Science-Metrix

Final Report

February 2006

Canadian Biotechnology Innovation Scoreboard

Prepared for

Industry Canada

Life Science Branch

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Science-Metrix specializes in the measurement and evaluation of science, technology and innovation. Our data collection and assessment methods include bibliometrics, scientometrics, technometrics, surveys and interviews, environmental scans, monitoring and intelligence gathering. We perform program and policy evaluations, benchmarking and sector analyses, market studies and strategic planning. Science-Metrix has a robust knowledge of life and environmental sciences.

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Executive Summary

The *Canadian Biotechnology Innovation Scoreboard* aims to analyze and evaluate specific aspects of the biotechnology field by comparing Canada with other international leaders in biotechnology. Scoreboards are designed to inform and stimulate debate among policy makers and other stakeholders. This scoreboard presents exhaustive, timely, relevant, accurate, comparable, and coherent data on biotechnology for Canadian policy makers. The policy areas addressed in the report are the following:

- Scientific and technological outputs of biotechnology research;
- Level of dissemination of biotechnology knowledge;
- Commercialization of biotechnology products;
- Economic, social, and environmental impacts of biotechnology activities.

The main difficulties encountered stemmed from a lack of standardization and, therefore, comparability of data presented in international reports. To address these difficulties, this report followed the guidelines presented in the OECD *Framework for Biotechnology Statistics,* published in June 2005. Problems of category and definition were resolved, while problems of comparability, coherence, reporting agent, and scope of the data were used as a basis for the inclusion or the exclusion of data in the scoreboard.

This report is subdivided into three sections, following the framework presented in Science-Metrix' report *Towards a Canadian Biotechnology Innovation Scoreboard*: (1) a scientometric analysis; (2) a technometric analysis; and (3) firms, workforce, and financial flows analyses. The scoreboard is based on 22 indicators. These indicators provide data in support of the analysis in each of the three sections.

The scoreboard shows that Canada is one of the world leaders in biotechnology. In particular, it reveals that Canada has the fastest growing biotechnology market in the world, and that Canada has benefited from high amounts of Business Enterprise Sector (BES) R&D investments in biotechnology, as well as high-value investments from Venture Capital (VC). The country also possesses significant numbers of biotechnology firms and employees, achieves significant revenues, and has a good Intellectual Property (IP) portfolio. In fact, Canada, as ranked among the top five countries, is leading in 14 out of 22 indicators.

However, Canada scores comparatively low for relative number of biotechnology papers, specialization of its output in biotechnology science and technology, average relative citation of its patents, and number of biotechnology BES employees per thousand labour force.

Other leading countries in biotechnology include the US, Denmark, the UK, Germany, Switzerland, Sweden, and France. Countries likely to play a major role in biotechnology in the near future include China and the Republic of Korea.

Acronyms

ARC	Average of Relative Citations
BERD	Business Enterprise Expenditures on Research and Development
BES	Business Enterprise Sector
BUDS	Biotechnology Use and Development Survey
CAD	Canadian Dollar
DBF	Dedicated Biotechnology Firm
EC	European Commission
IBF	Innovative Biotechnology Firm
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditures on Research and Development
HERD	Higher Education Expenditures on Research and Development
IP	Intellectual Property
ISI	Institute of Scientific Information
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity
RAC	Relative Average Citation
R&D	Research and development
SCI	Science Citation Index
STI	Science, Technology and Innovation
UN	United Nations
USD	United States Dollars
VC	Venture capital
USPTO	United States Patent and Trademark Office

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Introduction

The OECD (2005) argues that due to its wide range of applications, biotechnology has become an extremely active field with the potential to contribute significantly to social, economic, and environmental development. It is also mentioned that biotechnology has the potential to impact on "future economic development and structural changes in a variety of industries, namely pharmaceutical, food, agriculture, energy and chemical" (Allansdottir *et al.*, 2003: p.6). In recent years, governments have developed national biotechnology policies with the objective of enhancing the positive outcomes of biotechnology activities. Because the policy-making process relies on the establishment of strategic objectives and the evaluation of publicly funded research programmes, tools that use a wide range of indicators for extensive measurement have been devised in the last 10 years (OECD, 2005). These tools have been designed in order to describe and assess the development of biotechnology while addressing specific policy areas related to biotechnology.

Policy makers recently faced the problem of not having "systematic (internationally comparable) data on many aspects of biotechnology and its effects on the economy and society" (Allansdottir *et al.*, 2003: p.6). Problems of timeliness, accuracy, coherence, and completeness of biotechnology statistics were addressed in the recent OECD (2005) *Framework for Biotechnology Statistics*. When considering the increasing impact biotechnology is having on social, economic, and environmental issues, governments' need for comparable data is becoming a pressing issue. In this context, biotechnology scoreboards have been found to be valuable tools for the diffusion of reliable information as well as for the evaluation and assessment of biotechnology for specific policy areas. Use of these tools and their findings are likely to stimulate debate among policy-makers (Archambault *et al.*, 2005).

Scoreboards include numerous indicators and are updated on a regular basis. This allows multi-criterion analyses to be conducted to assist policy makers in understanding and evaluating research and development (R&D) activities and their outputs. Scoreboards in the form of statistical yearbooks and compendia, as well as benchmarking studies and indexes such as the Human Development Index (Archambault *et al.*, 2005), have existed for years. More recently, scoreboards have been used in association with science, technology, and innovation (STI) indicators.

In biotechnology, the European Commission's (EC) *Biotechnology Innovation Scoreboard*, published in 2002 as part of the European Trend Chart on Innovation, was one of the first attempts to use a scoreboard as a tool for the diffusion of information and the evaluation of national biotechnology strategies. Several other attempts to compile a biotechnology innovation scoreboard have been made, such as the OECD's biotechnology statistical compendium (2003). Both the EC scoreboard and the OECD overview of biotechnology statistics present compendia of available biotechnology data from publicly available sources, with the broad objective of providing comparative international data on biotechnology. The EC scoreboard achieves a greater level of specificity by evaluating, in a best performance index, the strengths and weaknesses of what has been termed "national systems of biotechnology innovation" (Furman *et al.*, 2002). Although both of these scoreboards are useful initial attempts to supply a tool for the evaluation of national system of biotechnology innovation, it is not clear whether they will be updated.

Most importantly, these scoreboards do not provide up-to-date information, as they are largely based on statistics taken from 2001 national surveys. Moreover, although these reports provided an overview of biotechnology developments in selected countries, a benchmarking of countries' achievements in biotechnology, and a biotechnology literature review, they did not provide insights into what these data meant for specific policy areas, nor did they address known methodological problems related to biotechnology statistics such as data scope, reporting agents, consistency of firm type categories, and definition of biotechnology (OECD, 2005). However, despite their flaws, these scoreboards represent a good basis for further research and enhancement of biotechnology statistics.

Thus, Science-Metrix' Canadian biotechnology innovation scoreboard is aligned with previous attempts, but is also responsive to specific problems associated with them. The main objective of the present scoreboard is to provide valuable information to policy-makers about the development of biotechnology in specific countries, with a focus on comparing Canadian biotechnology activities with those of other countries. The Canadian biotechnology innovation scoreboard takes account of the value of each indicator for specific policy areas and their specific meaning for the Canadian biotechnology field. The indicators fall into three categories and are described in three sections of the report: Part I, Scientific publications in biotechnology; Part II, Intellectual property in biotechnology; and Part III, Firms, workforce, and financial flows. The data presented in the scoreboard originate from various sources ranging from publicly available reports and statistics to specialized databases. Syntheses of these data and data sources are presented in appendices A and B. The scoreboard addresses the methodological problems commonly encountered with biotechnology statistics in order to provide timely, more significant, relevant, comparable, and accurate information on biotechnology.

Methods

There are substantial methodological impediments to the compilation of biotechnology statistics. As noted in the OECD's (2005) *Framework for Biotechnology Statistics*, problems pertaining to definitions, categories, consistency, accuracy, accessibility, timeliness, comparability, coherence, completeness, sampling errors, and exhaustiveness are common. The present report conforms to the guidelines provided by the OECD (2005) for addressing some common methodological problems, which also help in the identification of bias and limitations in the data available. As is the case for all statistical compendia, this study relies on a clear definition of its subject, which in this case is biotechnology. For this purpose, the report applies two definitions provided by the OECD (2005). The initial general definition is straightforward:

> The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services (OECD, 2005, p.9).

The more detailed definition is list-based:

> **DNA/RNA**: Genomics, pharmacogenomics, gene probes, genetic engineering, DNA/RNA sequencing/synthesis/amplification, gene expression profiling, and use of antisense technology.
>
> **Proteins and other molecules**: Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signalling, identification of cell receptors.
>
> **Cell and tissue culture and engineering**: Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.
>
> **Process biotechnology techniques**: Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration, and phytoremediation. Gene and RNA vectors: Gene therapy,viral vectors.
>
> **Bioinformatics:** Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.
>
> **Nanobiotechnology**: Applies the tools and processes of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics, etc. (OECD, 2005, p.9)

The indicators presented in the current study rely on Science-Metrix' 2004 report *Towards a Canadian Biotechnology Innovation Scoreboard*, which proposed an initial set of 20 absolute indicators related to human resources, companies, finance, and science and technology (S&T) in order to measure the performance of the Canadian biotechnology sector. Following a literature review of available international data, problems were identified related to availability, consistency, coherence, and timeliness of data for several of the indicators initially proposed. These problems affected comparability of the data. Thus, only 10 out of the 20 indicators initially proposed are used in this report, although 12 other indicators for which reliable data were available were incorporated into the scoreboard, producing a total of 22 indicators.

Data on scientific and technological outputs were available for all countries and did not introduce any problems. However, for human resources, companies and finance indicators data were available for only a limited set of the countries selected for inclusion in the scoreboard. Availability of data on each indicator for these countries is presented in Table IV in Appendix A. Given that the reliability of data for India was questionable, the country was excluded from the scoreboard, leaving a total of 23 countries. Details on indicators used in each section of the scoreboard and an assessment of the report's limitations are presented in the following subsections.

Scientometric analysis

Dataset

The scientometric analysis (Section 1) is based on the use of the Thomson ISI Science Citation Index Expanded (SCI Expanded) database. A subset of biotechnology papers was retrieved from this database using a set of keywords-in-title searches representing the two biotechnology definitions mentioned above, for the 2000-2004 period. Included in the dataset are four document types that are considered to be original contributions to scientific knowledge: articles, notes, reviews, and conference proceedings. The tables in this report refer to these four document types as "papers". The statistics were computed based on the resulting dataset.

Caveats

The use of keywords-in-title searches leads to an underestimation of scientific output, as some papers do not have titles that contain keywords specific to their fields. However, because keywords-in-title are more subject-specific than keywords-in-abstract or keywords-in-full text, this strategy reduces the occurrence of "false positives" (i.e. papers selected through a query, that do not belong to the field being investigated). Despite this tendency to underestimate scientific output, the keywords-in-title method is adequate given that the goal of this study is not to produce a census of papers in the field, but rather to provide an unbiased comparison of the scientific production of countries active in biotechnology.

The SCI Expanded provides the most extensive coverage of high-quality scientific research because it indexes approximately 6,000 of the world's leading scholarly science and technical journals in more than 150 disciplines. These journals are considered to be the most important peer-reviewed journals in their respective fields. They reflect significant scientific achievements and are the most widely cited journals in the world (over 80% of the world's citations). In addition, it is the only database that compiles the references made to and the citations received by papers. This information is invaluable in the benchmarking of scientific research.

Indicators

The biotechnology papers dataset was used to produce detailed statistics based on the following indicators:

- **Papers:** Number of scientific papers written by authors located in a given geographical, sectoral, organizational, or individual entity (e.g. country, city, or institution).
- **Papers per billion GDP:** Ratio of the number of papers in a given period of time over the Gross Domestic Product (GDP in USD PPP) for the period.

- **Specialization index (SI):** This is an indicator of the intensity of research of a given geographic or organizational entity (e.g. a country) in a given research area (domain, field) relative to the intensity of research in a reference entity (e.g. the world) in the same research area. The SI can be formulated as:

$$SI = \frac{(X_S/X_T)}{(N_S/N_T)}$$

where,

X_S = Papers from entity X in a given research area (e.g. Canada in biotechnology)

X_T = Papers from entity X in a reference set of papers (e.g. Canada in the whole SCI Expanded database)

N_S = Papers from the reference entity N in a given research area (e.g. world in biotechnology)

N_T = Papers from the reference entity N in a reference set of papers (e.g. world in the whole SCI Expanded database)

An index above 1 means that a given entity is specialized relative to the reference entity.

- **Average of relative citations (ARC):** This is an indicator of the scientific impact of papers produced by a given entity. In general, the number of citations received for each paper was counted for the year in which they were made and for the two subsequent years. So for papers published in 2000, citations received in 2000, 2001, and 2002 were counted. The exceptions are 2003, which comprises a citation window of two years (2003 and 2004), and 2004, which contains a citation window of only one year because citation data for the subsequent years are not yet available. For a paper in a given subfield (reference subfields are those defined by CHI Research Inc. for the National Science Foundation [NSF] and used in the Science and Engineering Indicators), the citation count was then divided by the average count of all papers in this subfield to obtain a relative citation count (RC). The ARC of a given entity is computed using the RC of each paper belonging to it.

Technometric analysis

Dataset

The technometric analysis is based on the use of the United States Patents and Trademark Office (USPTO) database. Delineation of the field of biotechnology was performed iteratively. First, keywords extracted from the *Biotechnology Use and Development Survey 2001* (McNiven *et al.*, 2003) were used to perform a search in patent titles and abstracts. Second, the classes from each of 20 patents selected by each keyword were extracted. From this list of US patent classes, a pre-selection of classes that were deemed relevant to the field of biotechnology was made. Third, each class was thoroughly analyzed to determine its pertinence to the field. The relevant classes were then used to construct the basic dataset for this study.

The technometric analysis aimed at comparing countries' 2004 IP portfolios of active biotechnology patents. Because issued patents generally provide assignees exclusive rights to use, make, sell, or import an invention for a period of 20 years following the original filing of the patent, IP portfolios in 2004 include patents issued no later than December 31st 2004 that were filed between 1985 and

2004. Thus, the patent dataset was created by retrieving patents issued no later than December 31st 2004 and filed during the 1985–2004 period. Patents that expired and that were not reinstated as a result of renewal fees not being paid were removed from the dataset in order that only active patents in any country's portfolio were retained.

Caveats

There are several well-known shortcomings to the use of statistics based on patents used to describe technological innovation in specific fields:

- Incompleteness: Many inventions are not patented, since patenting is only one way of protecting an invention;
- Inconsistency in quality: The importance and value of patented inventions vary considerably;
- Inconsistency across industries and fields: Industries and fields vary considerably in their propensity to patent inventions;
- Inconsistency across countries: Inventors from different countries have different propensities to patent inventions, and countries have different patent laws.

Despite these weaknesses, technometric indicators are widely used to compare the level of technological development of different geographic locations. Importantly, the USPTO database presents an obvious bias towards the USA. However, because the USPTO is one of the largest repositories of patented inventions in the world, its data are widely used to measure invention. In addition, because the USA is the largest market in the world, the most important inventions tend to be patented there. Thus, the USPTO database remains a potent tool for comparing other countries.

Indicators

The patent dataset was used to produce detailed statistics on countries' 2004 IP portfolios of active biotechnology patents based on the following indicators:

- **IP ownership:** Unlike scientific publications, patents include two fields that contain bibliographic information that can help in determining where a patent originates: the inventor field and the assignee field. An inventor is necessarily a physical person, whereas an assignee can be a physical person and/or an organisation. These fields are used to compute statistics on two indicators, namely invention and intellectual property (IP). This report presents data on IP which provides rights on inventions.
- **IP per billion GDP:** Ratio of IP ownership in the 2004 portfolio of a given geographic or organizational entity (e.g., a country) over the Gross Domestic Product (GDP) of the same entity in 2004.
- **SI:** An indicator of the intensity of patenting of a given geographic or organizational entity (e.g., a country) in a given area (domain, field) relative to the intensity of patenting in a reference entity (e.g., the world) in the same area. The SI can be formulated as:

$$SI = \frac{(X_S/X_T)}{(N_S/N_T)}$$

where,

X_S = IP ownership from entity X in a given portfolio (e.g., Canada's 2004 IP portfolio in biotechnology)

X_T = IP ownership from entity X in a reference portfolio (e.g., Canada's 2004 IP portfolio in the whole USPTO database)

N_S = IP ownership from the reference entity N in a given portfolio (e.g., the world's 2004 IP portfolio in biotechnology)

N_T = IP ownership from the reference entity N in a reference portfolio (e.g., the world's 2004 IP portfolio in the whole USPTO database).

An index above 1 means that a given entity is specialized relative to the reference entity.

- **Relative Average Citation (RAC):** This is an indicator of the number of times patents owned by a given geographic or organizational entity (e.g., a country) are cited relative to those of a reference entity (e.g., the world). The average number of citations received per patent in the IP portfolio of a given entity as of 2004 is divided by the average number of citations received per patent in the IP portfolio of the reference entity as of 2004. A RAC above 1 means that patents owned by a given entity are more cited, on average, than patents owned by the reference entity.

Firms, workforce, and financial flows analysis

Dataset

Biotechnology firms, workforce, and financial flows are essential components of the *Canadian Biotechnology Innovation Scoreboard*. They provide valuable information on different aspects of the Canadian biotechnology innovation system and allow for international comparison of those aspects. As the final objective of the scoreboard is to build an extensive table of the indicators that provide information on the strengths and weaknesses of Canada and competing countries in biotechnology, such indicators are essential even if they are known to have methodological limits. Therefore, methodological tools were needed to address availability and consistency issues. The method used in this study is based on the work of the OECD (2005) and EC (2002) and builds on the indicators identified in Science-Metrix' (2004) report *Towards a Biotechnology Innovation Scoreboard*.

The method used consisted of scanning publicly available reports and other sources of structured information on biotechnology, gathering available data on different indicators, standardizing the categories, and creating an extensive database of indicators on biotechnology. Data sources are presented in Appendix B.

Caveats

The present study conformed to the quality dimensions described in OECD (2005) for conducting a literature review. The following quality aspects were considered:

- **Relevance:** The link between the indicators and their relevance for the main policy areas is provided prior to the presentation of the data;
- **Timeliness:** Within the limits of data comparability, the scoreboard presents the timeliest data on biotechnology available from public sources;
- **Accuracy:** The scoreboard privileges data from national surveys, which are estimated with methods to minimize the deviation between the target value determined by a perfect process (true parameter) and the value determined by the imperfect process (estimate). The methods underlying the estimation of data presented in the scoreboard are presented in Appendix A;

- **Accessibility:** The scoreboard adopts a transparent approach to the presentation of data, methods and calculations;
- **Comparability:** The scoreboard is, for the most part, limited to comparison of data within the same time span; when data from different time spans are included in a comparison, this is made clear. The number of years available for each indicator and each country are provided in Appendix A;
- **Coherence:** The concepts and definitions used in international reports for describing and measuring biotechnology activities were reviewed in order to identify problematic discrepancies. Assessment of the coherence of biotechnology definitions and biotechnology firm type definitions underlying the data presented in the current report is provided in Appendix A;
- **Completeness:** The preliminary report 'Towards a Canadian Biotechnology Innovation Scoreboard' provides theoretical considerations of the utility of the indicators presented in the scoreboard for specific policy areas. These considerations show the completeness of the indicators for the specific user needs and priorities;
- **Scope and coverage:** Assessment of the scope and coverage of data presented in the current report is provided in Appendix A;
- **Reporting unit:** The scoreboard privileges data reported by official data sources such as governments and official statistical organizations. Data reporting sources used in the current report are indicated in Appendix A.

After considering these quality dimensions and after consultation with Antoine Rose (in 2005), Senior Analyst at Statistics Canada, the indicators and definitions in Science-Metrix' initial report were revised and modified.

An important refinement relates to the replacement of the term "*Biotechnology Industry*" by "*Business Enterprise Sector*" (BES). As noted by Rose, it is a common mistake to associate the concept of industry with the more general concept of an economic sector. The use of the expression biotechnology BES presents the advantage of defining the economic sector of biotechnology while not falsely imputing to biotechnology the attribute of being a homogeneous industry. As a United Nations (UN) methodology guide states:

> An industry consists of a group of establishments engaged on the same or similar kinds of production activity (UN, 1993, par. 5.5 and 5.40).

Because it is used in a wide variety of circumstances there is no harmonized definition of the term "industry" in business statistics (OECD, 2001); thus use of the term "*Biotechnology Industry*" raised the possibility of it not being consistent with the OECD's list-based definition of biotechnology. Another modification consisted of applying the generic term "*biotechnology firms*" to encompass all definitions of biotechnology firms encountered in international reports as no single definition was used across all of the countries included in the scoreboard. The definitions in the literature include:

- **Biotechnology Active Firm (BAF):** "Firm engaged in key biotechnology activities such as the application of at least one biotechnology technique to produce goods or services and/or the performance of biotechnology R&D" (OECD, 2005, p.10).
- **Innovative Biotechnology Firm (IBF):** "Biotechnology active firm that applies biotechnology techniques for the purpose of implementing new or significantly improved products or processes (per the Oslo Manual [OECD, 1997] for the measurement of innovation). It excludes end users who innovate simply by using biotechnology products as intermediate inputs (for

instance, detergent manufacturers that change their formulation to include enzymes produced by other firms via biotechnology techniques)" (OECD, 2005, p.10).

- **Dedicated Biotechnology Firm (DBF):** "Biotechnology active firm whose predominant activity involves the application of biotechnology techniques to produce goods or services and/or the performance of biotechnology R&D" (OECD, 2005, p.10).
- **Core Biotechnology Company:** "Firm that is active in R&D in biotechnology and for which biotech constitutes the firm's central activity" (Bloch, 2004).
- **Bioventure:** "Commercial enterprise that meets all four of the following conditions: 1) the company utilizes, or develops for, biotechnology, 2) the number of employees complies with the definition stipulated by Japan's 'Small and Medium Enterprise Basic Law' (i.e. manufacturing SMEs=300 employees or less; wholesale/service industry SMEs=100 employees or less; retail SMEs=50 employees or less), 3) the company is less than 20 years old, and 4) the company's primary operations involve research & development, funded research, manufacturing, or advanced scientific consulting" (JBA, 2005).

Because these definitions do not cover the same range of firm types, some (e.g. bioventure) being more restrictive than others (e.g. IBF), and because we had to include in the scoreboard data obtained using different definitions, international comparisons should be interpreted cautiously as data might either be overestimated or underestimated for one country relative to the others.

Another data availability problem concerns statistics on the biotechnology workforce. In particular, statistics on the government R&D workforce were only available for Canada. Moreover, for most countries, the total number of biotechnology employees for all sectors was not available. In fact, except for Canada, where workforce data and trends are presented, only BES data were available for international comparison.

Systematic collection, at an affordable price, of many of the financial indicators initially proposed proved difficult. There was a particular problem in relation to defining an indicator for the value of publicly traded biotechnology companies, as this required an inventory of companies at the international level in order to collect stock market data. Exhaustive listings of biotechnology companies are only available through national agencies. However, these agencies are seldom allowed to disclose their survey information. Other listings, such as the online Nature Biotechnology Directory that contains more than 8,000 references, were an option. However, this information is potentially biased due to the method used to collect data, namely voluntary questionnaires. The indicator could have been limited to the collection of international meta-data such as NASDAQ, AMEX, Toronto, or Yahoo Biotechnology Indexes. Such indexes have the advantage of displaying international and historical trends in the biotechnology sector for the stock market as a whole, but not every country has such an index, and using existing indices would create a bias in favour of the US. Consequently, because it was impossible to perform exhaustive and consistent international comparisons based on this indicator, it was discarded.

Indicators

The dataset, which was based on the literature review, was created to provide detailed statistics on the following indicators:

- **Biotechnology firms:** Within the context of the scoreboard, the generic term "biotechnology firms" is used to encompass data obtained using the following definitions of biotechnology firms: innovative biotechnology firms, dedicated biotechnology firms, core biotechnology companies, and bioventures.
- **Biotechnology firms per billion GDP:** Ratio of the number of IBF in a country in year X over the country's GDP in year X.
- **Biotechnology BES employees:** Number of biotechnology employees in the BES.
- **Biotechnology BES employees per thousand labour force:** Ratio of biotechnology BES employees in a country in year X over the country's labour force in year X.
- **Biotechnology BES R&D employees:** Number of biotechnology R&D employees in the BES.
- **Proportion of biotechnology BES R&D employees among biotechnology BES employees:** Ratio of the number of biotechnology R&D employees in the BES in a country in year X over the country's total number of biotechnology employees in the BES in year X.
- **Federal government expenditures on biotechnology R&D:** Only for Canada.
- **Federal government expenditures on biotechnology R&D as a percentage of total federal government expenditure on R&D:** Only for Canada.
- **Biotechnology BES R&D expenditures**
- **Biotechnology BES R&D expenditures as a percentage of business enterprise R&D (BERD):** Ratio of biotechnology BES R&D expenditure in a country in year X over that country's total Business Enterprise R&D (BERD) expenditure in year X.
- **Biotechnology VC:** VC raised by biotechnology firms in a given year.
- **Biotechnology VC per billion GDP:** Ratio of VC raised by biotechnology firms over countries' GDP.
- **Biotechnology market size:** Estimated size of demand for biotechnology goods and services in a country.
- **Average Annual Growth Rates of Biotechnology Markets:** The average of yearly growth of biotechnology markets in a given period;

  $$\frac{\left[\sum_{i=2}^{N}(X_i - X_{i-1})/X_{i-1}\right]}{N-1}$$

  where,

  X_i = Market size in year *i*
  N = Total number of years included in the dataset
- **Biotechnology company revenues:** Revenues of IBFs by year.
- **Biotechnology company revenues per billion GDP:** Ratio of IBF's revenues in a country in year X over the country's GDP in year X.

PART I SCIENTIFIC PUBLICATIONS IN BIOTECHNOLOGY

1 Scientific output at the international level

It has been suggested that, in a knowledge-driven economy focused on innovation, basic research has a direct economic impact at many levels, including: (1) increasing the stock of useful knowledge; (2) training skilled graduates; (3) creating new scientific instrumentation and methodologies; (4) forming networks and stimulating social interaction; (5) increasing the capacity for scientific and technological problem-solving; and (6) creating new firms (Salter and Martin, 2001). The number of papers that a country publishes in top-ranking peer-reviewed journals and their scientific impact constitute good proxies of scientific activities. In addition, these indicators allow for evaluation of the extent to which the knowledge produced by a country is disseminated.

This section provides an overview of the global rate of growth of scientific papers in the field of biotechnology at the world level (Section 1.1) and subsequently benchmarks countries based on their scientific output (Section 1.2). The benchmarking analysis is based on the 2000–2004 period to provide the most recent trends in the creation of knowledge in biotechnology.

1.1 Global trends in publishing biotechnology

The number of scientific papers published in biotechnology grew fairly rapidly between 1990 and 1995, but at a significantly lower pace between 1996 and 2004 (Figure 1). On average, the number of scientific papers at the world level grew by about 4% per year over the 1990–2004 period, increasing from about 11,000 papers in 1990 to about 19,000 papers in 2004. Thus, the biotechnology field has grown by about 75% over the past 10 years.

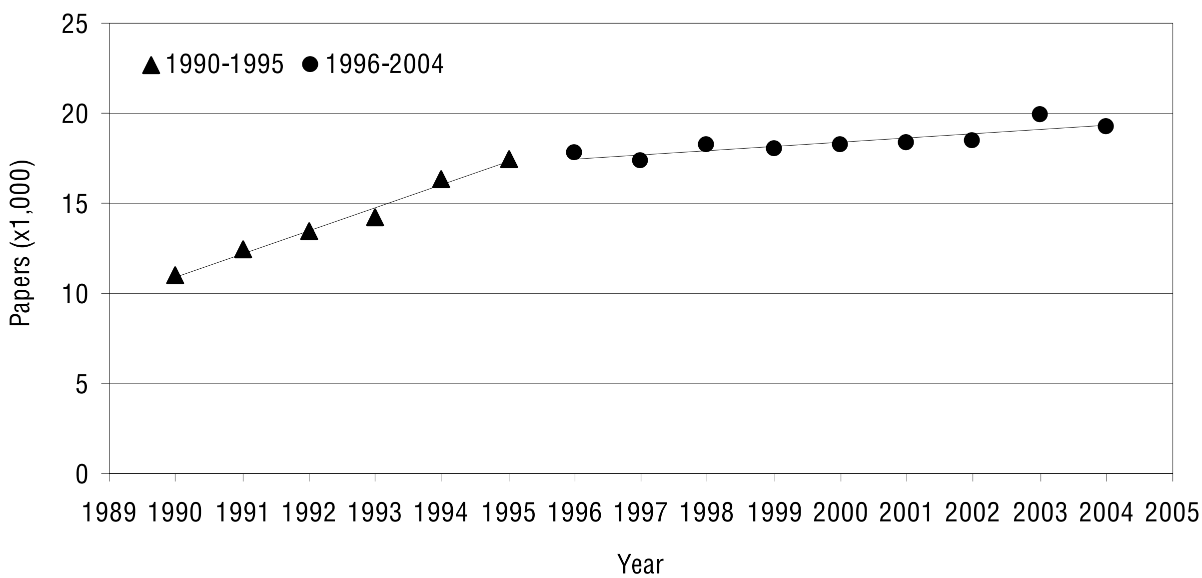

Figure 1 Biotechnology papers in SCI Expanded, 1990–2004

Source: Compiled by Science-Metrix from SCI Expanded (Thomson ISI)

1.2 Benchmarking selected countries based on their scientific output

When considering the total number of biotechnology papers published over the 2000–2004 period, the US dominates with about 32,000 papers, nearly three times as many as its closest competitor Japan, which published around 11,000 papers (Table I). Germany, the UK, and France follow, with numbers of biotechnology papers ranging from 8,698 to 5,753. China ranks 6th, followed closely by Canada in 7th place, with about 4,200 papers.

Table I Multicriteria ranking of selected countries based on the number of papers, the number of papers per billion GDP, the specialization index (SI), and the average of relative citations (ARC), 2000–2004

Country	Papers		Papers per billion GDP (USD PPP)		SI		ARC		Multicriteria ranking
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	
Australia	2,569	12	0.93	8	0.97	18	1.06	13	14
Austria	1,105	17	0.91	10	1.21	5	1.15	9	10
Belgium	1,506	15	1.02	7	1.18	6	1.24	4	4
Canada	4,199	7	0.89	11	1.01	13	1.21	6	8
China	4,266	6	0.14	23	0.99	16	0.59	23	21
Denmark	1,222	16	1.50	3	1.27	3	1.24	3	2
Finland	902	18	1.24	4	0.99	17	1.07	12	14
France	5,753	5	0.67	13	1.01	14	1.06	14	12
Germany	8,698	3	0.78	12	1.09	10	1.10	10	6
Ireland	369	23	0.57	19	1.06	11	0.93	17	22
Italy	3,847	8	0.51	21	0.96	19	0.94	16	18
Japan	11,288	2	0.64	14	1.31	2	0.86	19	8
Netherlands	2,724	11	1.10	5	1.15	8	1.23	5	3
New Zealand	450	21	1.03	6	0.84	22	0.88	18	19
Norway	515	20	0.61	16	0.82	23	1.17	8	19
Portugal	566	19	0.57	20	1.25	4	0.83	20	17
Republic of Korea	2,742	10	0.62	15	1.38	1	0.65	22	13
South Africa	441	22	0.20	22	0.96	20	0.77	21	23
Spain	2,859	9	0.59	18	1.01	15	1.01	15	16
Sweden	2,084	13	1.65	2	1.13	9	1.10	11	6
Switzerland	2,011	14	1.71	1	1.17	7	1.36	1	1
United Kingdom	7,838	4	0.92	9	0.94	21	1.20	7	10
United States	31,699	1	0.60	17	1.02	12	1.35	2	4
World	**94,160**		**0.38**		**1.00**		**1.00**		

Source: Compiled by Science-Metrix from SCI Expanded (Thomson ISI) and WorldData Annual Time Series (The Economist Intelligence Unit)

While scientific production in biotechnology for most countries in the top 10 (based on absolute output) levelled off in the mid 1990s, the scientific production of China (6th place) and the Republic of Korea (10th place) has increased, with an annual average growth in biotechnology papers of, respectively, 23% and 15% over the 2000–2004 period (calculated by exponential regressions). China's annual production of biotechnology papers overtook that of Canada in 2003 and France in 2004 and could surpass the annual production of other leading countries (i.e. the UK and Germany) in coming years. The Republic of Korea is also increasing its scientific production rapidly, and it outperformed Spain in 2004.

The number of biotechnology papers per billion GDP allows for comparison of the publication capacity of different countries while accounting for the potential bias resulting from differences in the scale of countries' economies. When considering each country's GDP, larger countries with high absolute production (e.g. the US, Japan, Germany, the UK, France, and China) are being overtaken by smaller countries with low absolute scientific output (Table I). Switzerland, Sweden, Denmark, Finland, the Netherlands, New Zealand, and Belgium rank 14th, 13th, 16th, 18th, 11th, 21st, and 15th in absolute output, and 1st, 2nd, 3rd, 4th, 5th, 6th, and 7th in relative output. Among the top 10 countries in absolute output, the UK is doing best, with a relative output ranking of 9th, and is followed by Canada in 11th place. It must be pointed out that with the exception of the UK, none of the top 10 countries in relative output have an average annual GDP exceeding USD$550 billion (at PPP) over the period. Canada's GDP is more than 1.5 times higher than that of the country with the next highest GDP among the top 10 in relative output (with the exception of the UK). Considering that the higher the GDP, the harder it is for a country to maintain a high relative output, Canada is performing quite well in scientific production in biotechnology.

The SI provides an assessment of the intensity of research in a specific field in a country relative to the intensity of research in the same field at the world level; a score above 1 means that a country is specialized in the research area relative to the world. Over the five-year period, the Republic of Korea and Japan were the most specialized, with, respectively, 38% and 31% more of their papers in the field of biotechnology than the world average (Table I). Denmark, Portugal, and Austria follow in 3rd, 4th, and 5th, with at least 20% more of their papers in the field of biotechnology than the world average. The US, Canada, France, and Spain are only slightly specialized having, respectively, only 2%, 1%, 1% and 1% more of their papers in the field of biotechnology than the world average.

The ARC is an indicator of the scientific impact of papers produced by a country in biotechnology. The leading countries in scientific impact are Switzerland, the US, Denmark, Belgium, and the Netherlands, with ARC scores ranging from 1.36 to 1.23 (Table I). Canada and the UK follow closely in 6th and 7th place with ARCs of, respectively, 1.21 and 1.20. It should be noted that the more papers a country produces, the harder it is for it to maintain a high ARC, and Canada, the US, and the UK are the only countries in the top 10 in absolute output to also rank in the top 10 for scientific impact. Although the Republic of Korea and China performed very well in absolute production of biotechnology papers and exhibited strong growth over the 2000–2004 period, they rank last when it comes to the impact of their biotechnology publications.

Overall, Canada (ranked 8th) performed quite well in scientific output in biotechnology and on the same level as Japan in the multicriteria benchmarking. In 1st place is Switzerland, followed by Denmark in 2nd place, the Netherlands in 3rd place, Belgium and the US in 4th place, and Germany and Sweden in 6th place.

PART II INTELLECTUAL PROPERTY IN BIOTECHNOLOGY

2 Technological output at the international level

Indicators of a country's IP portfolio of active biotechnology patents are useful for assessing their potential to commercialize biotechnology inventions and the level of dissemination and impact of the inventions it owns. This section benchmarks countries based on their 2004 IP portfolio of active biotechnology patents to provide an up-to-date view of their respective capacities to achieve economic gains from biotechnology R&D.

In terms of IP ownership, the US is out in front with close to 70% of the world's active biotechnology patents in the USPTO in 2004 (about 46,000 patents, Table II), although as mentioned in the methods section, the use of the USPTO database creates a bias favouring the US. Therefore the data in this section is better suited for comparing other countries.

Table II Multicriteria ranking of selected countries' 2004 IP portfolios in biotechnology using the following indicators: Intellectual property (IP) ownership, IP per billion GDP, specialization index (SI), and relative average citations (RAC)

Country	IP ownership		IP per billion GDP (USD PPP)		SI		RAC		Multicriteria ranking
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	
Denmark	886	8	5.14	1	5.61	1	0.90	4	1
United States	46,218	1	3.94	2	1.26	13	1.13	1	2
Netherlands	1,036	7	1.95	6	2.05	5	0.86	6	3
Canada	2,001	5	1.97	5	1.64	8	0.84	10	4
United Kingdom	2,089	4	1.11	11	1.91	6	0.86	7	4
Sweden	602	11	2.20	4	1.00	16	0.88	5	6
Switzerland	829	9	3.29	3	1.24	15	0.84	11	7
Australia	664	10	1.09	12	2.48	3	0.57	16	8
Japan	5,361	2	1.40	8	0.35	22	0.68	12	9
Norway	126	17	0.71	16	1.46	9	1.01	2	9
Belgium	422	13	1.31	9	2.30	4	0.54	19	11
Austria	195	16	0.75	15	1.32	12	0.93	3	12
Germany	2,875	3	1.22	10	0.74	20	0.66	14	13
Finland	273	15	1.71	7	0.84	17	0.84	9	14
France	1,868	6	1.02	13	1.24	14	0.60	15	14
New Zealand	96	19	0.98	14	2.60	2	0.40	22	16
Ireland	65	21	0.44	17	1.67	7	0.57	17	17
China	72	20	0.01	22	1.40	11	0.67	13	18
Spain	104	18	0.10	20	1.45	10	0.56	18	18
South Africa	27	22	0.05	21	0.75	18	0.86	8	20
Italy	437	12	0.27	19	0.72	21	0.48	21	21
Republic of Korea	340	14	0.34	18	0.27	23	0.50	20	22
Portugal	2	23	0.01	23	0.74	19	0.00	23	23
World	**67,106**		**1.19**		**1.00**		**1.00**		

Source: Compiled by Science-Metrix from USPTO database and WorldData Annual Time Series (The Economist Intelligence Unit)

Japan and Germany ranked 2nd and 3rd, with approximately 5,400 and 3,000 patents, respectively. Canada, with about 2,000 patents (about 2.5 times less than Japan), ranked 5th among selected countries, close behind the UK, which ranked 4th. Canada is followed by France (6th place), the Netherlands (7th place), Denmark (8th place), Switzerland (9th place), and Australia (10th place).

IP ownership of active biotechnology patents per billion GDP avoids bias due to differences in the scale of countries' economies. As in the case of scientific output, larger countries with high absolute IP ownership (e.g. Japan, Germany, and the UK) are being overtaken by smaller countries with low absolute IP ownership when taking account of each country's GDP (Table II). The only exception is the US which ranks 1st and 2nd in absolute and relative IP ownership, but again, the use of the USPTO database creates a bias in its favour. Canada retains its 5th-place ranking.

The SI is an indicator of the intensity of patenting in a specific field in a country relative to intensity of patenting in the same field in the world; a score above 1 means that a country is specialized in the field, in this case biotechnology, relative to the world. Highly specialized countries for patenting in biotechnology, with a proportion of their IP in the field of biotechnology more than twice that of the world average, include Denmark in 1st place, New Zealand in 2nd place, Australia in 3rd place, Belgium in 4th place, and the Netherlands in 5th place (Table II). The UK (6th place), Ireland (7th place), and Canada (8th place) follow, being the only other countries with at least 50% more of their IP in the field of biotechnology than the world average. Other countries specialized in biotechnology include Spain, New Zealand, China, Austria, the US, France, and Switzerland.

The RAC is an indicator of the number of times patents owned by a country are cited relative to the world average and can be used as a proxy for the technological impact of patents owned by a country in biotechnology; a score above 1 indicates that biotechnology patents owned by a country are cited more often than biotechnology patents on average. There are only two of the selected countries with a technological impact above the world average, namely the US in 1st place and Norway in 2nd place (Table II). A likely explanation for why most countries' technological impact is below the world average is that the average citation of patents owned by the US is greater than that of patents owned by other countries in the selection. Because the US owns close to 70% of the world's active biotechnology patents in the USPTO in 2004, US patents move the world average citation towards its own average citation level. Canada is 10th for this indicator.

Canada is clearly among the world's leaders with respect to its 2004 IP portfolio of active biotechnology patents. Indeed, Canada, along with Denmark and the Netherlands, ranks in the top 10 for all four indicators and ranks 4th, on a par with the UK, in the multicriteria benchmarking (Table II).

PART III FIRMS, WORKFORCE AND FINANCIAL FLOWS

3 Biotechnology firms

The number of biotechnology firms in a country indicates the extent to which biotechnology-related knowledge is diffused in that country (OECD, 2005). It has been found that biotechnology firms cannot function in autarky and are highly dependent on external institutions and other firms (Mangematin *et al.*, 2003). Moreover, since biotechnology firms are often spin-offs or start-ups from research institutions (Niosi and Bas, 2003), they tend to create links with universities, governments, and industries. Because the development of biotechnology firms is one of the main goals of most innovative policies in biotechnology, and because biotechnology firms are known to create links between the private sector and universities (which are likely to stimulate research) and the development of new products (Mangematin *et al.*, 2003), biotechnology firms are an important indicator of research activity and the commercialization of research in a country.

With close to 35% (1,830 firms) of the world's known biotechnology firms in 2003, the US leads in terms of commercialization capacity of biotechnology research among selected countries for which data on biotechnology firms were available (Figure 2).

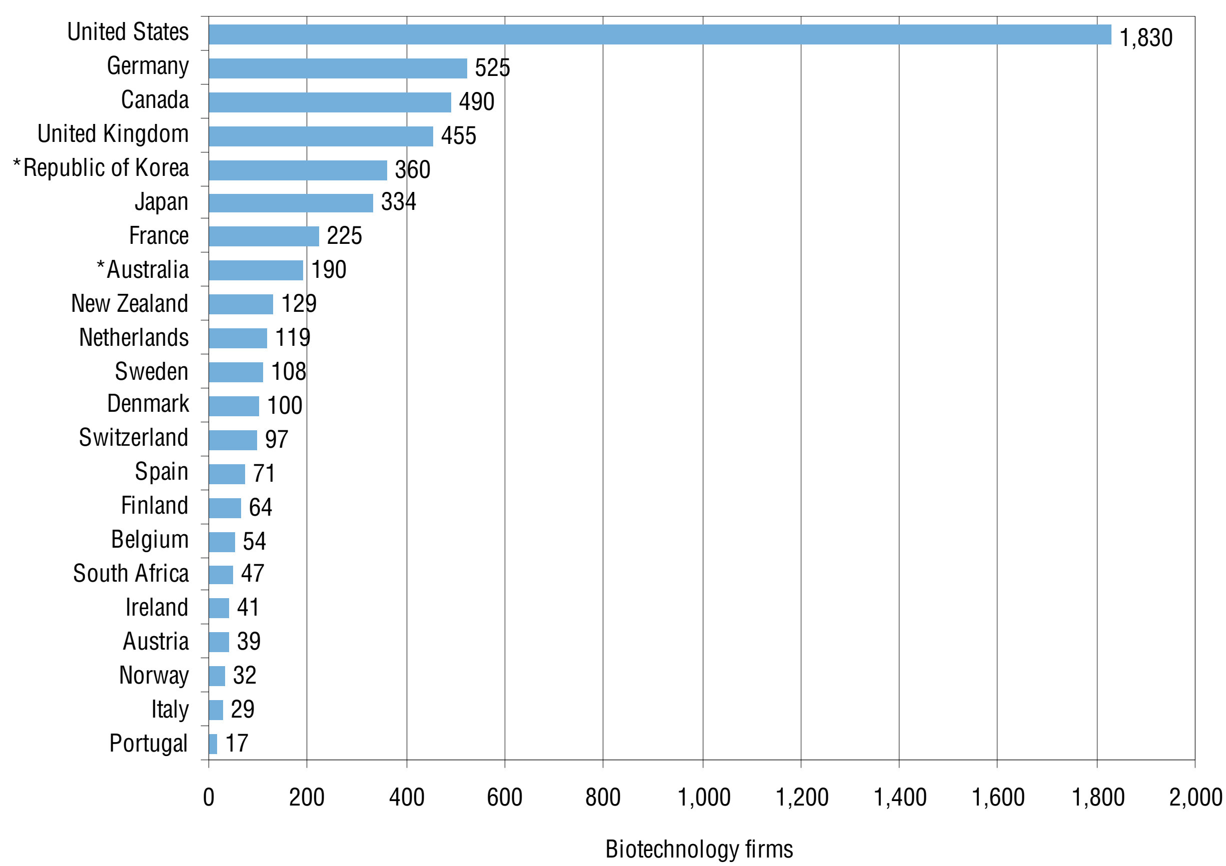

Figure 2 Number of biotechnology firms in selected countries, 2003

Note: * = data for 2001. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources)

With a share of 9% (490 firms) of the world's biotechnology firms, Canada ranks 3rd behind Germany, which has nearly 10% (525 firms) of the world's biotechnology firms. Thus, Canada can be considered a strong player in the commercialization of biotechnology research. The UK follows, with 455 biotechnology firms. The Republic of Korea ranks 5th based on the number of biotechnology firms in 2001. Due to the fact that the Republic of Korea's scientific output has grown considerably in the past five years, with an average annual growth of biotechnology papers of 15%, it is likely that it had more biotechnology firms in 2003 than in 2001 and could, if it has not already, soon outrank some of its nearest competitors (i.e., the UK, Canada, and Germany). Japan ranks 6th, but its number of biotechnology firms could be underestimated in comparison to other countries because the definition of biotechnology firms used for that country—"bioventure"—is very restrictive. It should be noted that this comparison aims to give an approximate positioning of countries internationally because the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods). The European countries taken together have about 2,000 biotechnology firms, contributing about 35% of the world's biotechnology firms.

Figure 3 shows the number of biotechnology firms of countries relative to their GDP. As for the absolute number of firms, Canada ranks 3rd, close behind Denmark, with 0.5 biotechnology firms per billion GDP. Ranking 9th in absolute number of biotechnology firms, New Zealand leads in relative terms and is the only country with more than one biotechnology firm per billion GDP. Among selected countries, New Zealand has the lowest GDP—less than two-thirds that of any other country analyzed. In fact, among the top 10 countries ranked for GDP, Canada leads in relative number of firms and is followed closely by the Republic of Korea, which ranks 4th for number of biotechnology firms and is also among the top 10 in terms of GDP, just behind Canada (the number of biotechnology firms per billion GDP in the Republic of Korea is based on 2001 data). It is likely that the absolute number of the Republic of Korea's biotechnology firms per billion GDP increased in 2003 because the average annual growth of its GDP in the past five years has been 7%, compared with an average annual growth of biotechnology papers of 15% over the same period. Thus, it is likely that the Republic of Korea has surpassed Canada for relative number of firms. Smaller countries with low GDP, such as Finland, Sweden, Switzerland, Australia, and Ireland, ranked 5th, 6th, 7th, 8th, and 9th, respectively. Larger countries with high GDP, such as the UK, Germany, the US, France, and Japan, did not perform as well in relative terms, ranking 10th, 11th, 15th, 17th, and 19th, respectively.

Ranking 3rd with respect to both absolute and relative number of biotechnology firms (Figure 2 and Figure 3), Canada has an environment favourable to the commercialization of biotechnology research, which is clearly a key aspect of its national biotechnology innovation system. Canada possesses many innovative biotechnology firms that are likely to be part of networks involving academia and governments as well as provide access and enable dissemination of new biotechnology knowledge that will promote innovation in biotechnology.

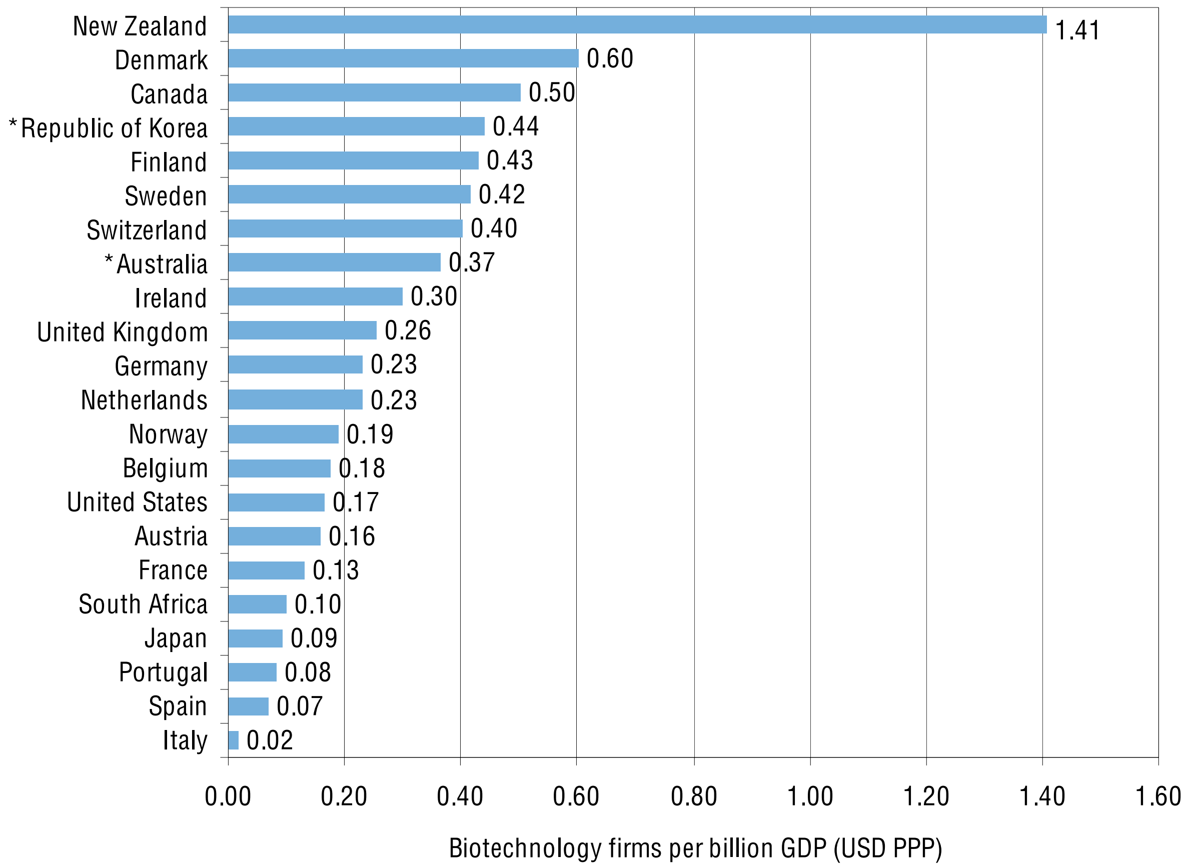

Figure 3 Number of biotechnology firms per billion GDP in selected countries, 2003

Note: * = data for 2001. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources) and WorldData Annual Time Series (The Economist Intelligence Unit)

4 Biotechnology workforce

The number of biotechnology employees in a country's BES is an indicator of the level of potential for commercialization of research (OECD, 2005). Relative to a country's total labour force, the number of biotechnology BES employees provides insight into the importance of biotechnology in the BES of the country. The R&D workforce is another factor that is likely to impact on the development of biotechnology; research staff is often more specialized than production staff, making this a good indicator of the workforce specialization in the field (Lee *et al.*, 2005). Moreover, employees have been described as the main vehicle for technology transfer (Hsu *et al.*, 2005). Thus, they play an important role in the production and dissemination of biotechnology knowledge. The biotechnology workforce is described in Section 4.1 ("Total biotechnology workforce") and Section 4.2 ("Biotechnology R&D workforce").

4.1 Total biotechnology workforce

Canada ranks 5th for BES biotechnology workforce among selected countries for which data were available, with close to 12,000 employees equalling about 4% of the world's reported biotechnology BES employees in 2003 (Figure 4).

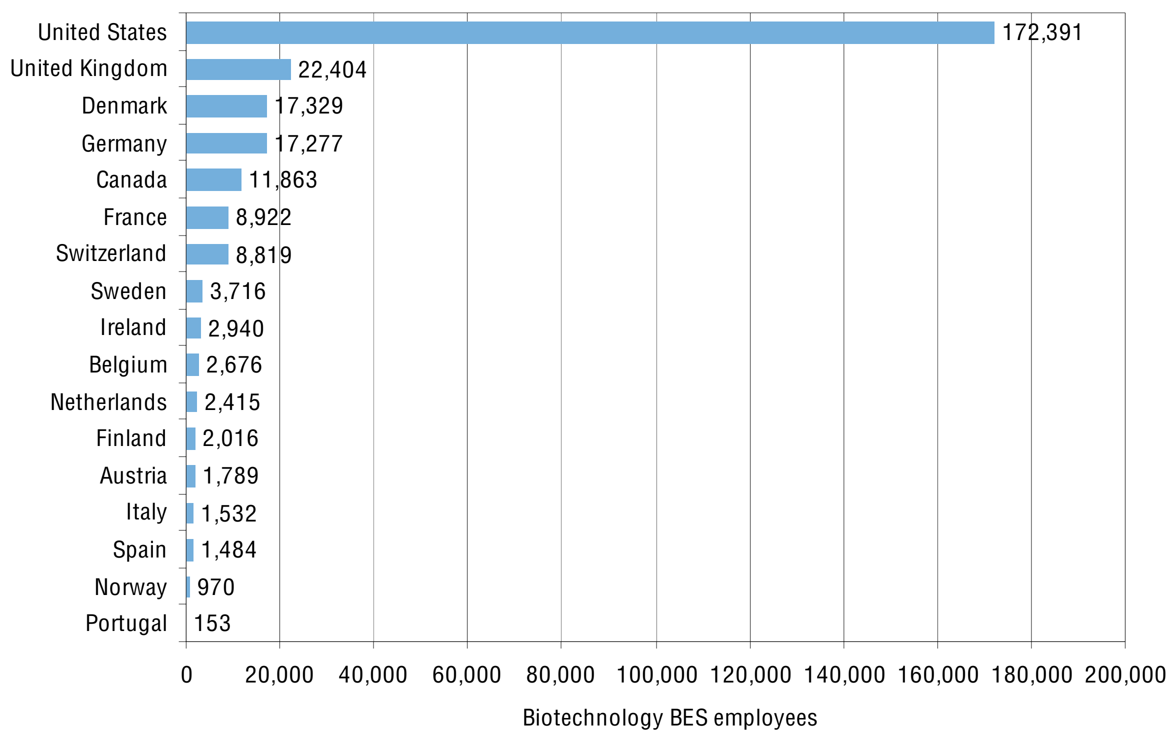

Figure 4 Number of biotechnology employees in the Business Enterprise Sector (BES) in selected countries, 2003

Note: This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

For number of biotechnology firms, the US leads with a share of about 62% (172,391 employees) of the world's reported biotechnology employees in the BES in 2003. The UK follows in 2nd place, with about 22,000 employees, 8% of the world's biotechnology BES employees. Denmark (3rd place) and Germany (4th place) are nearly equivalent, with, respectively, 17,329 and 17,277 biotechnology BES employees (around 6% of the world's total). France (6th place) and Switzerland (7th place) follow Canada, each with about 9,000 employees (approximately 3% of the world's reported biotechnology BES employees). Thus, Canada has a relatively high capacity for producing and commercializing biotechnology research. However, Germany, Denmark, the UK, and the US have a greater capacity to perform and commercialize biotechnology research as a result of the size of their biotechnology workforce in the BES.

In contrast to number of biotechnology employees in the BES, Canada does not perform as well in terms of biotechnology employees per thousand labour forces, ranking 8th out of the 17 countries for which data were available (Figure 5).

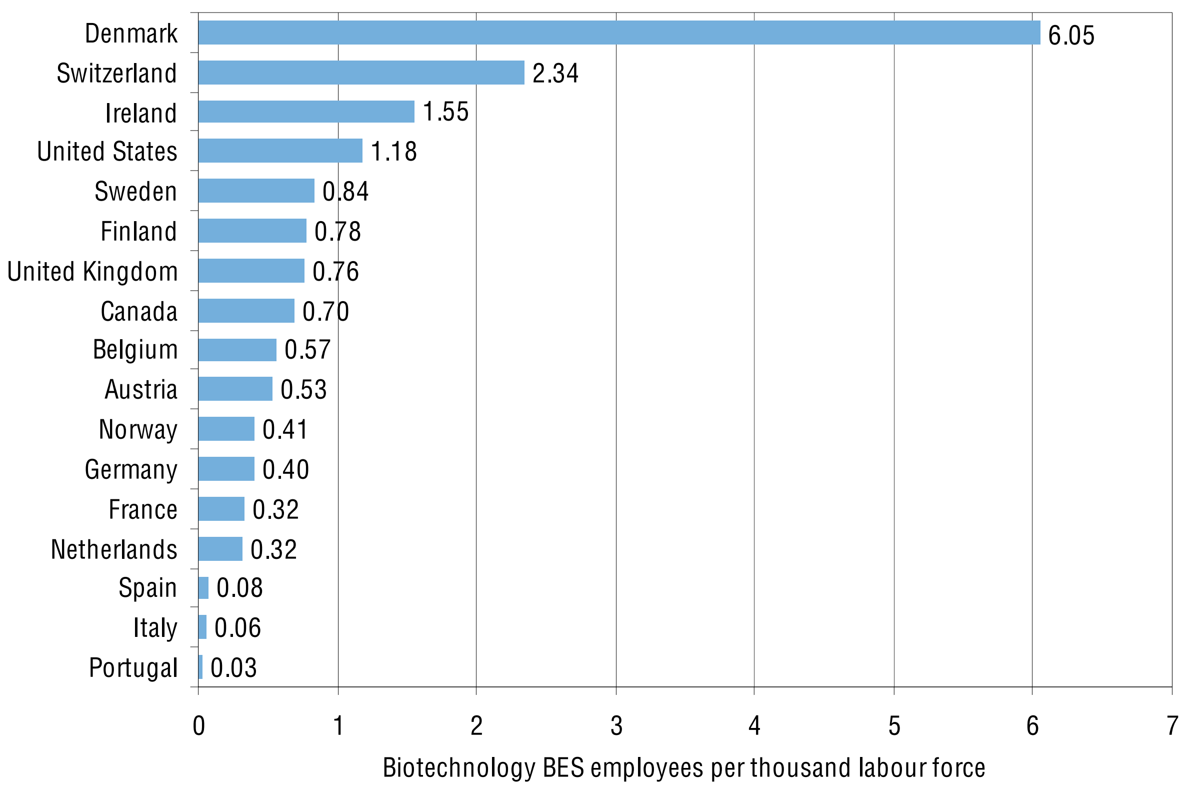

Figure 5 Biotechnology employees per thousand labour force in the BES in selected countries, 2003

Note: This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources) and WorldData Annual Time Series (The Economist Intelligence Unit).

In fact, Canada has only 0.7 biotechnology employees in the BES per thousand labour force, compared with 6.05 biotechnology BES employees per thousand labourers in Denmark, 2.34 in Switzerland, 1.55 in Ireland, and 1.18 in the US. Thus, the importance of biotechnology in the BES in Canada is lower than in these countries. Although Canada ranks 8th, it is not far behind Sweden, Finland, and the UK.

4.2 Biotechnology R&D workforce

The total number of biotechnology BES R&D employees indicates the biotechnology research and commercialization capacity and the impact of its workforce on future developments in the field of biotechnology, while the proportion of biotechnology BES R&D employees among total biotechnology BES employees indicates the specialization of its workforce. Once again, the US leads with nearly 64% of the world's reported biotechnology R&D employees in 2003 (Figure 6), although it ranks only 8th out of 11 countries in terms of specialization, with 43% of its biotechnology workforce being allocated R&D responsibilities (Figure 7).

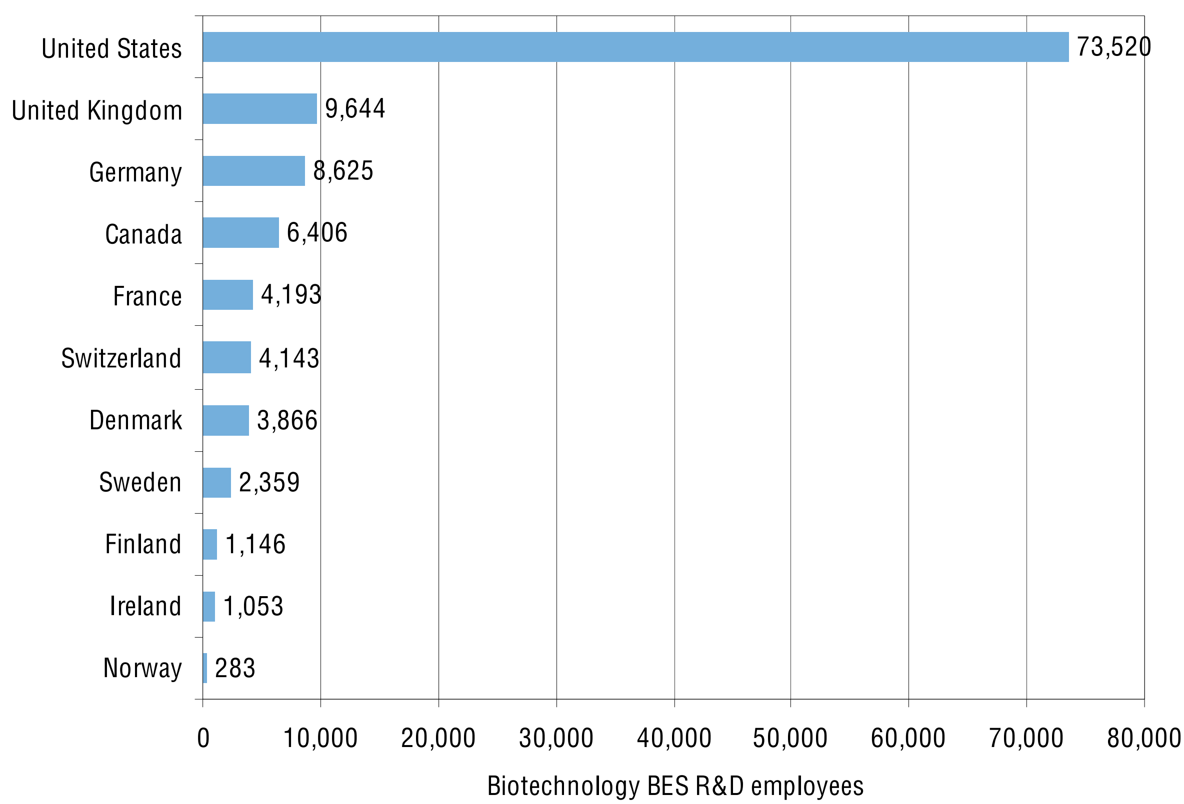

Figure 6 Biotechnology R&D employees in the BES in selected countries, 2003

Note: This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

The UK ranks 2nd for number of biotechnology BES R&D employees (Figure 6), but, like the US, it places much lower for proportion of biotechnology BES R&D employees among total biotechnology BES employees, ranking 7th (Figure 7). Both Germany and Canada perform well on the two indicators, ranking 3rd and 4th, respectively, for number of biotechnology BES R&D employees and 4th and 3rd, respectively, for proportion of R&D employees in the BES in biotechnology (Figure 6 and Figure 7). In fact, among the selected countries for which data were available, Germany, Canada, Finland, and Sweden are the only countries with at least 50% of their biotechnology workforce allocated to R&D; Sweden leads with 63%, followed by Finland (57%), Canada (54%), and Germany (50%). All of these countries, therefore, have a highly specialized biotechnology workforce. However, Sweden and Finland do not perform as well in absolute number of biotechnology BES R&D employees, ranking 8th and 9th, respectively, with no greater than one-third of the number of R&D employees in the BES in biotechnology in Canada. Although Germany ranks just before Canada in R&D workforce in the biotechnology BES, it has substantially more employees than Canada (8,625 German employees vs. 6,406 Canadian employees). Therefore, Germany is in fact closer to the UK, which ranks 2nd, with 9,644 biotechnology BES R&D employees. France and Switzerland are in 5th and 6th place, respectively, on both indicators.

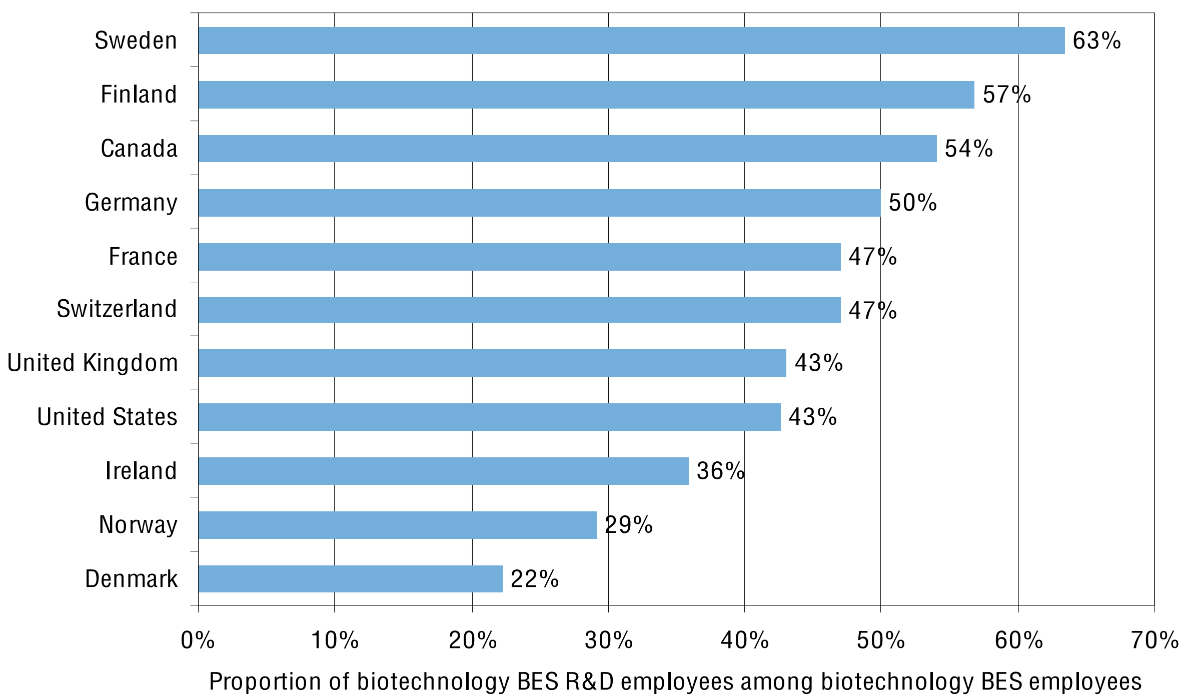

Figure 7 Proportion of biotechnology R&D employees among biotechnology employees in the BES in selected countries, 2003

Note: This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

When the biotechnology workforce is analyzed globally among selected countries for which data were available for all four indicators, the US remains in its dominant position and is followed by the UK, Canada, Switzerland and Germany (which ranked equivalently), Denmark, Sweden, and France and Finland (which also ranked equivalently). Thus, the US is clearly the country with the strongest innovation and production capacity among the selected countries and is, therefore, the most likely to lead future developments in the field of biotechnology. Canada has a strong capacity for disseminating biotechnology knowledge, ranking among the leaders for biotechnology workforce. Its high number of specialized workers likely has a positive impact on its capacity to stimulate economic, social, and environmental developments (OECD, 2005).

5 Biotechnology financial inputs

The main sources of financial contribution to biotechnology at the national level are R&D expenditures and venture capital (VC). Because R&D expenditures play an essential role in advancing basic knowledge, and VC is critical for promoting commercialization of research, both aspects are covered in the scoreboard (Section 5.1 and 5.2).

5.1 R&D expenditures

R&D expenditures for biotechnology provide basic information about the global biotechnology research capacity of a country (OECD, 2005). R&D expenditures thus indicate the extent to which a country can preserve and develop its biotechnology field, the impact on its national system of biotechnology innovation, and the stimuli they provide for research, resulting in the creation of national wealth in three domains: economic growth, social development, and environmental development (Furman *et al.*, 2002).

5.1.1 Trends in Canadian biotechnology R&D expenditures in the business enterprise and federal government sectors

Altogether, the business enterprise and federal government sectors spent nearly US$2 billion PPP on biotechnology R&D in 2003 in Canada; BES biotechnology R&D expenditure (US$1,194 million at PPP) was twice that of the federal government sector (US$576 million at PPP). In recent years, biotechnology R&D expenditures have experienced significant growth, with yearly average annual growth of about 20% in both sectors (estimated by exponential regressions). In fact, BES R&D expenditures on biotechnology increased from US$397 million at PPP in 1997 to US$1,194 million at PPP in 2003 and from US$248 million at PPP in 1998 to US$576 million at PPP in 2003 in the government sector (Figure 8 and Figure 9).

This has translated into considerable growth in the share of biotechnology BES R&D expenditure in total business enterprise expenditure on R&D (BERD) (11% yearly average annual growth estimated by exponential regression) and of the share of federal government expenditures on biotechnology R&D in total federal government expenditures on R&D (8% yearly average annual growth estimated by exponential regression). From 1997 to 2003, the portion of BERD allocated to biotechnology increased from 7% to 13%, while the portion of total federal government expenditures on R&D increased from 11% in 1998 to 16% in 2003 (Figure 8 and Figure 9). Thus, the importance of biotechnology in the Canadian economy has increased significantly over the years and appears to be a key component of the Canadian innovation system.

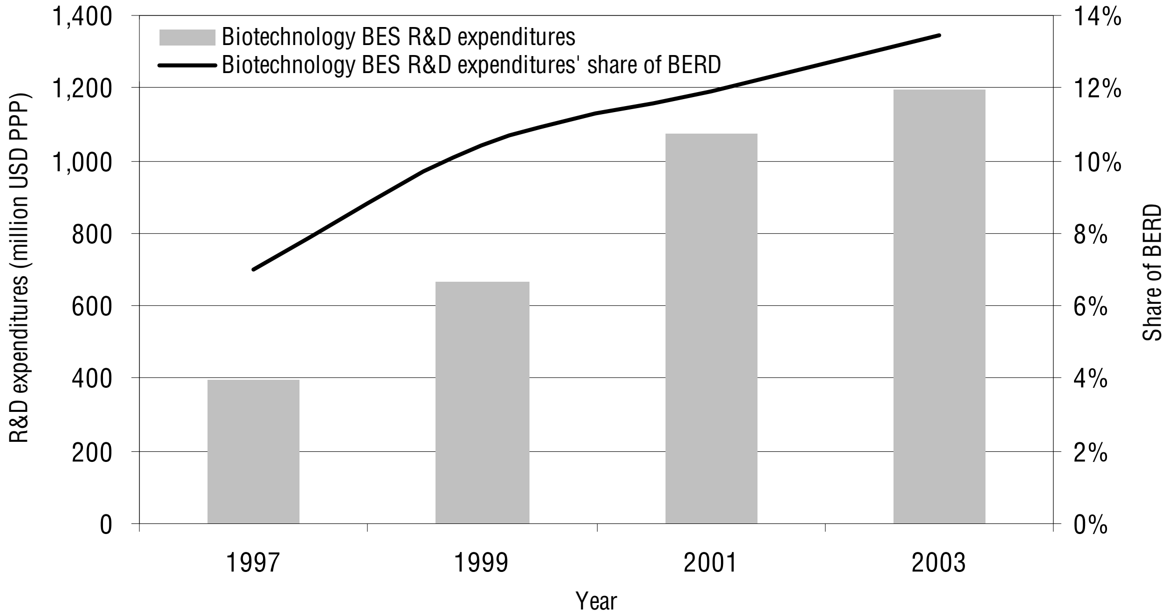

Figure 8 Canada's biotechnology BES R&D expenditures in million US$ PPP and as a percentage of Canada's business enterprise expenditures on R&D (BERD), 1997–2003

Source: Statistics Canada

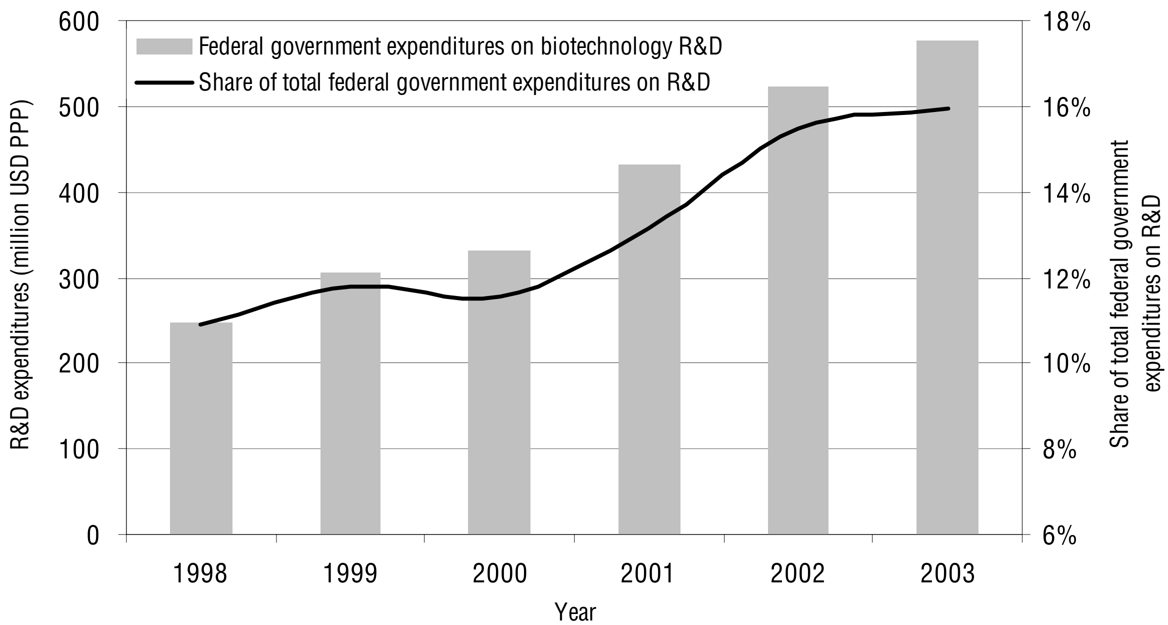

Figure 9 Federal government expenditures on biotechnology R&D in million US$ PPP and as a percentage of total federal government expenditures on R&D in Canada, 1998–2003

Source: Statistics Canada

5.1.2 International business enterprise sector

Biotechnology R&D expenditures in the BES sector are a major part of a country's total biotechnology R&D expenditures. Figure 10 presents BES R&D expenditures for biotechnology in 2003 in the selected countries for which data were available. The US outperforms all countries, allocating nine times more to R&D for biotechnology in the BES than its nearest competitors; R&D expenditures were close to US$17 billion at PPP in the US, while they were slightly less than US$2 billion at PPP in the UK. Germany follows in 3rd place, with R&D expenditures of about US$1.4 billion at PPP, and is followed closely by Canada, with R&D expenditures of about US$1.2 billion at PPP. Thus, Canada is a world leader for BES R&D expenditure on biotechnology, ranking 4th among selected countries for which data were available. Clearly, Canada has great potential for preserving and further developing its national biotechnology innovation system. Denmark is also an important player, ranking just below Canada.

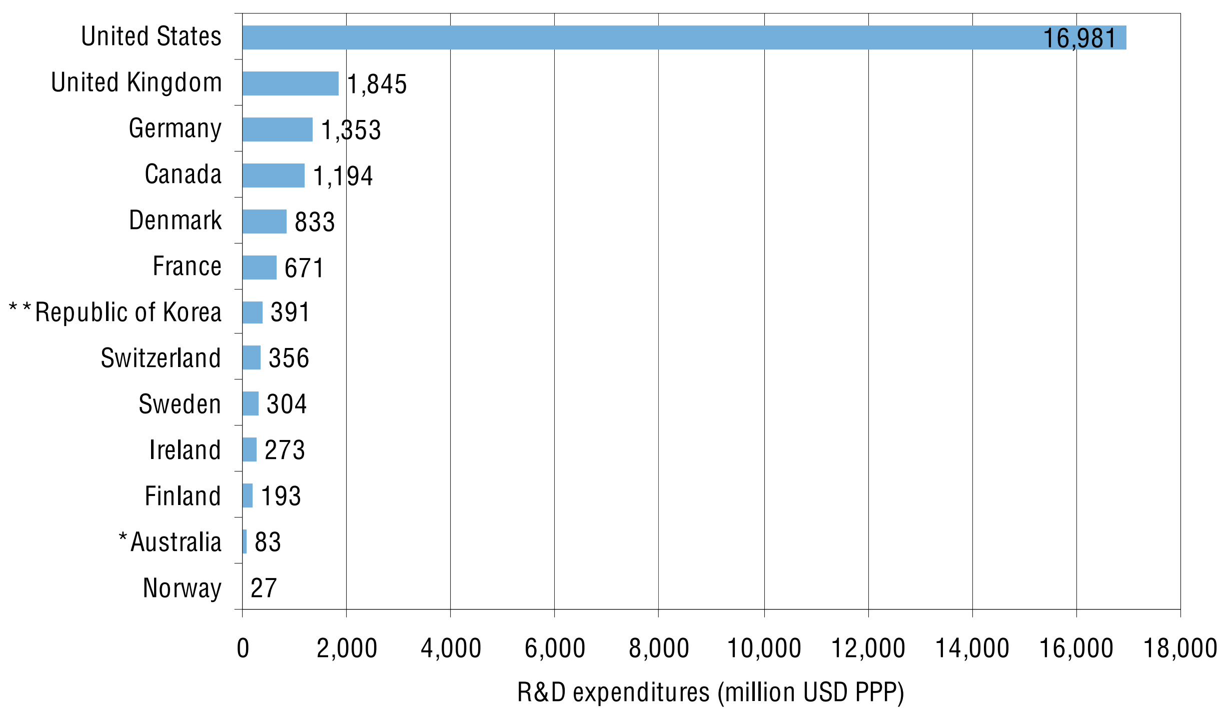

Figure 10 Business Enterprise Sector (BES) R&D expenditures on biotechnology in selected countries, 2003

Note: * = data for 2001; ** = data for 2004. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

When looking at countries' BERD, Denmark, which was ranked 5th for BES R&D expenditures for biotechnology, leads with 33% of its BERD allocated to biotechnology (Figure 11). Therefore, the country is a leader in both absolute and relative investment in biotechnology and clearly has biotechnology at the heart of its national biotechnology innovation system. Although Ireland is not performing particularly well in BES R&D expenditures for biotechnology, ranking 10th out of 13 countries for which data were available, it follows Denmark with respect to importance given to biotechnology, with 32% of its BERD in that field. Canada ranks 3rd in level of importance given to biotechnology, which was allocated about 11% of its BERD. The UK and the US follow in 3rd and 4th places with, respectively, 10% and 9% of BERD allocated to biotechnology. Germany is ranked 9th, with 4% of its BERD allocated to biotechnology.

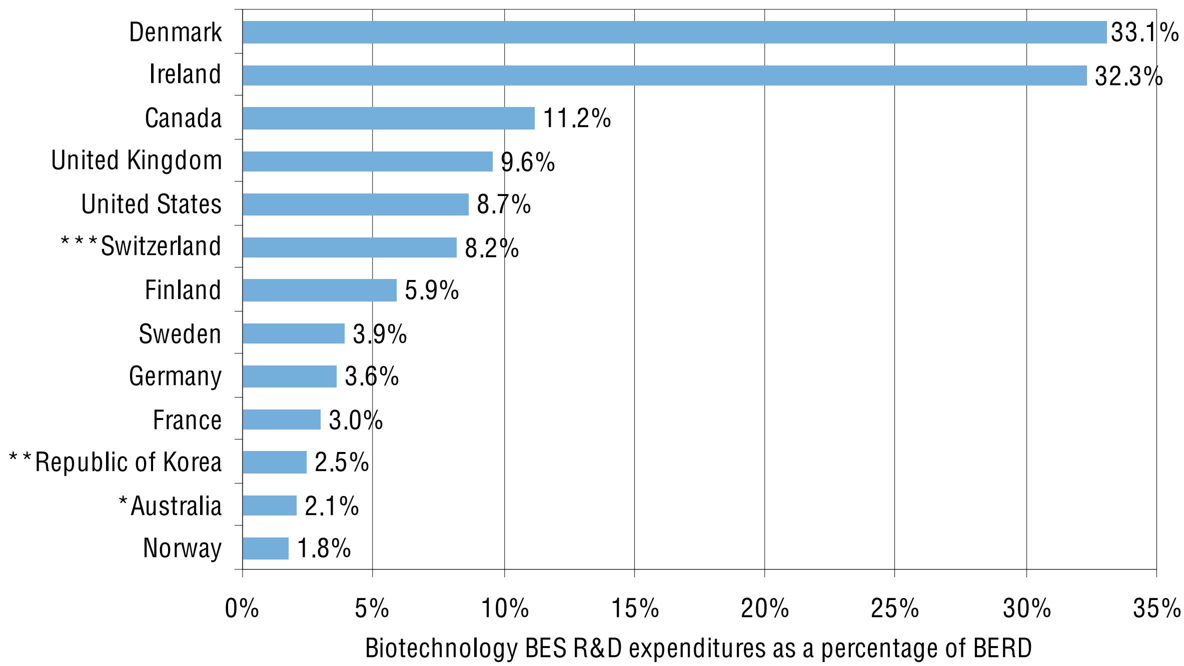

Figure 11 Business Enterprise Sector (BES) R&D expenditures on biotechnology in 2003 as a percentage of BERD in 2001 in selected countries

Notes: * = 2001 data for biotechnology BES R&D expenditures; ** = 2004 data for biotechnology BES R&D expenditures; *** = 2000 data for BERD; 2003 data are presented relative to 2001 data since 2003 data on BERD were not available for most countries. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources) and from SourceOECD

Figure 10 and Figure 11 illustrate Canada's international strength as a biotechnology research leader in the BES. Given the importance of R&D in the national system of innovation and its impact on national wealth, Canada is likely to be positioned as a world leader in the biotechnology sector.

5.2 Venture capital

The level of VC in biotechnology is an indicator of research possibilities and the capacity to commercialize research (OECD, 2005). It has been shown that access to VC is positively correlated with fast development and success in the biotechnology research sector (Niosi, 2003; Bas, 2004). Thus, VC is an indicator of the extent to which a country actually excels at producing research in order to attract VC investors and the extent to which a country possesses VC to guarantee future development of its biotechnology field.

The US leads for amount of VC raised for biotechnology in 2003, with slightly more than US$2 billion at PPP (Figure 12). It is followed by the Republic of Korea, which raised US$394 million at PPP. Canada is also a leader in terms of VC raised in 2003, ranking 4th, close behind Australia. Figure 5 shows that Canada raised US$300 million at PPP in VC while Australia raised US$304 million. Because Australia's data are for the year 2004, Canada might currently rank 3rd. The UK follows Canada in 5th place, with US$259 million at PPP. Germany comes next in 6th place and is followed by France in 7th place, Austria in 8th place, Sweden in 9th place, and Denmark in 10th place.

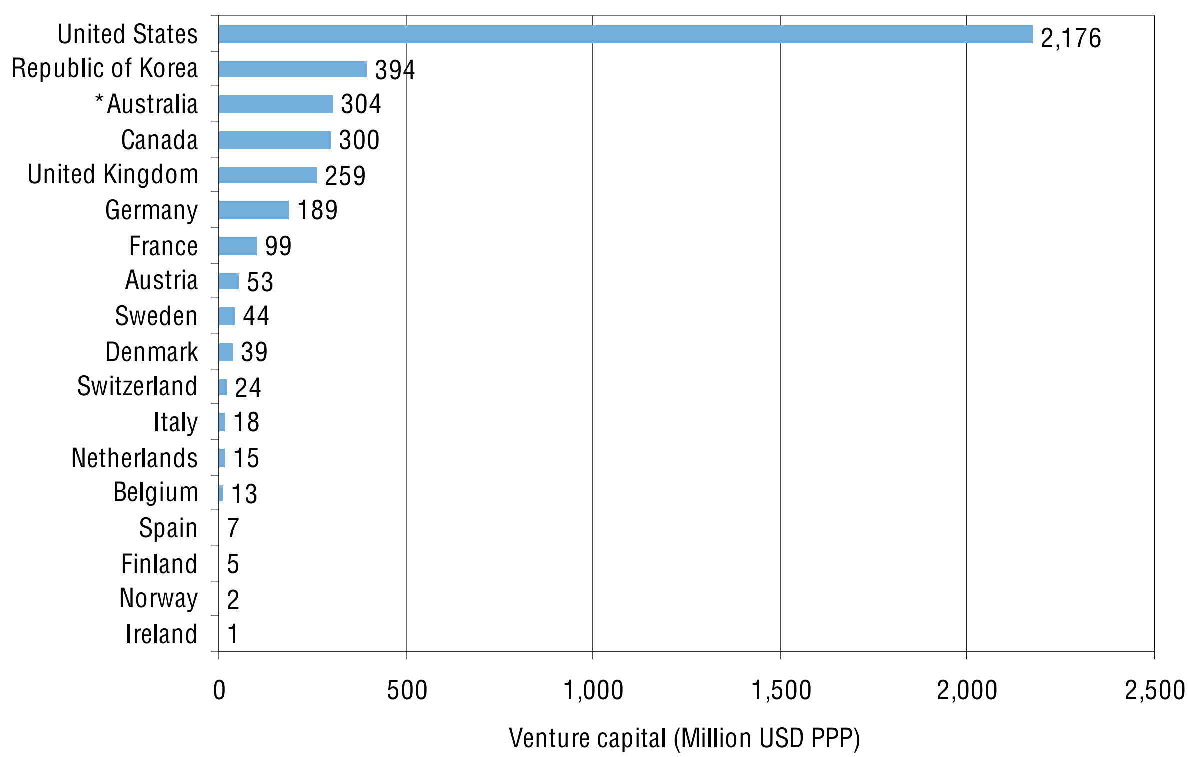

Figure 12 Biotechnology venture capital in selected countries, 2003

Note: * = data for 2004. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

Figure 13 shows biotechnology VC per million GDP in selected countries for 2003. The relative indicator allows for comparison of the extent to which a country is able to attract VC in biotechnology, while taking account of the size of each country's economy as both indicators are likely to be correlated. As was the case for absolute VC, Australia performs really well in relative VC, ranking 1st with about US$500 at PPP in biotechnology VC per million GDP. The Republic of Korea still ranks 2nd and is followed by Canada in 3rd place. Denmark and Austria are stronger in relative VC, ranking, respectively, 4th and 5th. Larger countries such as the US, the UK, and Germany perform less well in relative VC, ranking, respectively, 6th, 8th, and 10th.

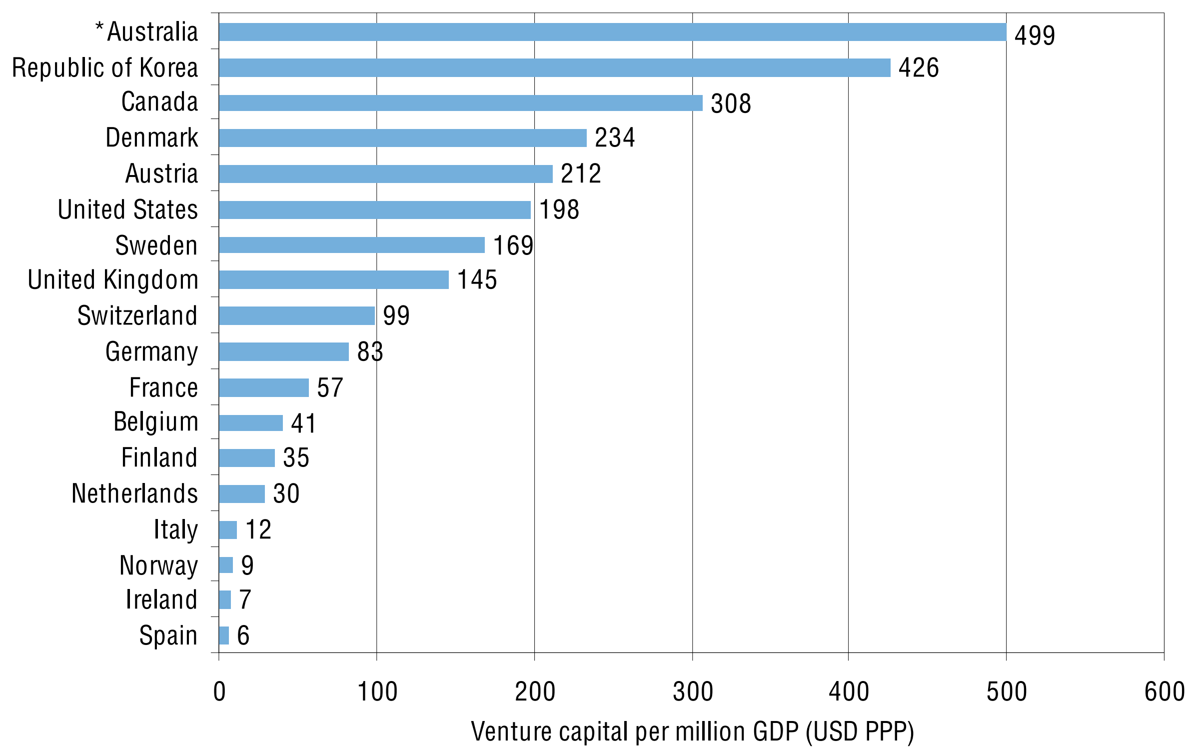

Figure 13 Biotechnology venture capital per million GDP (US$ PPP) in selected countries, 2003

Note: * = data for 2004. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources). and WorldData Annual Time Series (The Economist Intelligence Unit)

Canada is again among the leaders in biotechnology with respect to VC investment as measured by these indicators. In other words, Canada is able to attract more investment in biotechnology than many other countries, indicating that Canada excels in biotechnology research. Moreover, the fact that Canada attracts investors guarantees, to a certain extent, its future development in biotechnology. Thus, these data confirm that the conditions for success are present in Canada.

6 Biotechnology financial outputs

The present section covers the biotechnology market (Section 6.1) and revenues of biotechnology firms (Section 6.2).

6.1 Size of the local biotechnology market

The size of the local biotechnology market in different countries provides information on the economic demand for biotechnology products. Since investment usually occurs where demand is greatest, the size of the biotechnology market provides insight into where future investments in biotechnology are most likely to take place.

Together, the countries depicted in Figure 14 account for 90% of the world biotechnology market, which was estimated at some US$86.6 billion in 2003 (Datamonitor, 2004). Thus, these countries can be considered the most important worldwide. Among them, the US ranks first with a biotechnology market worth US$41 billion, a share of 47% of the world biotechnology market. Japan, with a market value of only US$13.3 billion, nevertheless ranks 2nd and accounts for 15% of the world biotechnology market. China with a biotechnology market of about US$5.1 billion and a world market share of approximately 6%, ranks 3rd. Canada ranks 4th with a value of US$4.4 billion, based solely on 2003 estimates. The UK, Germany, Belgium, and France rank, respectively, 5th, 6th, 7th, and 8th; the European countries together accounted for nearly 14% of the world biotechnology market in 2003. The Republic of Korea and Australia are last in the present country rankings.

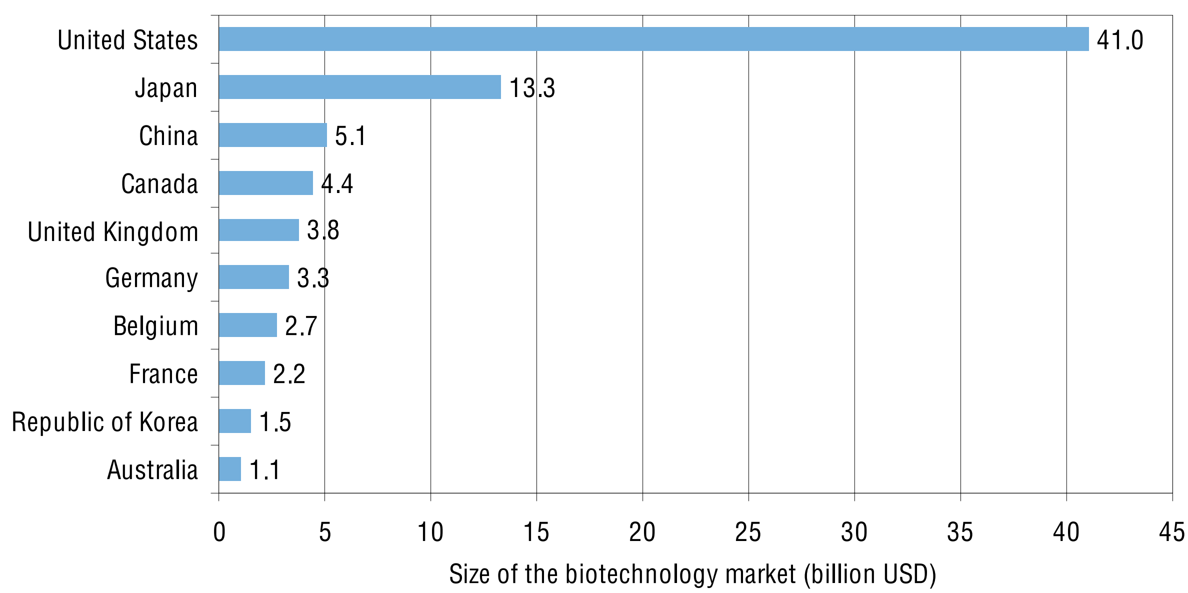

Figure 14 Size of the biotechnology market in selected countries, 2003
Source: Compiled by Science-Metrix from Datamonitor biotechnology reports

It should be noted that data from sources other than those drawn on for Figure 14 show India to be a significant contributor to the world biotechnology market; some sources rank India's biotechnology market 3rd among the selected countries (placing Canada in 5th place), with a value in 2001 estimated to be in the range of US$10.9 to US$18.7 billion (IMST, 2005; Chaturvedi, 2005). However, these data should be interpreted with a degree of caution as India's definition of biotechnology is broader than the definition proposed in the OECD's *2005 Framework for Biotechnology Statistics* (Chaturvedi, 2005). Hence, the data for India are inconsistent with the results presented here, and therefore that country was excluded from the present international comparison.

The average annual growth of local biotechnology markets in recent years (1999–2003) reveals where future demand for biotechnology products is most likely to come from, and therefore where new investments are most likely (Figure 16). According to Datamonitor (2005), the world biotechnology market experienced an average annual growth of 16% between 1999 and 2004. Among the selected countries, only four did better than the world average—namely Canada (in 1st place), the Republic of Korea (in 2nd place), China (in 3rd place), and Belgium (in 4th place). In fact, Canada's biotechnology market experienced an exceptionally high average annual growth of 41%, more than twice that of the world average and about 50% more than its nearest competitors. Canada's biotechnology market, the 4th in importance worldwide, tripled between 1999 and 2003, increasing from US$1.1 to US$4.4 billion. The US, which has the largest biotechnology market in the world, ranks 5th, with an average annual growth equal to that of the world. Australia is in 6th place, followed by France, Germany, the UK, and Japan.

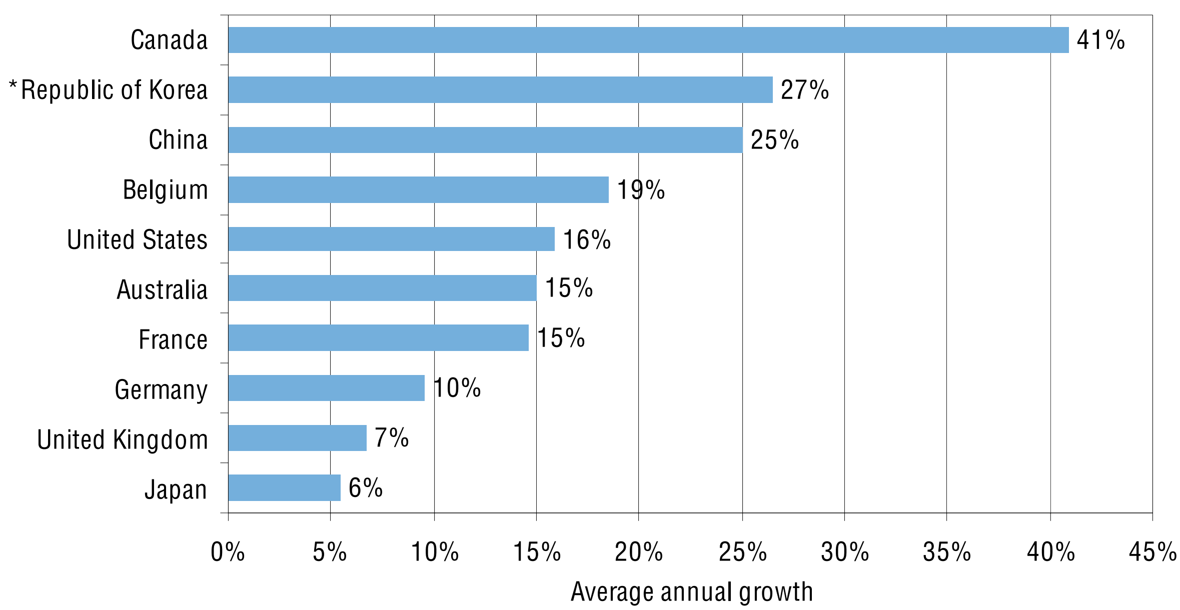

Figure 15 Average annual growth of the biotechnology market in selected countries, 1999–2003

Note: * = data for 2000–2004

Source: Compiled by Science-Metrix from Datamonitor biotechnology reports

6.2 Company revenues

Company biotechnology revenues indicate the levels of commercialization of biotechnology research, application or use of research results, and impact of research in a country (OECD, 2005). Thus, company biotechnology revenues provide information about the impact of biotechnology R&D on a country's economy.

Again, the US outperforms other countries, with biotechnology revenues of about US$43 billion at PPP, eight times higher than its nearest competitor, the UK, with biotechnology revenues of about US$5 billion at PPP (Figure 16). Denmark is important in terms of financial outputs, ranking 3rd with revenues of about US$4 billion at PPP. Germany and Canada, ranking 4th and 5th, respectively, are almost on a par, each with just over US$3 billion at PPP.

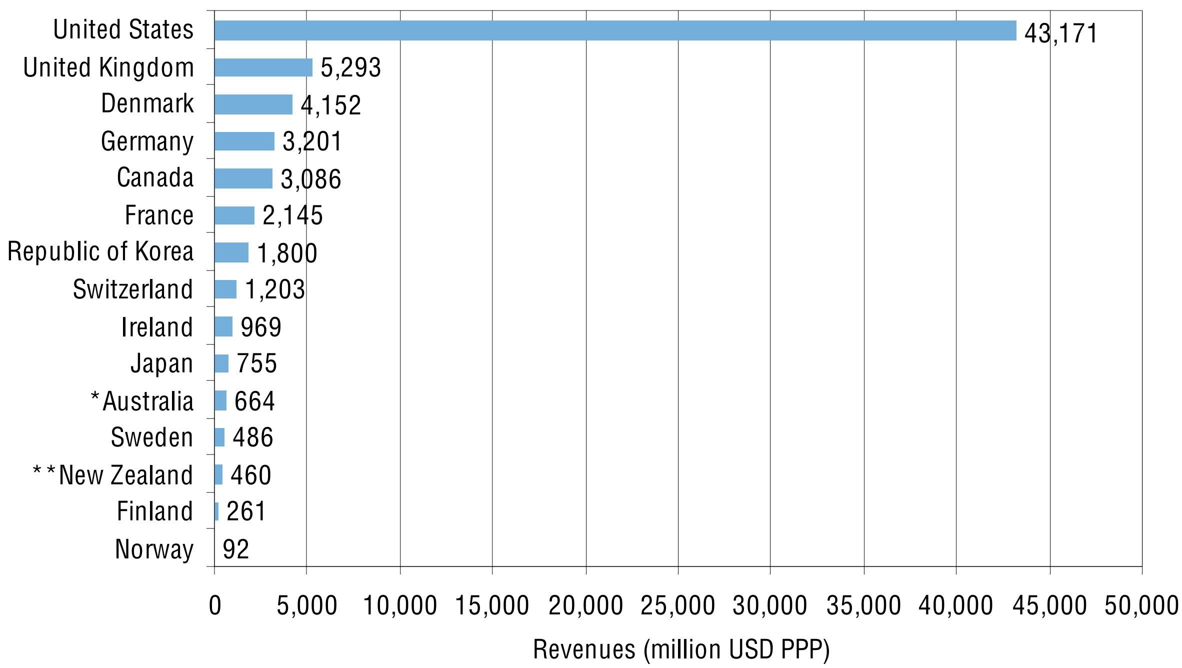

Figure 16 Biotechnology company revenues in selected countries, 2003

Note: * = Data for 2000; ** = Data for 2004. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

When company biotechnology revenues are presented relative to GDP, smaller countries outperform larger ones (e.g. the US, the UK, and Germany) in absolute revenues. Denmark is the clear leader, with revenues per million GDP of about US$25,000 at PPP, more than three times the revenues per million GDP of Ireland (about US$7,000 at PPP), which is in 2nd place (Figure 17). Switzerland and New Zealand are in 3rd and 4th places, respectively, with similar revenues per million GDP. The other countries with biotechnology revenues per million GDP above US$2,000 at PPP are the US in 5th place, Canada in 6th place, and the UK in 7th place. Canada is consistently among the leaders for all aspects of financial outputs of biotechnology.

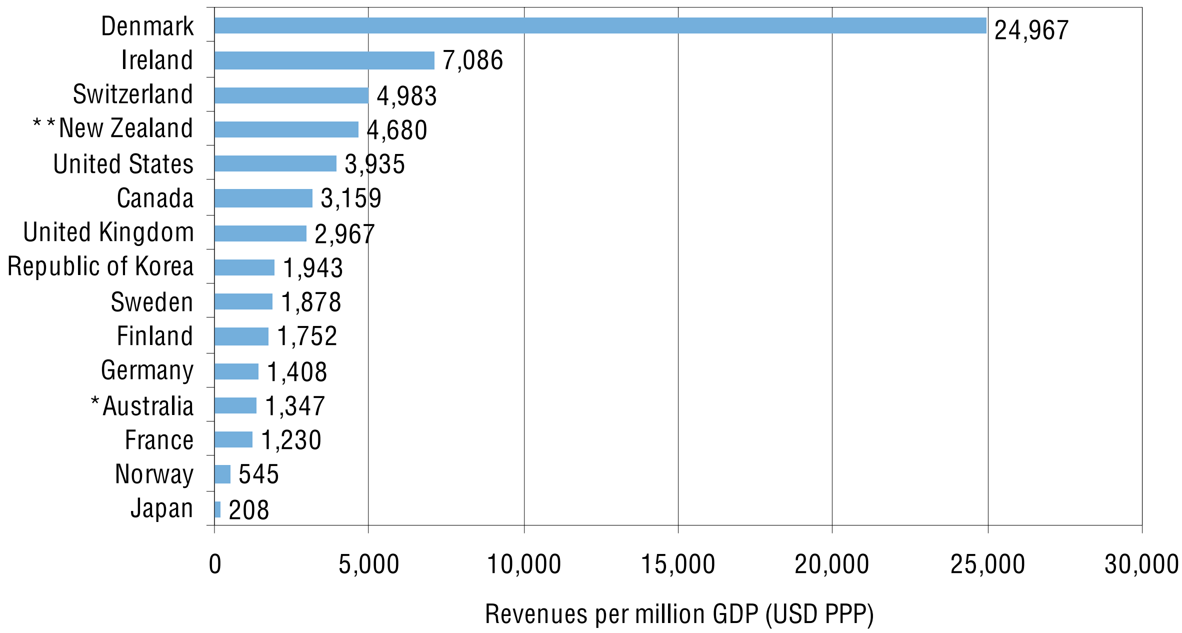

Figure 17 Biotechnology company revenues per million GDP in selected countries, 2003

Note: * = Data for 2000; ** = Data for 2004. This comparison aims to give an approximate positioning of countries internationally since the definition of biotechnology firms underlying the current data is not the same for all countries (see Methods).

Source: Compiled by Science-Metrix from international reports (see Appendix B for data sources).

PART IV MAIN FINDINGS

7 Canada's ranking in biotechnology

Overall, it can confidently be stated that, based on available data, Canada was among the world leaders in biotechnology in 2003. For the 22 indicators for which data were gathered, Canada ranks in the top five among selected countries for which data were available for 14 indicators (Table III). Canada stands out in terms of average annual growth of its biotechnology market, ranking 1st among selected countries. It ranked 3rd among selected countries for five indicators: absolute number of biotechnology firms; relative number of biotechnology firms; percentage of BES biotechnology employees allocated to R&D; percentage of BERD allocated to biotechnology; and relative amount of biotechnology VC. Canada ranks 4th with respect to the following indicators: number of biotechnology BES R&D employees; BES R&D expenditure on biotechnology; biotechnology VC; and size of the biotechnology market. Canada ranks 5th in terms of absolute and relative IP ownership, number of biotechnology BES employees, and biotechnology companies' revenues.

However, although Canada can be considered a world leader in biotechnology, it has some weaknesses, as denoted by its low ranking for 2 out of the 22 indicators assessed. These relate to Canada's scientific output and are based on the relative number of biotechnology papers produced by Canada and its specialization in biotechnology (Table III). Canada is also lagging somewhat with respect to the average relative citation of its patents (ranking 10th), the SI of its technological output (ranking 8th), and the number of biotechnology BES employees per thousand labour force (ranking 8th). Future efforts in the Canadian biotechnology field should focus on those aspects where Canada lags behind other countries. Other leaders in the field of biotechnology include the US, Denmark, the UK, Germany, Switzerland, Sweden, and France. Countries that are likely to become major biotechnology players in the near future include China and the Republic of Korea.

Table III Canada's ranking by biotechnology indicator among selected countries for which data were available

Indicator*/Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Scientific publications in biotechnology																							
Number of papers	US	JP	DE	UK	FR	CN	**CA**	IT	ES	KR	NL	AU	SE	CH	BE	DK	AT	FI	PT	NO	NZ	ZA	IE
Number of papers per billion GDP	CH	SE	DK	FI	NL	NZ	BE	AU	UK	AT	**CA**	DE	FR	JP	KR	NO	US	ES	IE	PT	IT	ZA	CN
Specialization index	KR	JP	DK	PT	AT	BE	CH	NL	SE	DE	IE	US	**CA**	FR	ES	CN	FI	AU	IT	ZA	UK	NZ	NO
Average of relative citations	CH	US	DK	BE	NL	**CA**	UK	NO	AT	DE	SE	FI	AU	FR	ES	IT	IE	NZ	JP	PT	ZA	KR	CN
Intellectual property in biotechnology																							
Intellectual property	US	JP	DE	UK	**CA**	FR	NL	DK	CH	AU	SE	IT	BE	KR	FI	AT	NO	ES	NZ	CN	IE	ZA	PT
Intellectual property per billion GDP	DK	US	CH	SE	**CA**	NL	FI	JP	BE	DE	UK	AU	FR	NZ	AT	NO	IE	KR	IT	ES	ZA	CN	PT
Specialization index	DK	NZ	AU	BE	NL	UK	IE	**CA**	NO	ES	CN	AT	US	FR	CH	SE	FI	ZA	PT	DE	IT	JP	KR
Relative average citation	US	NO	AT	DK	SE	NL	UK	ZA	FI	**CA**	CH	JP	CN	DE	FR	AU	IE	ES	BE	KR	IT	NZ	PT
Firms, workforce and financial flows																							
Biotechnology firms	US	DE	**CA**	UK	KR	JP	FR	AU	NZ	NL	SE	DK	CH	ES	FI	BE	ZA	IE	AT	NO	IT	PT	
Biotechnology firms per billion GDP	NZ	DK	**CA**	KR	FI	SE	CH	AU	IE	UK	DE	NL	NO	BE	US	AT	FR	ZA	JP	PT	ES	IT	
Biotechnology BES employees	US	UK	DK	DE	**CA**	FR	CH	SE	IE	BE	NL	FI	AT	IT	ES	NO	PT						
Biotechnology BES employees per thousand labour forces	DK	CH	IE	US	SE	FI	UK	**CA**	BE	AT	NO	DE	FR	NL	ES	IT	PT						
Biotechnology BES R&D employees	US	UK	DE	**CA**	FR	CH	DK	SE	FI	IE	NO												
BES R&D employees over BES employees in biotechnology	SE	FI	**CA**	DE	FR	CH	UK	US	IE	NO	DK												
Biotechnology BES R&D expenditures	US	UK	DE	**CA**	DK	FR	KR	CH	SE	IE	FI	AU	NO										
Biotechnology BES R&D expenditures over BERD	DK	IE	**CA**	UK	US	CH	FI	SE	DE	FR	KR	AU	NO										
Biotechnology venture capital	US	KR	AU	**CA**	UK	DE	FR	AT	SE	DK	CH	IT	NL	BE	ES	FI	NO	IE					
Biotechnology venture capital per million GDP	AU	KR	**CA**	DK	AT	US	SE	UK	CH	DE	FR	BE	FI	NL	IT	NO	IE	ES					
Size of the biotechnology market	US	JP	CN	**CA**	UK	DE	BE	FR	KR	AU													
Average annual growth of the biotechnology market	**CA**	KR	CN	BE	US	AU	FR	DE	UK	JP													
Company biotechnology revenues	US	UK	DK	DE	**CA**	FR	KR	CH	IE	JP	AU	SE	NZ	FI	NO								
Company biotechnology revenues per million GDP	DK	IE	CH	NZ	US	**CA**	UK	KR	SE	FI	DE	AU	FR	NO	JP								

Note: * Data were not available for all countries for all indicators; thus the rankings provided in the present scoreboard not reflect their positioning in the world, but within the group of countries for which data are presented. The coding of countries' names is based on the ISO 3166 codes.

Conclusion

A growing number of analysts, academic scholars, and policy makers see biotechnology as a major contributor to the future economic and social development of countries, and thus the measurement and evaluation of biotechnology activities have become increasingly important to governments and academic and business enterprise organizations. As a result, efforts have been undertaken in a number of countries to measure their biotechnology activities and compare them with those of competitor countries. Indeed, most OECD countries have already undertaken national biotechnology surveys, and many non-OECD countries are following suit. Thus, policy-makers are being faced with the problem of not having "systematic (internationally comparable) data on many aspects of biotechnology and its effects on the economy and society" (EC, 2002, p.6). Other problems related to timeliness, accuracy, coherence, and completeness of biotechnology statistics were addressed in an OECD (2005) report.

The *Canadian Biotechnology Innovation Scoreboard* had the following two objectives: (1) to provide policy makers with an information tool by presenting comparable Canadian and international data relative to specific areas of biotechnology; and (2) to develop solutions addressing methodological problems raised in recent biotechnology literature. The scoreboard provides comparable data on three poles of biotechnology activities: (1) scientific activities; (2) technological activities; and (3) firms, workforce, and financial activities. The *Canadian Biotechnology Innovation Scoreboard* compiles the ranking of selected countries for which data were available for the 22 biotechnology indicators assessed, putting emphasis on Canada's ranking.

The scoreboard shows that Canada is a world leader in biotechnology. In particular, it demonstrates that Canada has the fastest growing biotechnology market in the world and that Canada has benefited from high amounts of BES R&D investments in biotechnology, as well as high-value investments from VC. The country also possesses significant numbers of biotechnology firms and employees, obtains significant revenues, and has a good IP portfolio. In fact, Canada (ranked among the top five countries) is leading in 14 out of 22 indicators.

This study addressed some methodological problems with biotechnology statistics. Most are related to the comparability of international data and the timeliness of the data. Some of these problems could not be resolved, and therefore the scoreboard has some limitations. The study revealed the particular difficulties associated with the lack of timely publicly available data, which makes it impossible to present trends at the international level. International data on government and university investments in biotechnology R&D are also not included in publicly available sources. In addition, very little information was available on collaboration between governments, universities, and BES, which rendered the assessment of this fundamental aspect of the biotechnology innovation process unfeasible. Finally, the lack of publicly available biotechnology firm databases made it impossible to compare the value of publicly traded biotechnology companies.

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SourceOECD Science and Technology Statistics. 2004. Research & Development Statistics - Total Business Expenditure on Research and Development (BERD) by Industry (Table 13) *ISIC Rev.2* Vol 2004 release 02 - Statistiques de la Recherche - Développement - Total DIRDE par industrie (Tableau 13) *CITI Rev. 2* Vol 2004 édition 02

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Appendix A Characterization of available statistics

Table IV presents data availability by country and by indicator based on the data sources listed in Appendix B. The table shows that data for most indicators can be retrieved fairly easily for a single year, but they are not usually available for time-series analyses. The following tables characterize these data in greater details. Table V examines company and product-level indicators, Table VI financial-level indicators, and Table VII workforce-type indicators. Each of these tables highlights the following characteristics of the data based on data quality aspects of biotechnology surveys as prescribed by the OECD's *Framework for Biotechnology Statistics* (2005):

- **Source:** indicates the source of the data, and complete references are presented in Appendix B;
- **Data Scope:** indicates whether the data presented are from national or international surveys or from limited data;
- **Reporting unit:** indicates whether the data were produced by a government agency or if they originated from another institutional source;
- **Firm type:** indicates the firm definition that was used to estimate the number of biotechnology firms;
- **Consistency with OECD's definition of biotechnology:** indicates whether the data are consistent with the OECD's definition of biotechnology or if the definition of biotechnology used is not specified.

This characterization is not exhaustive but concentrates on aspects that are critical to an understanding of the limits of the *Canadian biotechnology innovation scoreboard*.

Legend (for tables IV to VII)

Data scope

LD	Limited data
NSS	National scope survey
ISS	International scope survey

Reporting unit

GR	Governmental reporting unit
AR	Academic reporting unit
PR	Private Reporting Unit
IOR	International Organization Reporting Unit

Firm type

AFB	Active firms in biotechnology
BIO	Bioventures
CORE	Core Biotechnology Companies
DBF	Dedicated Biotechnology Firms
IBF	Innovative Biotechnology Firms
TOTAL	Includes DBF, IBF and AFB
NS	Firm type not specified

Consistency with OECD's definition of biotechnology

C	Consistent with OECD's definition of biotechnology prescribed
IN	Inconsistent with OECD's definition of biotechnology
NS	Biotechnology definition not specified

Table IV Data availability per country and by indicator

Firms, workforce and financial flows indicators	Australia	Austria	Belgium	Canada	China	Denmark	Finland	France	Germany	India	Ireland	Italy	Japan	Netherlands	New Zealand	Norway	Portugal	Rep. of Korea	South Africa	Spain	Sweden	Switzerland	UK	USA	Number of countries for which these data are availbale
	Number of years for which these data are available for each country																								
Business enterprise sector R&D expenditures	1			**4**		5	2	1	1	2	1				1	2		1			2	1	1	1	**15**
Business enterprise sector total R&D employees	1			**1**		2	2	2	2		2					2	1				1	1	2	2	**13**
Exports				**4**											1			1							**3**
Government R&D expenditures	3			**6**		4	3	1	3	4	1			1	1	1			1		1				**13**
Government total R&D employees	1			**6**																					**2**
Imports				**3**																					**1**
Number of firms	2	1	2	**4**		5	3	3	3	2	3	1	1	1	3	3	1	1	1	1	2	2	3	3	**23**
Products in Phase I		1	1	**4**		1	1	1	1		1	1		1		1	1			1	1	1	1	1	**17**
Products in Phase II		1	1	**4**		1	1	1	1		1	1		1		1	1			1	1	1	1	1	**17**
Products in Phase III		1	1	**4**		1	1	1	1		1	1		1		1	1			1	1	1	1	1	**17**
Revenues	2			**4**		1	2	1	1	2	1		1	1	2	1		1			2	1	1	3	**17**
Size of the local market	5		5	**5**	5			5	5	3			5	1				4					5	5	**12**
Total business enterprise sector employees		1	1	**4**		2	2	3	2		2	1		1		2	2			1	1	1	2	2	**17**
Total employees						1	1	1	1		1		1	1	4			1			2			3	**11**
Total R&D employees	1			**1**		1		2	2	2			1		1			1							**9**
Total R&D expenditures	1	1	4				4	2	2		2		1		1	2			1			2	2	1	**14**
Universities R&D expenditures	3						1														1				**3**
Venture capital	1	1	2	**3**		2	2	3	1	1	1	1		1		1		1	1	1	2	1	1	6	**20**
Number of distinct indicators available	**11**	**7**	**8**	**15**		**12**	**13**	**14**	**14**	**7**	**12**	**6**	**6**	**10**	**8**	**11**	**6**	**8**	**4**	**6**	**12**	**10**	**11**	**12**	

Source: Sources are presented in Table V, VI and VII, and in Appendix B

Table V Available data on biotechnology firms and products in selected countries, 1998–2004

Indicator	Source	Firm type	Reporting Unit	Data Scope	Consistency with OECD's definition of biotechnology	Australia	Austria	Belgium	Canada	China	Denmark	Finland	France	Germany	India	Ireland	Italy	Japan	Netherlands	New Zealand	Norway	Portugal	Rep. of Korea	South Africa	Spain	Sweden	Switzerland	UK	US
Biotehnology firms and products																													
Number of firms	AU	AFB	GR	NSS	C	X																							
	AU	CORE	GR	NSS	C	X																							
	AU	TOTAL	GR	NSS	C	X																							
	BAK	CORE	PR	LD	C																		X						
	CAN	IBF	GR	NSS	C				X																				
	CAN-1	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C		X	X			X	X	X	X		X	X		X		X	X				X	X	X	X
	DNK	CORE	GR	NSS	C						X																		
	EC	DBF	IOR	ISS	C			X				X		X		X					X					X	X	X	
	EY	TOTAL	PR	LD	NS																							X	
	EY-1	NS	PR	LD	NS																								X
	FIN	CORE	GR	NSS	C							X																	
	FR	CORE	GR	NSS	C								X																
	FR	TOTAL	GR	NSS	IN								X																
	FR-2	CORE	PR	LD	C								X																
	GE	CORE	PR	LD	C																				X				
	GER	CORE	GR	NSS	IN									X															
	IND	NS	IOR	NSS	IN										X														
	JAP	BIO	PR	NSS	C													X											
	NZ	AFB	GR	NSS	C															X									
	NZ	CORE	GR	NSS	C															X									
	NZ	TOTAL	GR	NSS	C															X									
	NZ-1	TOTAL	GR	NSS	C															X									
	NZ-2	CORE	GR	NSS	NS															X									
	OECD	DBF	IOR	LD	C																					X			
	SA	CORE	GR	NSS	C																			X					
	SA	TOTAL	GR	NSS	C																			X					
	SW	CORE	GR	NSS	C																					X			
Products in Phase I	CAN	IBF	GR	NSS	C				X																				
	CAN-1	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C						X	X	X	X		X					X					X	X	X	
Products in Phase II	CAN	IBF	GR	NSS	C				X																				
	CAN-1	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C						X	X	X	X		X					X					X	X	X	
Products in Phase III	CAN	IBF	GR	NSS	C				X																				
	CAN-1	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C						X	X	X	X		X					X						X	X	
Products in Phase IV	CAN	IBF	GR	NSS	C				X																				
	CAN-1	IBF	GR	NSS	C				X																				

Note: Refers to the Legend and Source Appendix formerly presented

Table VI Available data on biotechnology financial indicators in selected countries, 1998–2004

Indicator	Source	Firm type	Reporting Unit	Data Scope	Consistency with OECD's definition of biotechnology	Australia	Austria	Belgium	Canada	China	Denmark	Finland	France	Germany	India	Ireland	Italy	Japan	Netherlands	New-Zealand	Norway	Portugal	Rep.of Korea	South Africa	Spain	Sweden	Switzerland	UK	USA
Financial flows																													
Biotechnology dedicated R&D expenditures by biotechnology firms	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
Business Enterprise Sector R&D Expenditures	AU	DBF	GR	NSS	C	X																							
	CAN	IBF	GR	NSS	C				X																				
	CAN-1	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C						X	X	X	X		X					X					X	X	X	X
	DNK	TOTAL	GR	NSS	C						X																		
	FIN	CORE	GR	NSS	C							X																	
	IND	NS	IOR	NSS	IN										X														
	KOR	CORE	AR	LD	C																		X						
	NZ-1	TOTAL	GR	NSS	C															X									
	OECD	CORE	IOR	LD	C	X															X								
	SW	TOTAL	GR	NSS	C																					X			
Exports	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
	KOR-2	IBF	GR	NSS	C																		X						
	NZ	DBF	GR	NSS	C															X									
Financing: united capitals	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
	CAN-3	TOTAL	GR	NSS	C				X																				
Government R&D Expenditures	AU	CORE	GR	NSS	C	X																							
	CAN-3	IBF	GR	NSS	C				X																				
	DNK	TOTAL	GR	NSS	C						X																		
	FIN	CORE	GR	NSS	C							X																	
	FIN-2	IBF	AR	LD	C							X																	
	FR-2	IBF	PR	LD	C								X																
	IND	NS	IOR	NSS	IN										X														
	NET	CORE	GR	NSS	NS														X										
	NZ-1	TOTAL	GR	NSS	C															X									
	OECD	CORE	IOR	LD	C																X								
	OECD	TOTAL	IOR	LD	C									X															
	SA	TOTAL	GR	NSS	C																			X					
	SW	TOTAL	GR	NSS	C																					X			
Imports	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
Revenues	AU	DBF	GR	NSS	C	X																							
	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C						X	X	X	X		X					X					X	X	X	X
	EY-1	NS	PR	LD	NS																								X
	FIN	CORE	GR	NSS	C							X																	
	IND	NS	IOR	NSS	IN										X														
	JAP	BIO	PR	NSS	C													X											
	KOR-2	IBF	GR	NSS	C																		X						
	NZ-1	TOTAL	GR	NSS	C															X									
	NZ-2	TOTAL	GR	NSS	C															X									
	SW	TOTAL	GR	NSS	C																					X			
Size of the Local Market	BAK	CORE	PR	LD	C																		X						
	DM	NS	PR	ISS	C	X																							
	DM	TOTAL	PR	ISS	NS			X	X	X			X	X				X										X	X
	IND-3	NS	PR	LD	IN										X														
	IND-4	NS	PR	LD	IN										X														
	IND-5	NS	PR	LD	IN										X														
	KOR-2	IBF	GR	NSS	C																		X						
	NET	CORE	GR	NSS	NS														X										
Total R&D Expenditures	AU	DBF	GR	NSS	C	X																							
	DNK	TOTAL	GR	NSS	C						X																		
	EC	DBF	IOR	ISS	C																X								
	EC	TOTAL	IOR	ISS	C			X				X	X	X		X											X	X	
	FIN	CORE	GR	NSS	C							X																	
	FR-2	IBF	PR	LD	C								X																
	IR	TOTAL	PR	NSS	C											X													
	JAP	BIO	PR	NSS	C													X											
	NZ-2	TOTAL	GR	NSS	NS															X									
	OECD	DBF	IOR	LD	C									X															
	OECD	NS	IOR	LD	NS																X								
	OECD	TOTAL	IOR	LD	C																						X	X	X
	SA	TOTAL	GR	NSS	C																			X					
	SW	TOTAL	GR	NSS	C																					X			
Universities R&D Expenditures	AU	DBF	GR	NSS	C	X																							
	FIN	CORE	GR	NSS	C							X																	
	OECD	DBF	IOR	LD	C	X																							
	SW	TOTAL	GR	NSS	C																					X			
Venture Capital	AU-1	TOTAL	PR	LD	NS	X																							
	BEL	n.a.	AR	LD	NS			X																					
	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
	CAN-3	TOTAL	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C		X	X			X	X	X	X		X	X		X		X					X	X	X	X
	DNK	TOTAL	GR	NSS	C						X																		
	EY-1	NS	PR	LD	NS																								X
	FIN	CORE	GR	NSS	C							X																	
	FR-2	IBF	PR	LD	C								X																
	GE	CORE	PR	LD	C																				X				
	KOR	CORE	AR	LD	C																		X						
	OECD	TOTAL	IOR	LD	NS																								X
	SA	TOTAL	GR	NSS	C																			X					
	SW-1	TOTAL	GR	NSS	C																					X			
	USA	TOTAL	GR	NSS	NS																								X

Note: Refers the Legend and Source Appendix formerly presented

Table VII Available data on biotechnology workforce in selected countries, 1998–2004

Indicator	Source	Firm type	Reporting Unit	Data Scope	Consistency with OECD's definition of biotechnology	Australia	Austria	Belgium	Canada	China	Denmark	Finland	France	Germany	India	Ireland	Italy	Japan	Netherlands	New Zealand	Norway	Portugal	Rep. of Korea	South Africa	Spain	Sweden	Switzerland	UK	USA
Workforce																													
Business Enterprise Sector Total R&D Employees	CAN	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C						X	X	X	X		X					X	X				X	X	X	X
	OECD	TOTAL	IOR	LD	C	X																							
Government Total R&D Employees	CAN-3	IBF	GR	NSS	C				X																				
	OECD	TOTAL	IOR	LD	C	X																							
Total Business Enterprise Sector Employees	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
	CI	DBF	PR	ISS	C		X	X			X	X	X	X		X	X		X		X	X				X	X	X	X
	FR	IBF	GR	NSS	C								X																
	GE	CORE	PR	LD	C																				X				
Total Employees	DNK	CORE	GR	NSS	C						X																		
	EY-1	NS	PR	LD	NS																								X
	EY-2	TOTAL	PR	LD	NS																								X
	FIN	CORE	GR	NSS	C							X																	
	FR	IBF	GR	NSS	C								X																
	JAP	BIO	PR	NSS	C													X											
	KOR	CORE	AR	LD	C																		X						
	NET	CORE	GR	NSS	NS														X										
	NZ	CORE	GR	NSS	C															X									
	NZ-1	CORE	GR	NSS	C															X									
	NZ-2	CORE	GR	NSS	NS															X									
	OECD	TOTAL	IOR	LD	C																								X
	SW	TOTAL	GR	NSS	C																					X			
	SW-1	TOTAL	GR	NSS	C																					X			
Total Number of Employees	CAN	IBF	GR	NSS	C				X																				
	CAN-2	IBF	GR	NSS	C				X																				
Total R&D Employees	CAN-1	IBF	GR	NSS	C				X																				
	DNK	CORE	GR	NSS	C						X																		
	FR	TOTAL	GR	NSS	C								X																
	FR-2	IBF	PR	LD	C								X																
	GER	CORE	GR	NSS	C									X															
	IND	NS	IOR	NSS	IN										X														
	JAP	BIO	PR	NSS	C													X											
	KOR	CORE	AR	LD	C																		X						
	NZ	CORE	GR	NSS	C															X									
	OECD	TOTAL	IOR	LD	C	X																							
Universities Total R&D Employees	OECD	TOTAL	IOR	LD	C	X																							

Note: Refers to the Legend and Source appendix formerly presented

Appendix B Data sources

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