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Canadian biotechnology policy: designing incentives for a new technology

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Abstract. Since the early 1980s Canada has created a set of incentives in order to develop the new biotechnology based on genetic engineering. In the beginning, the emphasis was on agriculture and environmental biotechnology, but already by the late 1980s the focus had changed towards human health products and services. Even if the federal government was the original policymaker, several provinces added their own incentives in order to nurture a local industry. Although policies have been changing in scope and goals, the results have been positive and the country has acquired a certain leadership in several biotechnologies. National and regional innovation systems are the organising framework of this paper as they have proved useful in analysing the institutional canvas of biotechnology.

1 Introduction

The new biotechnology is a set of generic technologies, most prominent of which is genetic engineering, applied over a wide industrial spectrum.(1) The commercial application of biotechnology to a variety of industries started in 1976 with the launching of Genentech on the US stock market. The rise of biotechnology has been phenomenal. In 1997 it was estimated that there were 2500 biotechnology firms in the world (Banham, 1997). By 2002 the number of firms in the world had grown to around 5000; there were 1700 firms in the United States, 400 in Canada, and at least 2000 in Western Europe (Nature Biotechnology, 2002).

This paper starts with a discussion of technology policy in high-tech industries, with an emphasis on biotechnology, then retraces the efforts undertaken by the Canadian governments (federal and provincial) to nurture the development of this new set of generic technologies through a variety of incentives, institutions, and organisations. The paper concludes with the necessity of multidimensional public support as a condition of the growth of biotechnology.

2 Technology policy in high-tech industries

Long-term economic growth is widely seen as a consequence of technological innovation. Because of externalities and the long-term and uncertain results of investing in information, private firms underinvest in the creation of new scientific and technological knowledge. Public policy is necessary to correct these imbalances.

A wide variety of science and technology policies and institutions have been designed in all the market economies, each nation having developed its own set of solutions to the same general problem. The concept of a national system of innovation(2) was developed in

(1) See appendix A for a list of sectors and appendix B for a list of these technologies.

(2) National innovation systems are sets of agents (innovative firms, universities, government laboratories, venture capital firms, and public agencies) as well as the relationships among these agents (financial, personal, or technological) that contribute to the adoption, development, and transfer of new science and technology within national borders (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Niosi et al, 1993).

the 1980s and adapted to biotechnology later (Bartholomew, 1997). These national systems of innovation are country-specific, historically-shaped configurations of institutions and organisations that may support or impede the growth of scientific and technical knowledge. The same observation applies to regional innovation systems (de la Mothe and Paquet, 1998). Most advanced technologies, and biotechnology is not an exception, tend to concentrate geographically in a few regions in developed nations, such as California, Route 128 in Massachusetts, and the Research Triangle in North Carolina in the United States, and Cambridge, Oxford, and London in the United Kingdom. Policy solutions, either national or regional, are far from optimal and are at best 'satisfying', x-efficient(3) responses to the same general question (Niosi, 2002). This section will emphasise the particular nature of technology policies in knowledge-intensive activities such as biotechnology.

Science-based industries and technologies that developed mostly (but not exclusively) in the postwar period are a set of activities that make intensive use of knowledge produced in research universities and government laboratories, as well as in R&D-intensive firms (Pavitt, 1984). Since the very first studies of this new activity, the role of universities in biotechnology has been widely regarded as crucial (Kenney, 1986). Generous funding by the federal government of research universities and public laboratories has been at the root of the US leadership in biotechnology. But the set of institutions and regulations that nurtured the creation of US biotechnology go far beyond the funding of advanced research.

A favourable set of patenting laws (the granting of patents to living material) was also a condition of development, because biotechnology R&D, particularly in the area of human health, is a multiyear process requiring strong and long-term intellectual property protection. Patents reassure participants that free-riding would not become an obstacle to getting returns on investments.

Venture capital is also quite often cited as a key institution that has spurred the development of US and British biotechnology (Kenney, 1986). Venture capital brings funds but also complementary competencies to biotechnology firms, in order to improve the management of the new firms. Public policy favouring venture capital also tends to nurture the development of core biotechnology firms.

But public funding of basic research and government incentives for the constitution of a venture capital pool may not be enough to create biotechnology in a particular location. The organisational design of universities, government laboratories, and capital markets also seems crucial. It may well be that the organisation of US (as well as British and Canadian) universities, which include routines such as faculty positions open to world applicants regardless of their national origin, interuniversity competition for professors and students, and relative acceptance of lecturers' part-time release for extrauniversity consultancy and entrepreneurship, are helpful in nurturing such a university-based activity. As Bartholomew has aptly underlined, some countries, like Japan, allow promotion and funding mostly on the basis of seniority rather than merit. In most European nations academic positions are open only to local citizens, thus reducing the flow of talent into university research. And the stock markets of North America are more receptive to these core biotechnology firms than most of their European counterparts.

(3) Harvard economist Harvey Liebenstein coined the term x-efficiency to underline the fact that the efficiency of firms is a variable, not a constant, and thus to counter the tendency of neoclassical economists to treat all firms as being at an optimal level of efficiency.

3 The emergence of Canadian biotechnology (1980 – 2002)

During the last twenty years (1980 – 2002), Canada has become the second major country in biotechnology, after the United States and ahead of the United Kingdom, judging by the number of firms, the number of patents obtained, products in the pipeline, and venture capital invested. However, the Canadian science base in biology is smaller than that of several industrial nations. Thus, in 1999 Canada ranked sixth in the total number of refereed articles in biological sciences [after the United States, Japan, the United Kingdom, Germany, and France (NSF, 2002)] but second (after only the USA) in the total number of biotechnology firms. The size of the science base, thus, is no guarantee of the development of the commercial biotechnology sector as such.

In 2001, in spite of its advanced science, Britain had only 270 biotechnology companies. By year 2000 the 333 diminutive German companies had only four products in clinical trials. That year, both the British and the German specialised biotechnology firms (SBFs) had only ten initial public offerings (IPOs). By contrast, the 240 French companies had no IPO in 2000 and a few products in the pipeline. In 2000, conversely, Canada (with an economy half the size of the above-mentioned countries) had fifteen IPOs and by January 2001 nearly 400 SBFs. Canadian core biotechnology firms (out of which over 200 were in human life sciences) had hundreds of human health products in clinical trials, out of which thirty were in phase 3 and fifty in phase 2 (Ernst & Young, 2002).

In 2001 venture capital firms invested US $3236 million in US biotechnology.[(4)] In Canada venture capital invested US $534 million in the same year.[(5)] In the United Kingdom, in the meantime, venture capital invested US $452 million in fifty-seven companies.[(6)] In 2001 all Continental Europe SBFs received US $550 million in venture capital (Deloitte and Touche, 2002).

In Canada the growth of the industry has been fairly rapid and is illustrated by the number of companies that Statistics Canada has been able to track and survey. In 1984 the national statistical office found some fifty SBFs. In 2001 the number had grown to around 400. Also, the number of publicly traded companies was only five in 1990 against 89 in 2002. Tables 1, 2 and 3 (over) summarise the official figures of the industry by 2001. Quebec and Ontario appear as the main provinces (and Montreal, Toronto, and Vancouver as the main centres) of Canadian biotechnology (Niosi and Bas, 2001).

This rapid growth cannot be understood without reference to federal and provincial policy incentives. This paper therefore will analyse the policy incentive context from which Canadian biotechnology has emerged.

Table 1. Canadian biotechnology, 1989 – 2003 (source: Statistics Canada).

	1989	1993	1997	2001
Number of firms	207	268	282	391
R&D expenditure (Can $ million)	116	223	926	1.44 billion
Total R&D personnel	3337	4845	9019	
Total personnel			31924	
Total revenues			14 billion	

(4) National Venture Capital Association of the United States, http://www.nvca.org
(5) Canadian Venture Capital Association, http://www.cvca.ca
(6) British Venture Capital Association, http://www.bvca.co.uk

Table 2. Canadian biotechnology in 2001 by province (source: Statistics Canada, 2003; and Canadian Venture Capital Association, http://www.cvca.ca).

	Number of firms	Biotechnology revenues (Can $ million)	Biotechnology expenditures in R&D (Can $ million)	Venture capital in biotechnology (Can $ million)[a]
Canada	391	3749	1441	628
Quebec	135	1625	443	242
Ontario	106	1417	395	129
British Columbia	71	417	428	205
Alberta	25	125	121	na
All other	54	165	54	25

[a] na—not available.

Table 3. Canadian biotechnology in 2001 by application (source: Statistics Canada, 2003).

	Number of firms	Biotechnology revenues (Can $ million)	Biotechnology expenditures in R&D (Can $ million)
Human health	207	2605	1209
Food	49	603	123
Agriculture	68	252	55
Environment	33	276	18
All other	34	14	38

4 The role of the federal government

Biotechnology was declared a federal government priority as early as 1983 with the launching of the first National Biotechnology Strategy (NBS) (Walsh et al, 1995). The mandate to promote biotechnology was given to Department of Industry Canada, with inputs from three other federal departments: Agriculture and Agri-Food, Environment, and Health. A National Advisory Committee on Biotechnology and an Interdepartmental Committee on Biotechnology were created later. The NBS was a multidimensional programme aimed at fostering industrial, university, and governmental R&D in biotechnology, promote the development of human resources, and nurture collaboration among the different agencies. Also, the regulatory environment was modified in order to speed up the protection of intellectual property in the emerging technology.

It would be difficult to overstate the role of the federal government. This section summarises the main elements of the NBS of 1983, including the 1998 revision of the strategy. Through the Centres of Excellence Program of 1986, seven biotechnology university – industry networks were created. They were the Arthritis Network, the Bacterial Diseases Network, the Genetic Basis of Human Diseases Network, the Health Evidence Application and Linkage Network, the Protein Engineering Network, the Stroke Network, and the Stem Cell Network. These networks brought together researchers from different universities, government laboratories, and private firms in integrated long-term research programmes.

Three government laboratories were also created under the aegis of the National Research Council (NRC). They were the Biotechnology Research Institute (BRI) of Montreal (launched in 1987), the Institute for Bio-Diagnostics of Winnipeg, (1992), and the Institute for Marine Biosciences of Halifax (1990). Two other institutes were expanded and revamped to focus on biotechnology: the Institute for Biological Sciences in Ottawa and the Plant Biotechnology Institute in Saskatoon. These centres added close to a thousand permanent and guest researchers to Canadian biotechnology.[7] The largest of these facilities is Montreal's BRI with an annual operating budget of over Can $23 million and over 400 researchers half of whom are permanent employees of the Institute. In 2001/02, these NRC laboratories spent some Can $83 million in biotechnology research. In addition, the Industrial Research Assistance Program, administered by the NRC, provides Can $5 million every year in support to biotechnology small and medium-sized enterprises (SMEs).

Other major government laboratories in biotechnology research include the nineteen national centres of Agriculture and Agri-Food Canada, with a total budget for biotechnology of around Can $57 million in 2001/02 for in-house research, and Can $11 million for collaborative research with private companies. Also, Environment Canada and Natural Resources Canada public laboratories conduct biotechnology research in their specific domains.

Canadian science councils also spend sizable funds in biotechnology research. These include the Natural Science and Engineering Research Council (NSERC) with Can $40 million in biotechnology projects in 2000/01, and the Canadian Institutes of Health Research with Can $133 million for the same purpose during the same year. A new funding agency, Genome Canada, established in 1999/2000, has a total endowment of Can $300 million, and has created five centres across Canada (Atlantic, Quebec, Ontario, Prairies, and British Columbia) attracting additional matching funds from provincial governments and industrial corporations. Another new federal funding agency, the Canadian Foundation for Innovation, created in 1997, with a total capital of Can $3.15 billion, has distributed major support for university infrastructure in biotechnology projects across Canada.

Venture capital was promoted through several means. For example, the Business Development Bank of Canada launched a biotechnology fund. By 2002 it had offices in Calgary, Halifax, Montreal, Ottawa, Toronto, and Vancouver, and had invested in forty SBFs across Canada. Several provinces followed suit and developed provincial venture capital funds, of which CDP Capital, a subsidiary of the Quebec Caisse de Dépôt et Placement is one of the largest. By 2002 CDP Capital had invested in eighteen Canadian biotechnology firms, mostly but not exclusively located in the Province of Quebec.

Also, federal tax credit regulations were adapted to the specific needs of these core biotechnology firms. Canada allows a 20% Scientific Research and Experimental Development tax refund for all R&D expenditures that can be used to offset federal taxes payable. The unused credits can be carried forward for ten years, a disposition that suits many SBFs that do not yet have revenues. A 35% tax credit is also applicable to some R&D expenditures for the first Can $2 million in Canadian privately controlled corporations (KPMG Inc., 2002).

Technology Partnerships Canada, a federal initiative launched in 1996, picked biotechnology as one of its priority areas of investment, and supported no fewer than twenty Canadian biotechnology firms with multimillion dollar loans. From 1997 to March 2002 TPC has distributed Can $263 million for R&D projects in biotechnology.

The regulation infrastructure was also developed. It included the revamping of Canada's patent law. The result was a multiplication of biotechnology patents. Patents are essential in biotechnology. On the one hand, they ensure the exclusivity of the idea

[7] Federal laboratories are not, however, the cornerstone of a regional cluster. The two essential elements of these regional systems seem to be research universities and venture capital. Thus some thriving regions have no government laboratory (Toronto, Vancouver) and others with little dynamism do host these laboratories (such as Halifax).

to the inventor thus allowing the pursuit of research in such an uncertain, complex, and expensive field. On the other hand, venture capital firms use patents as a major milestone when evaluating funding requests from core biotechnology firms. In other words, without patent protection, no growth would occur in biotechnology (Niosi, 2003). Since 1982, the Canadian patent law has been amended several times to include patent protection of different types of life forms. They include:

(a) genetic material; in Canada genes and gene sequences can be patented on the basis that they are chemical compounds removed from their natural state;

(b) unicellular organisms; microbial forms are patented;

(c) nonhuman multicellular organisms, such as genetically modified mice and other animals, can be patented since 2000.

In this sense, Canada has followed the lead of other countries such as the United States, the United Kingdom, Australia, and Japan (Frendo, 2001). Indeed, several major mammals such as pigs and cows have already been cloned and patented in Canada. However, it has banned the cloning of human beings.

Thus, the Canadian federal government has now created one of the most favourable legal, funding, regulatory, and protection environments for biotechnology R&D in the world, in terms of both direct and indirect funding of around Can $400 million in 2001.

5 The role of the provincial governments

Several provincial governments have built on the Canadian framework, and improved, for their specific territorial jurisdictions, the environment in which SBFs are created and evolve. Quebec, Ontario, and British Columbia are the most remarkable in terms of the number of their supporting policies. See tables 4–6 (over).

5.1 Quebec

Different provincial governments have followed different approaches in their support policies. By far the most interventionist has been Quebec. Through a complex and dense set of public policies, this province has created a favourable environment for the development of biotechnology. The first and most remarkable was the creation, in 1969, of provincial funding councils that allocate grants for academic research over and above those distributed by the federal agencies. In biotechnology the most important of them is the *Fonds québécois de recherche en santé* (Quebec Health Research Fund).

The provincial tax credit is also the most generous. Companies conducting R&D in Quebec may deduct

"—A basic refundable 20% tax credit on salaries paid in Quebec;

—A refundable 40% tax credit on the first C$ 2 million in salaries that a SME pays in Quebec in a given year;

—A 40% refundable tax credit to taxpayers, which conduct an eligible contract with a prescribed research centre;

... The Quebec tax credit could therefore represent 55% of eligible additional expenditures" (KPMG Inc., 2002, page 14).

In addition, Quebec offers guarantee programmes for SMEs up to Can $500 000, loan-guarantee programmes for SMEs up to Can $125 000, and several employment incentives for companies investing in the Laval Biotechnology Development Centre (Laval is a northern suburb of Montreal with the major agglomeration of biotechnology companies). In 2002 Quebec announced the development of three other Biotechnology Development Centres, in the cities of St-Hyacinthe (for agriculture), Lévis (a suburb of Quebec City) and Sherbrooke (the third largest metropolitan agglomeration in the province). The occupants of these centres receive substantial fiscal advantages over and

Table 4. R&D tax incentives in Quebec, Ontario, British Columbia, and Alberta (source: Koebberling and Dettmers, 2000; KPMG Inc., 2002).

Tax credit	Additional tax deduction
Quebec	
Available for corporations on R&D salaries and eligible expenditures under various types of research contracts. Rates for corporations: 40% for small firms (assets under Can $25 million) on R&D salaries up to Can $2 million; 40% to 20% for medium firms (assets between Can $25 million and Can $50 million) on R&D salaries up to Can $2 million; 20% for large firms (assets over Can $50 million) and 20% for R&D salaries over Can $2 million. Rates for contract R&D: 20% to 40% of eligible expenditures. Fully refundable: 100% of eligible expenditures. Two-year exemption for foreign research.	Not applicable
Ontario	
Ontario Innovation Tax Credit (1994 budget) Available for small CCPCs[a] (that is, those eligible for the enhanced rate of federal SRED tax credit) on SRED[b] current expenditures and 40% of SRED capital expenditures. Annual limit on SRED expenditures: Can $2 million. Rate: 10%. Fully refundable: 100% of eligible expenditures; no carryover of unused or unrefunded credits. Ontario Business-Research Institute Tax Credit (1997 budget) Applicable for corporations on SRED expenditures incurred in Ontario under approved contracts with eligible research institutes (universities, colleges, hospital research institutes, and certain nonprofit research organisations). Annual limit on SRED expenditures: Can $20 million. Rate: 20%. Fully refundable: 100% of eligible expenditures.	R&D Super Allowance Mandatory deduction. Base amount: average SRED expenditures of previous three years. Rates: non-CCPCs—25% up to base amount and 37.5% on incremental SRED expenditures: CCPCs—35% up to base amount and 52.5% on incremental SRED expenditures.
Alberta	
Not applicable	Not applicable
British Columbia	
Available for corporations on R&D salaries and eligible expenditures. Annual limit on SRED expenditures: Can $2 million. Rate: 10%. Refundable for CCPCs/applies against British Columbian corporate income tax owing for non-CCPCs	

[a] CCPC—Canadian-controlled private companies.
[b] SRED—Scientific Research and Economic Development.

Table 5. Summary of provincial practices in science and technology (S&T) policy and programmes (source: Koebberling and Dettmers, 2000; KPMG Inc., 2002).

Policy/programme theme	Quebec	Ontario	Alberta	British Columbia
1 Economic strategy				
1.1 Overall economic strategy	Focus on Jobs	A Road to Prosperity	Get Ready Alberta	
1.2 Technology sector strategy				BC High Tech Strategy
2 S&T strategy				
2.1 Overall S&T strategy	Accelerating Research and Innovation	Building Innovation Capacity	Sustaining the Alberta Advantage	
2.2 Sectoral S&T strategy				BC High Tech Strategy
3 S&T structure				
3.1 Ministry with S&T as sole business	Ministry of Research, S&T		Ministry of Innovation and Science	
3.2 Ministry with S&T and another sector		Ministry of Energy, S&T		
3.3 Agency with S&T and another sector				Information, S&T agency
4 Interdepartmental coordination				
4.1 Coordination at the highest level	Interdepartmental Committee for Research S&T	InterMinistry Council in S&T and innovation	S&T activities consolidated under Ministry of Innovation and Science	
4.2 External review body				Premier's Advisory Council on Science and Technology
5 Budget and expenditures				
5.1 Ministry/agency budget, 1999–2000 (Can $ million)	183.1	133.2 for S&T	220	23.8 for S&T
5.2 Provincial government S&T expenditures, 1998–99 (estimate) (Can $ million)	no data available	368	222	221
5.3 Provincial government estimated R&D expenditures, 1998–99 (Can $ million)	206	246	171	74

Table 5 (continued).

Policy/programme theme		Quebec	Ontario	Alberta	British Columbia
5.4	Provincial government R&D expenditures per capita, 1998 (Can $)	28	22	59	18
6	Investment strategies	Partnership; leveraging; interministry approach; university – industry mechanism; international linkages; tax incentives.	Partnership; leveraging; contract R&D; interministry coordination; university – industry mechanism; international linkages; tax incentives.	Partnership; leveraging; contract R&D; targeted approach; national and international R&D investment.	Partnership; leveraging; university – industry mechanism; funding agencies for programme delivery; sector-specific approach; tax incentives.
7	Programmes				
7.1	Public support for R&D	Innovation Quebec which includes many of the programmes of the Ministry of Research, Science and Technology and the funding agencies	Ontario R&D Challenge Fund; Premier's Research Excellence Awards	Alberta Science and Research Authority's Science and Research Fund; Energy Research Funding; Agriculture Research Institute Fund	Tech BC; Technology Assistance Program; Industrial Partnership Program; Strategic Research Program.
7.2	Training and guiding inventors	Support for development of inventions			
7.3	Technology acquisition of government	Development of technology applications			
7.4	Sector-specific projects or initiatives under the ministry or agency		ICT (information and communications technology); life sciences and technologies	ICT; biotech	High-tech sector package; Fisheries Development and Diversification Program

Table 5 (continued).

Policy/programme theme	Quebec	Ontario	Alberta	British Columbia
7.5 Upgrading of S&T infrastructure	Support for equipment purchase in Canadian Council of Technicians and Technologists network	Ontario R&D Challenge Fund; Ontario Innovation Trust	Research Excellence Envelope; Intellectual Infrastructure Partnership Program	Knowledge Development Fund
7.6 Support for R&D between local and foreign researchers	Financial assistance for S&T cooperation	International S&T agreements		International S&T memoranda of understanding
7.7 Increasing linkages between local and foreign researchers and firms	Hosting of convention			
7.8 Technology commercialisation fund		Biotech Commercialisation Centre Fund	Alberta Science and Research Authority's Technology Commercialisation Grant	Product Development Fund; Kootenay Product Development Fund MART
7.9 Promotion of S&T awareness and careers				
7.10 Support for S&T human resource development				Great Scholarships; First Job in S&T; Advanced Systems Institute Fellowship Program; Advanced Systems Institute Graduate Recruitment Assistance Program
7.11 S&T awards from government	Quebec Science Awards			BC S&T Awards
7.12 Encouraging S&T development locally				Regional Science Councils

Table 5 (continued).

Policy/programme theme		Quebec	Ontario	Alberta	British Columbia
8	Agencies				
8.1	Funding and implementing agencies	Fonds pour la Formation de Chercheurs et de l'Arde à la Recherche; Fonds de la recherche en santé du Québec; Conseil québécois de la recherche sociale; Valorisation Recherche—Quebec		Alberta Science and Research Authority; Alberta Research Council; Alberta Agriculture Research Institute; Alberta Heritage Foundation for Medical Research; Alberta Oil—Technology and Research Authority; Icore	Advanced Systems Institute; BC Biotechnology Alliance; UBCMAGIC; PATSCAN (Patent Research and Consulting Service); Science Council of British Columbia; Science World; Vancouver Aquarium; VIATec (Vancouver Island Advanced Technology Centre)
8.2	S&T advisory body	Conseil de la science et de la technologie du Québec; Conseil d'Évaluation des technologies de la santé	Ontario Science and Innovation Council		University–Industry Liaison Offices; Regional Technology Centers
9	University–industry linkage mechanisms	Centres for Liaison and Transfer	Ontario Centers of Excellence		University–Industry Liaison Offices; Regional Technology Centers
10	Performance measures	Innovation capacity of enterprises	Innovation capacity	Innovation system	High-tech sector (being developed)
11	Provincial R&D tax incentives	20–40% credit	20% refundable and super allowance		10% credit

Table 6. Public policy of provincial government for biotechnology development (source: KPMG Inc., 2002; Statistics Canada, 2003).

	Quebec	Ontario	British Columbia	Canada[a]
Number of biotechnology companies	135	106	71	391
R&D tax credit (%)	40 (15 CCPC)[b]	10	10	20
Tax credit for R&D with institutions (%)	40	20	0	na
Employment incentive	yes	yes	yes	yes
Government equity investment pool	yes	no	yes	no
Venture capital investment in 2000 (Can $ million)	242	129	205	628
Life sciences (Can $ million)	352	247	310	2 800

[a] na—not applicable.
[b] Canadian-controlled private companies.

above fiscal credits, and pay lower rental fees. The public purse thus contributes to reducing the operating costs of the firms, and eventually increases synergy among the occupants of the centres.

In 1999 Quebec biotechnology firms spent Can $337 million in R&D, which is approximately 40% of Canada's R&D expenditure in biotechnology by SBFs (Statistics Canada, 2001), and Can $443 million in 2001 (31% of the Canadian total). Some twenty companies located in the province are quoted on the stock exchange. As Quebec constitutes only 23% of Canadian population, it is safe to conclude that the French-speaking province represents a high share of Canada's biotechnology.

5.2 Ontario

The most populous Canadian province has traditionally been less interventionist than Quebec. Venture capital in Ontario is mostly private. Nevertheless, the province has used different measures to support biotechnology, including fiscal incentives and targeted research funds for university research. The following is a list of some of the most important provincial public policies.

The *Ontario Business Research Institute Tax Credit* offers a 20% tax credit to all private biotechnology firms subcontracting research work to provincial universities and research centres.

The *Ontario Research Performance Fund* was launched in 2001 with an annual budget of Can $30 million to support R&D expenditures.

The *Ontario Innovation Tax Credit* adds a 10% tax rebate to all firms conducting R&D in Ontario.

The *Ontario Innovation Trust*, launched in 1999 with a total investment of Can $750 million to help universities, research hospitals, and public institutes to improve their R&D infrastructure.

The *Biotechnology Commercialisation Centre Fund*, also launched in 1999, has Can $20 million to create or reinforce regional biotechnology incubator centres in the cities of London, Ottawa, and Toronto.

The *Ontario Research and Development Challenge Fund*, founded in 1997, will spend Can $500 million during ten years to promote collaboration between private and public research centres.

The *Premier's Research Excellence Awards* were launched in 1998 with an initial fund of Can $75 million in order to attract and retain the best researchers in all areas of science.
The *Ontario Research Performance Fund is* a year-2000 initiative of Can $30 million to support the costs of researchers working in the province.
The *Ontario Genomics Initiative* of year 2000 received a Can $75 million fund aimed at increasing provincial competencies in research on the human genome.
The *Ontario Cancer Research Network*, another year-2000 initiative, with a Can $50 million fund, aims at accelerating research into new promising therapies.

As a result of so many initiatives, Ontario is host to over 100 core biotechnology firms (27% of all Canadian enterprises) and follows Quebec in the number of companies. Some sixty of them are located in Toronto and over twenty five are quoted on the stock exchange. Like Montreal, Toronto has a long and distinguished experience in pharmaceutical and human biotechnology research, with research taking place at the University of Toronto (the largest Canadian university) and also in many R&D laboratories of multinational pharmaceutical corporations, as well as in domestic and international clinical research organisations. In 2001, SBFs located in Ontario spent Can $395 million on R&D (or 27% of the Canadian total) and collected Can $1.4 billion in total revenues (38% of the Canadian total).

5.3 British Columbia

The western province of Canada, and particularly Vancouver, is a rising cluster in biotechnology. According to Statistics Canada, seventy-one (18%) of the total core biotechnology firms in Canada are located in this province, and 85% of them were founded since 1992. Also, as in Quebec and Ontario, a majority of the firms in British Columbia are conducting research into human health, by far the most promising and the fastest growing niche. In 2001 their R&D expenditures amounted to Can $428 million (30% of the Canadian total) but their revenues, because of their relative youth, represented only Can $417 million (or 11% of the Canadian total). However, in 2001 British Columbia collected Can $205 million in venture capital (or 30% of the Canadian total) a figure that shows the growing importance of the province in the investors' forecasts.

Government policies, if not as visible as in Quebec and Ontario, have also been supportive of the creation and growth of biotechnology firms. They include the Centre for Molecular Medicine and Therapeutics, the NRC Innovation Centre of the University of British Columbia (UBC), the BC Cancer Agency, the Canadian HIV Trials Network, the Centre for Integrated Genomics including the BC Cancer Research Centre's Genomics Sequence Centre, and the UBC Biotechnology Laboratory. Since 1994 the BC Biotechnology Alliance (now BC Biotech), founded by the provincial Ministry of Advanced Education has gathered over 200 members.

In order to understand biotechnology in British Columbia it is necessary to understand the role of the research universities (mainly UBC and Simon Fraser University in Vancouver and the University of Victoria, located in the City of Victoria on Vancouver Island). Collectively these universities and their affiliated hospitals have spun off nearly 70% of the core biotechnology firms in the province. Most conspicuous is UBC's University–Industry Liaison Office, founded in 1984 and responsible for the creation of over 100 companies in several areas, nearly sixty of which were in biotechnology. It has collected over Can $1.3 billion from private investors in order to support these companies. The total market capitalisation of these UBC biotechnology companies exceeded Can $6 billion in December 2000.

Smaller, but no less active, are the other two other major universities, which have also spun off some rapidly growing human biotechnology companies in Vancouver or Victoria.

5.4 Alberta

Alberta is the fourth most important province in Canadian biotechnology. Among the main biotechnology regions, Alberta is the only one without tax credits for R&D. The oil-rich province has not developed any specific policy to create or attract venture capital to the region. Conversely, in 1921 Alberta created one of the first and most affluent provincial research organisations, the Alberta Research Council (ARC). With an annual budget of over Can $84 million a year, ARC hosts a major biotechnology laboratory with over forty US patents in agricultural, forest, and human health biotechnology.

Also, Alberta imitated Quebec in developing its own funding agencies for scientific research. In 1980 the provincial government created the Alberta Heritage Foundation for Medical Research (AHFMR) with an endowment of Can $700 million to support medical research. AHFMR spends over Can $40 million every year in grants and awards. In 2000 a sister organisation, the Alberta Heritage Foundation for Science and Engineering Research, with a total endowment of Can $1 billion was created to support natural science (including biotechnology) and engineering across the province. In the meantime, an umbrella organisation, the Alberta Science and Research Authority was created in 1994 to suggest science and technology policies to the provincial government, as well as to assess and monitor the scientific activities taking place in the province.

As a result of this set of regional policies, Alberta occupies fourth position in Canadian biotechnology, after Quebec, Ontario, and British Columbia. The province is host to some twenty-five SBFs, which in 2001 spent Can $121 million on R&D (8.4% of the Canadian total). Their revenues stemming from biotechnology products represent 35% of the Canadian sum.

6 Conclusion

Biotechnology is a generic technology with many potential applications but, by 2002, little return on investment. As such, it attracts some attention from the financial community but does not command any priority. Conversely, governments foresee future benefits for the economy and society in the backing of this set of new technologies. Thus the national and regional development of biotechnology seems to depend on the continuous, generous, and multilayered support of public authorities.

The Canadian case shows that governments have backed this new technology with many different incentives and institutions, from the funding of academic research to the direct and indirect funding of private sector R&D, to the development of a large venture capital pool and the protection of intellectual property. Thanks to these policies and institutions, Canada occupies second rank among nations, after the United States, but before European nations and Japan, in spite of its smaller population and (in absolute terms) science base.

Within Canada the relative importance of the four major regions corresponds basically to the size of the public support of biotechnology. However, the Province of Quebec, second in population, ranks in biotechnology before Ontario, Canada's most populous province, thanks to the multifaceted effort of its government in favour of each and every stage of biotechnology development from basic research to venture capital and technology commercialisation. British Columbia comes closer to the second place most probably because of its efficient university-research commercialisation organisations.

The use of the national and regional systems of innovation concepts is to some extent validated in the case of biotechnology because, in both cases, the emphasis is on the systemic character of innovation and the key role given to the state as coordinator and last-resort decisionmaker. Biotechnology is a case of governmental nurturing of an innovation system (or rather a national set of innovation systems) to support early entry into a new generic technology.

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Appendix A

Table A1. Definition of the sectors.

Sector	Components
Human health	Diagnostics
	Therapeutics
	Gene therapy
Agriculture and food	Plant biotechnology
	Animal biotechnology
	Biofertilisers, biopesticides, bioherbicides
	Bioprocessing
	Functional food, neutraceuticals
	Nonfood applications of agricultural products
Environment	Biofiltration
	Bioremediation and phytoremediation or plantremediation
	Diagnostics
Other	Genomics and molecular modelling
	Fish health
	Broodstock genetics
	Bioextraction
	Microbiologically enhanced petroleum or mineral recovery
	Industrial bioprocessing
	Custom synthesis (chemical or biological)

Appendix B

Table B1. List of biotechnologies.

Technology	Components
Selection and modification technologies	Recombinant DNA
	Antibodies and antigens
	Peptide synthesis
	Rational drug design
	Monoclonal antibodies
	Gene probe
	Gene therapy
	DNA amplication
Environment biotechnology	Bioaugmentation
	Bioremediation
	Bioreactors
	Phytoremediation
	Biogas cleaning
Culture and use of biological material	Tissue culture
	Somatic embryo genesis
	Bioprocessing
	Biosensing
	Biobleaching
	Bioleaching
	Microbial inoculant