6	8	0	2	0	**IBD** 1	1	1	
1993	5	3	6	0	1	2	0	0	0	
1994	4	4	2	0	2	5	0	2	2	
1995	1	5	4	2	0	3	0	4	0	
1996	1	2	3	0	0	0	0	0	0	
1997	3	1	1	0	0	0	0	0	0	
1998	0	0	0	0	0	0	0	0	0	
Total	104	75	71	8	21	25	7	19	12	

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	Winnipe
1	51	28	**39***	8	3	9	**24****	2	**4****
2	50	**15****	11	3	2	**8****	3	1	3
3	23	4		2	2	3	3	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

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

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 and main government laboratories (1989-99)

Region	Number of patents	Percentage
Toronto	178	46
Montreal	66	17
Edmonton	50	13

Ottawa	31	8
Vancouver	21	5
Saskatoon	20	5
Calgary	7	2
Winnipeg	7	2
Quebec City	4	1
Other	3	1
	387	100

Source: US Patent Office: US Patent Database.

Table 6: 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

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

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

1999	3	3	2 1/2	1	0	2	1
Totals	24	15	8	4	1	27	27

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: Information Technology. R&D Expenditure in Ottawa region, 1997/8 (selected organizations)

Technology	Firm/Laboratory	Period	R&D Expenses ($M)	
Telecom equipment	Nortel Networks	FY 1997	1568	
	Newbridge	FY 1998	259	
	Mitel	FY 1998	85	
	JDS Fitel	FY 1998	17	
	Plaintree	FY 1997	10	
	Milkyway	FY 1997	4	
Total telecom			2177	
Software	Corel	FY1997	90	
	Cognos	FY1998	48	
	Crosskeys	FY1997	6	
Hardware	DY4	FY1997	19	
	Lumonics	FY1997	20	
	Mosaid	FY1997	11	
	AIT	FY1997	5	
Soft and hardware	ITT, NRC	FY 1998	8	

Source: Ottawa Economic Development Corporation: Ottawa Facts, 1998.

Table 9: Information technology. Patents granted to private firms in four major cities (1990-9)

Year	Ottawa	Toronto	Montreal	Vancouver
1990	50	7	17	7
1991	51	15	18	6
1992	42	13	5	2
1993	44	18	11	3
1994	53	18	18	2
1995	62	9	11	3
1996	78	15	10	17
1997	63	17	11	13
1998	132	23	18	25
1999	74	19	7	13

Total	647	154	126	91

Source: US Patent Office: US Patent Database.

Table 10: Information technology. Economic concentration of patents in major cities (1990-99)

Firms	Ottawa	Toronto	Montreal	Vancouver
#1	476 (75%)	46 (30%)	52 (41%)	31 (34%)
#2	82 (13%	17 (11%)	11 (9%)	23 (25%)
#3	41 (6%)	13 (1%)	8 (6%)	12 (13%)
#4	13 (2%)	13 (1%)	7 (6%)	5 (5%)
#5	12 (2%)	13 (1%)	6 (5%)	3 (3%)
#6	7 (1%)	11 (1%)	5 (4%)	3 (3%)
#7	6 (1%)	10 (1%)	5 (4%)	2 (2%)
#8	5 (1%)	3 (2%)	4 (3%)	2 (2%)
Subtotal	642 (99%)	113 (73%)	98 (78%)	81 (89%)
Total	647 (100%)	154 (100%)	126 (100%)	91 (100%)

Source: US Patent Office: US Patent Database.

Table 11: Industrial Materials. Privately-held patents in major cities, 1990-1999

Year	Toronto	Montreal	Ottawa	Calgary	Edmonton	Vancouver
1990	23	12	2	4	1	1
1991	18	10	3	6	4	2
1992	21	11	5	6	2	1
1993	22	8	1	9	1	1
1994	15	14	0	7	4	1
1995	17	11	2	6	1	0
1996	11	14	1	4	6	0
1997	12	8	0	4	7	0
1998	13	14	0	8	13	0
1999	7	4	2	4	6	0
Total	159	106	16	58	45	6

Source: US Patent Office: US Patent Database.

Table 12: Industrial Materials. Economic concentration of patents in major cities

Firm	Toronto	Montreal	Ottawa	Calgary	Edmonton	Vancouve
#1	47 (30%)	44 (42%)	6 (38%)	10 (17%)	14 (32%)	2 (33%)
#2	42 (26%)	25 (24%)	4 (25%)	9 (16%)	8 (18%)	1 (17%)
#3	33 (21%)	18 (17%)	4 (25%)	3 (5%)	7 (16%)	1 (17%)
#4	15 (9%)	11 (10%)	1 (6%)	3 (5%)	2 (7%)	1 (17%)
#5	4 (3%)	4 (4%)	1 (6%)	3 (5%	2 (7%)	1 (17%)
#6	4 (3%)	2 (2%)	0	2 (3%)	2 (7%)	0
#7	4 (3%)	1 (1%)	0	2 (3%)	2 (7%)	0
#8	4 (3%)	1 (1%)	0	2 (3%)	2 (7%)	0

Subtotal	149 (94%)	106 (100%)	16 (100%)	34 (59%)	39 (87%)	6 (100%)
Total	159(100%)	106 (100%)	16 (100%)	58 (100%)	45 (100%)	6 (100%)

Source: US Patent Office: US Patent Database.

Table 13: Industrial Materials. Geographic concentration of patents in major cities

City	Number of patents (%)
Toronto	159 (41%)
Montreal	106 (27%)
Calgary	58 (15%)
Edmonton	45 (12%)
Ottawa	16 (4%)
Vancouver	6 (2%)
Total	390 (100%)

Source: US Patent Office: US Patent Database.

Table 14: Biotechnology, Information Technology and Materials. Number of Firms and R&D Expenditures among The 100 Largest Canadian Corporate R&D Spenders

Technology	Number of corporations	R&D Expenditure
Information Technologies	39	C$M 5698
Biotechnology & pharmaceuticals	27	C$M 1191
Materials	15	C$M 496
Total	81	C$M 7385

Source: Evert Communications: “Canadian Corporate Directory R&D Database”, Research Money, 13, 11, 1999.