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A Comparison of International R&D Performance: An Analysis of Countries That Have Significantly Increased Their GERD/GDP Ratios During the Period 1989-1999

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The Working Papers publish research related to science and technology issues. All papers are subject to internal review. The views expressed in the articles are those of the authors and do not necessarily reflect the views of Statistics Canada.

The Science and Innovation Information Program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 (**Science and Technology Activities and Impacts: A Framework for a Statistical Information System,** Cat. No. 88-522). The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).

It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/cgi-bin/downpub/research.cgi?subject=193.

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Executive Summary

Canada has set itself the goal of improving its R&D performance; the target is to become one of the top five R&D performing countries in the world by 2010. Using the GERD/GDP ratio as a measure of R&D performance, Canada ranked 15th as of 1999 with a ratio of 1.84%. To have ranked amongst the top five in 1999, Canada would have required a ratio of 2.69%.

Of all of the OECD countries none improved its rank by ten positions between 1989 and 1999. The two countries that achieved the greatest improvement in their positions are Iceland, which moved from 18th position to ninth and Finland, which moved from ninth to second. Other OECD countries are also likely to be working to improve their R&D performance over the next ten years. In addition to the countries that have joined the OECD the 1990's, a number of other countries might be joining in the next decade. This means that not only are the goal posts moving, there are more players on the field.

Between 1989 and 1999, six countries increased their proportion of GDP allocated to R&D by a greater amount than Canada. These countries, along with the members of the G-7, will be used as comparisons to illustrate areas of strength and weakness in Canada's R&D performance.

Countries with the greatest rates of increase in their GERD/GDP ratio also reported some of the greatest increases in total R&D spending, but some countries which reported the largest increases in R&D spending did not report significant increases in GERD/GDP because of equally substantial increases in GDP. Canada increased real R&D spending between 1989 and 1999 at a rate that exceeded all other members of the G-7.

Those countries that significantly improved their R&D performance generally reported higher than average levels of R&D in institutions of higher learning and very high levels of business R&D. R&D done by business can be seen as the driving force of change in overall GERD/GDP ratios in all high R&D performance countries.

Government funding of business R&D accounted for only a small portion of funds in all high R&D performance countries. In all but one of these countries, the proportion of funds for business R&D from government dropped between 1989 and 1999. About half of these countries also reported more funding from foreign sources. In 1999, Canada reported 27% of funding for business R&D came from foreign sources, up from 17% in 1989.

The countries that significantly improved their R&D performance report the highest rates of increase in the amount of R&D by the business sector as a percentage of GDP. The high R&D performers reported high proportions of their total business R&D in electronics and a shift towards more R&D in electronics between 1989 and 1999. By contrast the larger G-7 countries reported R&D which was more diversified across many sectors. Canada's business R&D profile was concentrated in electronics and services, and thus more like the high R&D performers than the other members of the G-7.


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We must strive for Canada to become one of the top five countries for research and development by 2010." **Speech from the Throne, January 30, 2001**

Introduction

In January 2001, the government of Canada announced the broad objective to be recognized as one of the most innovative countries in the world. The innovation strategy, *Achieving Excellence: Investing in People, Knowledge and Opportunity*[1], which was released in February 2002, identified two long-term goals:

- Vastly increase public and private investments in knowledge infrastructure to improve Canada's R&D performance.

- Ensure that a growing number of firms benefit from the commercial application of knowledge.

Measurable targets were set in order to track Canada's progress in achieving these goals. One of the targets that was set was for Canada to rank among the top five countries in the world in terms of R&D performance by 2010.

This target is, indeed, an ambitious one, as at the time of the government announcement Canada was ranked 15th among OECD countries in terms of its GERD/GDP ratio[2] (Gross Domestic Expenditure on Research and Development/Gross Domestic Product). The fifth-ranked country, at that time, was Korea with a GERD/GDP ratio of 2.68, compared to Canada's at 1.84. For Canada to achieve the Korean level of performance would require a 3.5% increase in the GERD/GDP ratio each year for the next ten years. Even if this increase can be achieved, it might not ensure that Canada obtains a ranking of 5th in ten years, as it is always possible that certain other countries will surpass the Canadian performance during the next ten years.

Not withstanding the challenges faced in becoming the fifth ranked country[3], it is clear that Canada must increase its GERD/GDP ratio in order to increase in ranking. What have been the experiences of other OECD countries? Have there been other countries that have achieved the improvement in their ranking by ten positions or have achieved significant increases in their GERD/GDP ratios? If they have, how have these increasing in rankings and GERD/GDP ratio been achieved? These are the questions that will be addressed in this study. By examining the cases where significant increase in R&D performance has been achieved, the study will provide insight into how Canada can improve its performance in order to achieve the stated target of moving from 15th to 5th. In addition, the performance of those countries that do most of the R&D within the OECD (the members of the G-7) will also be reviewed.

In the first section of the paper, OECD countries that have achieved significant improvement in their R&D performance during the period 1989-1999 will be identified. Section two will compare the changes in R&D levels in comparison to the increase in the GERD/GDP ratio for the set of countries that achieved significant

[1] Government of Canada, *Achieving Excellence: Investing in People, Knowledge and Opportunity: Canada's Innovation Strategy,* 2002. The other component of the innovation strategy which deals with the issue of skills is found in Government of Canada, *Knowledge Matters: Skills and Learning for Canadians, 2002.*

[2] The GERD/GDP ratio has long been used as an indicator for national R&D performance. It is an internationally comparable indicator as OECD member countries have collected R&D statistics since the mid 1960s using the standards outlined in the Frascati manual: OECD, *"Proposed Standard Practice for Surveys of Research and Experiment Development, 2002".* For more detail on the definitions of R&D outlined in the Frascati Manual see Annex 2. There has been discussion of an alternative indicator of R&D performance, namely GERD per capita. This paper will focus on the GERD/GDP indicator.

[3] A number of commentators have pointed to the human resource challenges involved in a substantial increase in R&D activities. (David Crane, *"New technologies will demand skilled Canadian workers"* , The Chronicle Herald, November 3, 2001, p. C3, James Roche, "*Canada needs more high-tech experts to be a world leader",* Globe and Mail, April 5, 2001, p. B14, and *OECD Science, Technology and Industry Outlook 2000*, p.84-88)

improvement in R&D performance. The following sections will examine in more detail the determinants of the significant increase in GERD/GDP, specifically, the performance of R&D by different sectors, the changes in funding of business R&D, and the changes in performance of R&D by industry sector. The final section will conclude with a general discussion of the determinants of increases in the GERD/GDP for those countries that achieved significantly increased R&D performance and of the broader question of the choice of indicators to measure R&D performance.

Section 1: Identification of countries that achieved significantly increased R&D performance during the period 1989 to 1999

The work of the OECD allows for making international comparisons and learning by example. The organization collects a variety of indicators on research and development and data are available from virtually all of its members[4]. The GERD/GDP ratio is a key indicator of R&D performance and one that was referred to in the Speech from the Throne[5] as a means of measuring Canada's performance over the next decade. During the period 1989 to 1999, have any countries managed to meet the target of improving their ranking by ten points over those ten years? The answer is no.[6]

Of the 22 countries who were OECD members in 1989, only two recorded improvements of more that five positions. Finland and Iceland reported moving up seven and nine positions respectively between 1989 and 1999. During this period, Canada dropped from 13th to 15th place, one of thirteen countries that reported a change of two places or less.

[4] Data are not available for Luxembourg but are generally available for the twenty-nine other countries who were members in 1999.
[5] Canada ranked 13th in terms of per capita spending on R&D in 1999, the measure referred to in the Prime Minister's Response to the Speech from the Throne (2001).
[6] Note that Iceland was able to shift ten positions between 1990 and 1999. In 1990, it fell to 18th position and therefore was able to improve its position by 10 places within the space of 10 years. OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Table 1.1: GERD/GDP Rankings: A Comparison of 1989 and 1999

OECD Members [a]	1989	1999	Change
Iceland	17	8	9
Finland	9	2	7
Denmark [c]	12	10	2
Japan	4	3	1
Sweden	2	1	1
United States	5	4	1
Austria	14	14	0
New Zealand [b]	18	18	0
Belgium	11	12	-1
Ireland	19	20	-1
Switzerland [d]	3	5	-2
Canada	**13**	**15**	**-2**
Australia [c]	15	17	-2
Spain	20	22	-2
Portugal [e]	21	23	-2
Netherlands	8	11	-3
France	6	9	-3
Greece	22	27	-5
Italy	16	21	-5
Germany	1	7	-6
United Kingdom	7	13	-6
Norway	10	16	-6
Korea	--	6	--
Czech Republic	--	19	--
Poland [e]	--	23	--
Hungary	--	25	--
Slovak Republic	--	26	--
Turkey	--	28	--
Mexico	--	29	--

[a] Czech Republic, Hungary, Korea, Poland and the Slovak Republic joined the OECD after 1989

[b] based on 1997 figures instead of 1999

[c] based on 1998 instead of 1999

[d] based on 2000 instead of 1999

[e] Poland and Portugal had GERD/GDP ratios of 0.68 in 1999

Source: OECD, MSTI database 2002

The largest drops in GERD/GDP rank were reported by four members of the G-7. Germany, the United Kingdom, France and Italy reported drops in rank of either five or six positions. The data indicate that unification may have had a significant impact on the German GERD/GDP ratio[7]. The United Kingdom reported fairly strong growth in GDP, which pulls the GERD/GDP ratio down unless R&D spending increases at the same high rate. The United States and Japan remained fairly stable, each improving one position between 1989 and 1999.

[7] OECD, Main Science and Technology Indicators (MSTI) database, July 2002 – In 1989, Germany ranked first in the OECD with a GERD/GDP ratio of 2.86. In 1990 its GERD/GDP ratio began to fall. By 1994 it had dropped to 2.26, ranking eighth amongst OECD members. Since 1997 it increased steadily and by 1999 it was 2.44.

An alternative means of examining the GERD/GDP indicator is to identify those countries that increased their GERD/GDP ratio by a significant amount between 1989 and 1999. Canada reported an increase in its GERD/GDP ratio of 0.33% of GDP. There were six countries that reported a greater increase. Finland, Iceland, Sweden, Austria, Denmark and Ireland. These countries also all managed to increase their GERD/GDP ratios by over one-third while the OECD average declined marginally (-2%).[8] Ireland was able to accomplish this increase despite almost doubling in its GDP per capita during the period.[9] [10]

Table 1.2 - GERD/GDP, Absolute and Percentage Change between 1989 and 1999

OECD Members	1989	1999	Absolute change	Percentage change
Finland	1.80	3.22	1.42	79
Iceland	1.01	2.33	1.32	131
Sweden	2.83	3.78	0.95	34
Denmark [b]	1.51	2.09	0.58	38
Austria	1.35	1.83	0.48	36
Ireland	0.80	1.21	0.41	51
Canada	**1.47**	**1.80**	**0.33**	**22**
Belgium	1.64	1.96	0.32	20
Greece	0.37	0.67	0.30	81
Portugal	0.46	0.75	0.29	63
Australia [b]	1.27	1.51	0.25	19
New Zealand [a]	0.87	1.11	0.24	28
Japan	2.70	2.94	0.24	9
Spain	0.72	0.88	0.16	22
United States	2.62	2.66	0.04	2
Norway	1.69	1.70	0.01	1
Netherlands	2.04	2.02	-0.02	-1
France	2.29	2.19	-0.10	-4
Switzerland [c]	2.83	2.64	-0.19	-7
Italy	1.24	1.04	-0.20	-16
United Kingdom	2.15	1.88	-0.27	-13
Germany	2.86	2.44	-0.42	-15
Korea	--	2.47	--	--
Czech Republic	--	1.25	--	--
Poland	--	0.75	--	--
Hungary	--	0.69	--	--
Slovak Republic	--	0.68	--	--
Turkey	--	0.63	--	--
Mexico	--	0.40	--	--
OECD	**2.26**	**2.21**	**-0.05**	**-2**

[a] 1997 instead of 1999

[b] 1998 instead of 1999

[c] 2000 instead of 1999

Source: OECD, MSTI database 2002

[8] Note that this decline in the OECD's GERD/GDP ratio is in part a result of changing membership, as mentioned above, and the impact of Germany's contribution to GERD, which declined immediately following unification.

[9] OECD, Main Science and Technology Indicators (MSTI) database, July 2002

[10] When using the GERD/GDP ratio one should keep in mind that it can also "improve" as a result of economic downturns. If the GDP (the denominator) decreases while R&D remains constant, the GERD/GDP ratio will increase.

Although complete data for Korea are not available for 1989, it did manage to significantly improve its R&D performance over a short period of time. Data begin in 1991 when Korea reported a GERD/GDP ratio of 1.92%, which increases to 2.68% in 2000.[11] This represents an absolute change of 0.76% of GDP qualifying Korea as a country experiencing significant improvement in R&D performance.

Several of the G-7 also reported absolute declines in their GERD/GDP ratios. The same countries that reported the greatest drops in rank also reported declines in their GERD to GDP. The United States and Japan changed very little. By this measure Canada reported significantly better results than the majority of the members of the G-7.

The countries that have reported the greatest improvement in R&D performance, based on the absolute change in GERD/GDP ratio, are: Austria, Denmark, Finland, Iceland, Ireland, Korea and Sweden. These countries, along with the G-7 countries, will be examined in more detail in the following sections. They will be referred to as the "high R&D performers".

Section 2: Growth in GERD vs. GERD/GDP ratio

Did the countries that experienced strong growth in their GERD/GDP also report higher growth in spending on R&D?

Between 1989 and 1999, OECD countries as a whole reported that the total amount of money spent on R&D almost doubled. When effects of inflation[12] and the changing membership in the OECD are removed, however, the picture changes somewhat with an overall growth rate of just over 30%.[13]

[11] The ratio for 1999 (2.47%) is quite a bit lower than the five-year average of 2.60% (1996-2000).

[12] The impact of inflation is largely removed by using constant value currency. Constant value currencies require that an arbitrary year be set at 100 and that the value of the currency for all other years be adjusted accordingly. The MSTI database contains GERD data in constant value 1995 PPP dollars. This requires that the national currencies also be converted into Purchasing Power Parity dollars. The PPP dollar is a means of converting the purchasing power of the local currency, based on a standard basket of goods and services, into US dollars (as opposed to applying the official exchange rate). The downside of the use of a monetary conversion factor is that it introduces the possibility of changes in total spending that are a result of changes in the conversion factor and not actual changes in terms of the actual amount spent in the national currency. The use of PPP dollars is, however, generally accepted as the best means of comparing spending between OECD members.

[13] OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Table 2.1 - Changes in R&D spending, 1989-1999

	Gross Expenditures on R&D (GERD)			Gross Domestic Product (GDP)			GERD/GDP ratio		
Country	**1989**	**1999**	**Change (%)**	**1989**	**1999**	**Change (%)**	**1989**	**1999**	**Change (%)**
	(1995 PPP$)			(1995 PPP$)					
Austria	2,013	3,485	73	148,942	190,386	28	1.35	1.83	36
Denmark [a]	1,625	2,770	70	107,783	132,768	23	1.51	2.09	38
Finland	1,792	3,757	110	99,597	116,710	17	1.80	3.22	79
Iceland	58	167	188	5,737	7,162	25	1.01	2.33	131
Ireland	383	1,136	197	47,908	94,019	96	0.80	1.21	51
Korea [b]	7,565	14,797	96	393,891	599,189	52	1.92	2.47	29
Sweden	4,786	7,439	55	169,179	196,703	16	2.83	3.78	34
Canada	9,104	14,064	54	621,174	783,183	26	1.47	1.80	22
France	25,398	28,775	13	1,109,359	1,315,714	19	2.29	2.19	-4
Germany	38,895	45,264	16	1,357,875	1,854,397	37	2.86	2.44	-15
Italy	13,125	12,784	-3	1,061,339	1,229,681	16	1.24	1.04	-16
Japan	70,132	90,212	29	2,593,674	3,071,561	18	2.70	2.94	9
United Kingdom	21,532	23,066	7	1,000,163	1,228,025	23	2.15	1.88	-13
United States	167,593	229,280	37	6,408,700	8,626,701	35	2.62	2.66	2
OECD Total	**382,351**	**523,296**	**37**	**16,898,719**	**23,705,899**	**40**	**2.26**	**2.21**	**-2**

[a] 1998, not 1999

[b] 1991, not 1989

Source OECD, Main Science and Technology Indicators (MSTI) database, July 2002

All of the selected countries with significantly improved R&D performance reported real growth in R&D spending of over 50%. Ireland reported the greatest increase in R&D, tripling the amount it spent on R&D between 1989 and 1999. Iceland reported increases in R&D spending of similar magnitude, while Korea almost doubled its R&D spending (between 1991 and 1999) and Austria and Denmark increased their spending by about 70%. Sweden reported the lowest rate of increase (55%), which was almost identical to what Canada experienced. In no case did a country that experienced strong growth in its GERD/GDP ratio, not experience strong growth in R&D spending. Strong growth in GDP dampened the effect of increases in R&D spending on the GERD/GDP indicator, particularly in the cases of Ireland and Korea.

Canada reported a rate of growth in real R&D spending that was generally lower than the high R&D performers. However, its GDP growth, while lower than Ireland and Korea, was comparable to Austria and Iceland and higher than in the two highest R&D performing countries, Finland and Sweden.

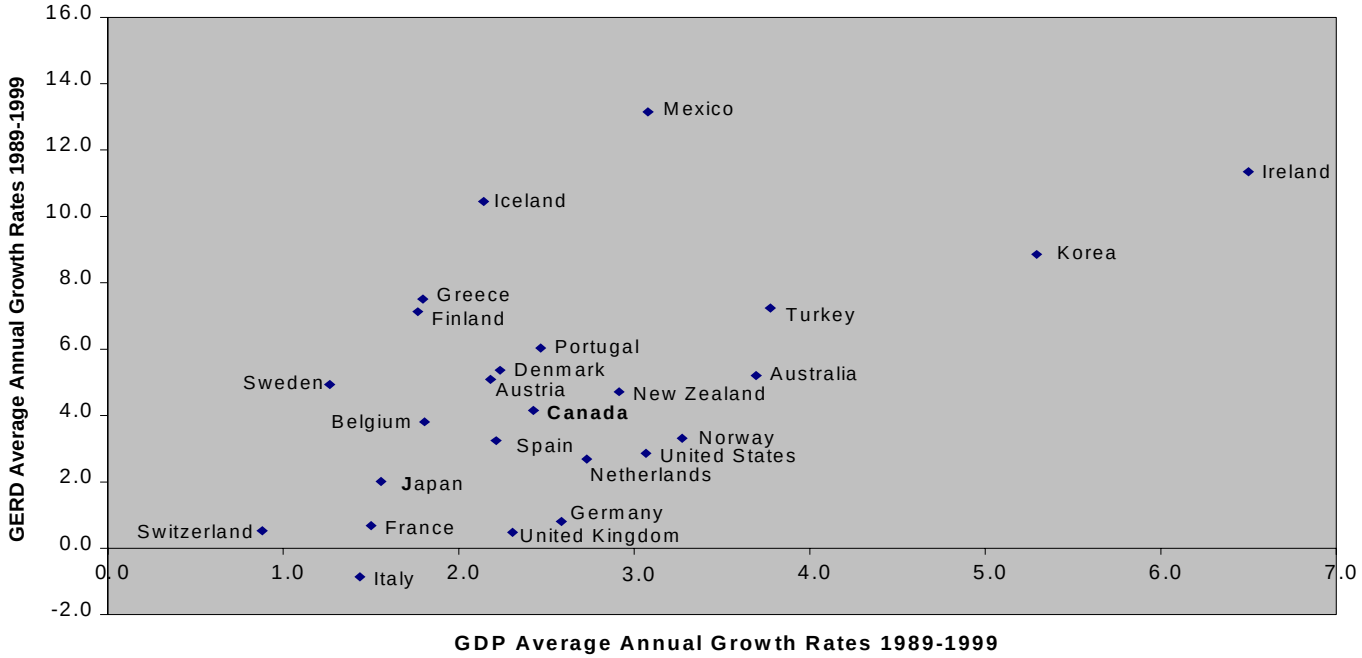
By contrast, Canada increased real R&D spending at a rate that exceeded all other members of the G-7. Canada's rate of real GDP growth also exceed the rates of all G-7 members except Germany (whose figures were impacted by unification) [14] and the United States. The top five R&D countries (United States, Japan, Germany, France, United Kingdom), in terms of absolute funds spent, accounted for about 80% of all OECD R&D spending in 1989 and just over 75% by 1999[15]. The drop is likely attributable to the addition of new members during the 1990s.

[14] While real spending on R&D in Germany did decrease somewhat during the early 1990s, by 1996 it had returned to a path of steady growth. Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

[15] OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Whether improved R&D performance is identified by growth in the GERD/GDP ratio or growth in R&D spending, the same group of countries consistently come out as the top performers. These countries do not, however, report similar levels of spending per capita. Sweden and Finland's spending per capita was over twice that of Ireland.[16] The data indicate that countries can improve their GERD/GDP ranking regardless of where they rank in terms of per capita spending.

Canada placed in the middle of the pack during the 1990s in terms of growth in R&D spending and GDP



Section 3: Growth by R&D Sector

Research and development activities in all OECD countries are performed primarily by three sectors: business, institutions of higher learning[17] (primarily universities) and government institutions. (For a detailed breakdown of R&D spending by all OECD members, see Table A in the appendix.)

In 1989, most of the high R&D performance countries reported that 20% to 30% of total R&D was done in institutions of higher learning, government facilities accounted for around 20% and the remainder was done by business. By 1999, R&D in universities was about 20% of the total, government R&D was between 10% and 15%, and business R&D accounted for between 65% and 75% of total R&D. In almost all cases the increase in the proportion of R&D activity by businesses was matched by a decrease in the proportion of government-performed R&D. Sweden was the only exception in that the shift came from a reduction in the proportion of R&D done in institutions of higher learning instead of reductions in government R&D spending. This can be explained by the already low level of government research and the higher than average level of R&D in institutions of higher learning in Sweden in 1989.

[16] If per capita levels of R&D spending were the chosen indicator of R&D performance, Sweden, Iceland and Finland would remain at or near the top of the list, but the United States would vie with Sweden for top position. Switzerland, Japan and Germany would also have to be added. Canada would remain in the middle of the pack. In 1999, in terms of total R&D spending, the United States accounted for 44%. The top five countries, the United States, Japan, Germany, France and UK, accounted for 79%. Canada accounted for 2.6% of all R&D spending and ranked 7th, behind Korea. Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

[17] This category also includes hospitals that conduct research.

The most notable feature of the data is that in every high R&D performance country the proportion of total R&D done by business increased between 1989 and 1999. The reverse was also true – those countries which reported declines in GERD/GDP ratios consistently reported declines in the proportion of GDP going to business R&D. (See ***Table A*** in the appendix.)

Amongst the G-7 countries only two other countries, the United States and France, reported increases in the proportion of R&D spending by business. France reported a significant drop in the percentage of GDP allocated to government research. The United States reported an absolute increase in the percentage of GDP allocated to business R&D combined with a drop in the proportion of GDP allocated to R&D by government. Italy reported a decline in business R&D that paralleled its drop in overall R&D.

Canada reported an increase in business R&D as a percentage of GDP and as a proportion of all R&D spending. While Canada's business R&D figures improved, its overall level of business R&D, both as a percentage of GDP and as a proportion of all R&D, remained lower than the high R&D performance countries except Ireland and all of the G-7 except Italy.

R&D by business can be seen as the driving force of change in overall GERD/GDP ratios.

Figure 3.1

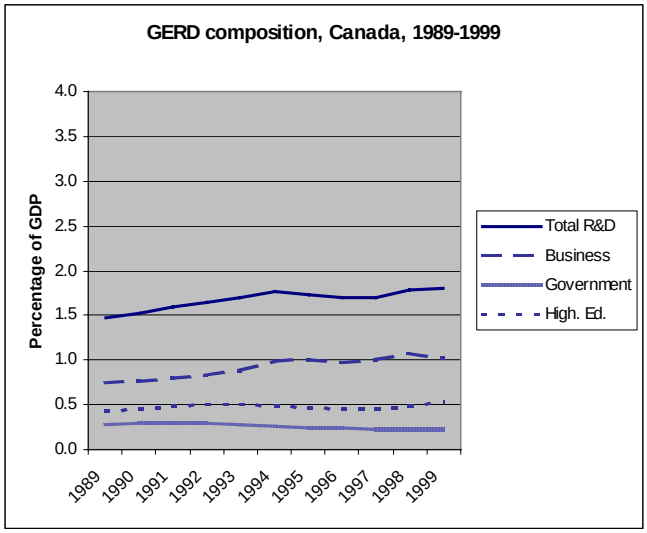


Figure 3.2

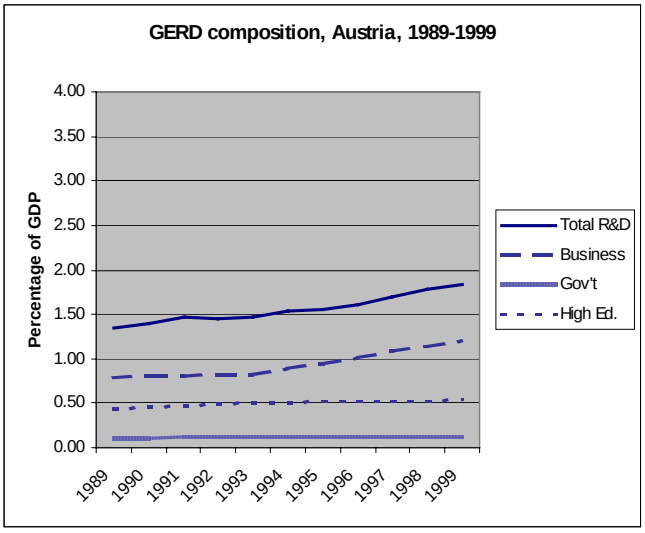


Figure 3.3

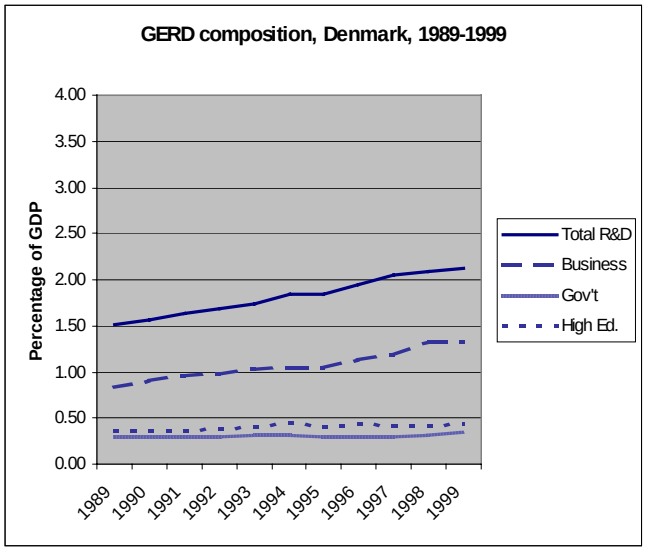


Figure 3.4

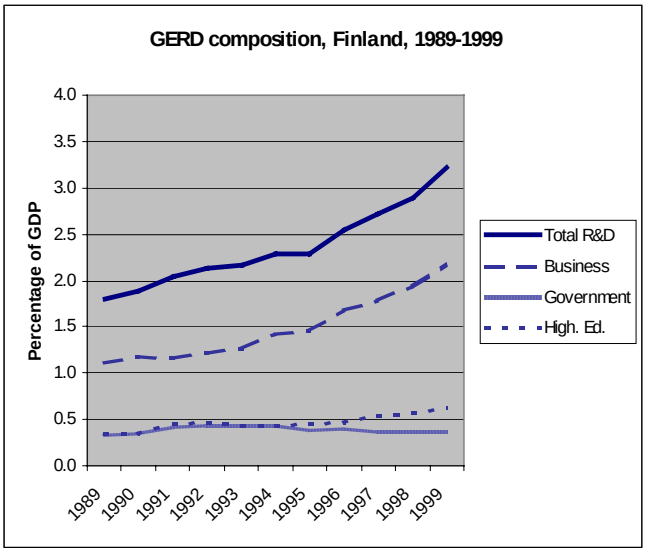


Figure 3.5

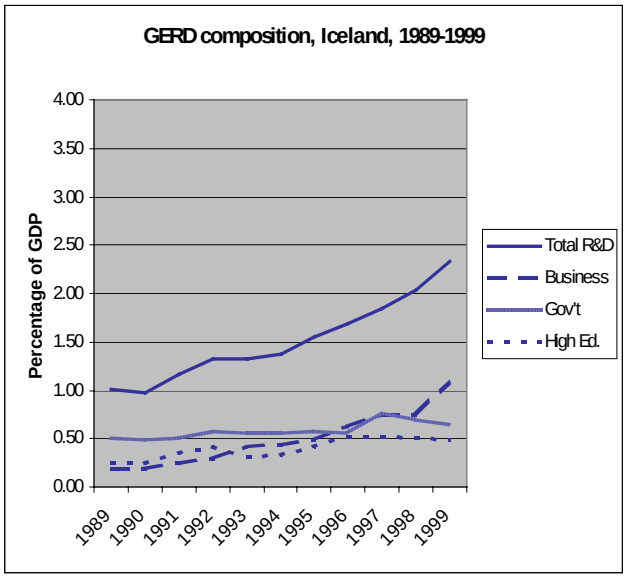


Figure 3.6

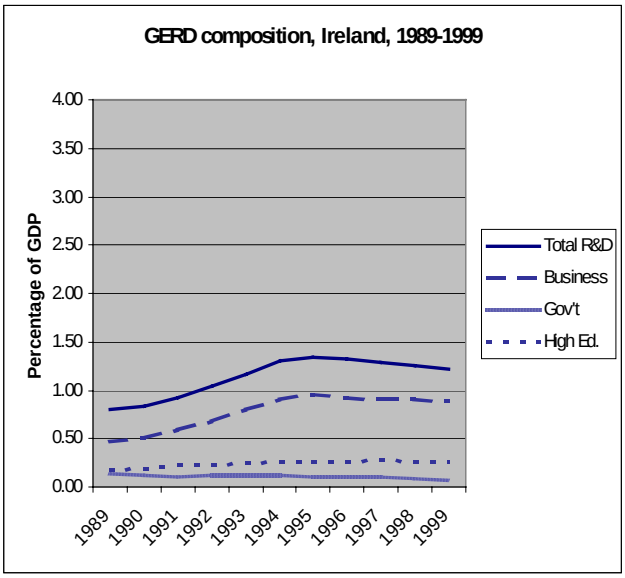


Figure 3.7

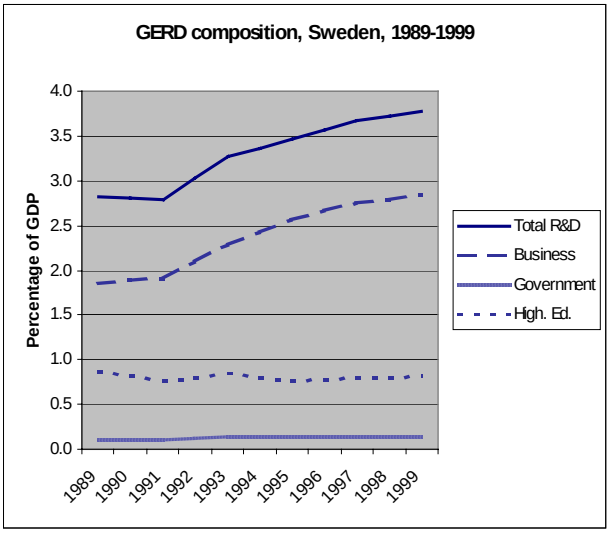
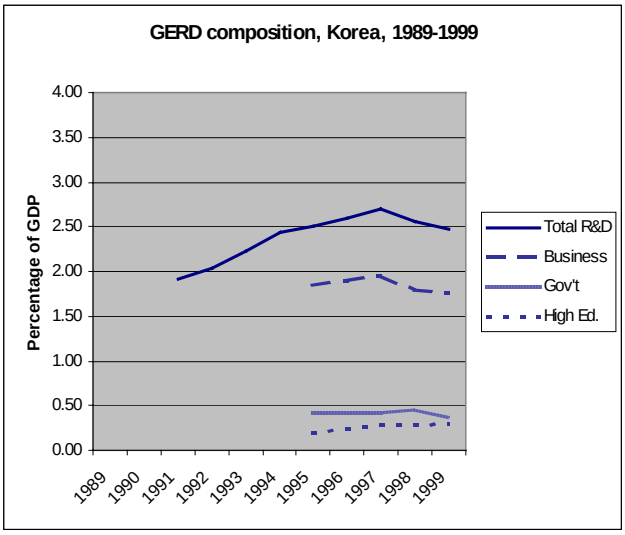


Figure 3.8



Source OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Amongst almost all of the countries with significantly improved R&D performance, spending as a proportion of GDP increased in every sector (business, government and higher education). The only two exceptions were Ireland, which reported a decrease in the proportion of GDP spent in government research and Sweden, which reported a decline in R&D in universities. (Even with the reported drop, Sweden maintained a level of spending on R&D by institutions of higher education that was higher than all other countries and more than double the OECD average.) More commonly, the countries with higher R&D performance showed significant increases in R&D spending in all categories.

While there is no clear pattern with respect to the level of government spending, the countries reporting significantly improved R&D performance do report higher proportions of GDP going to research in universities and other institutions of higher education. Only Ireland and Korea report levels lower than the OECD average. Denmark is just above the average while the others are significantly higher.

Business R&D as a percentage of GDP increased significantly in all of the high R&D performance countries. In both Finland and Sweden, the proportion of GDP allocated to only business R&D (BERD) in 1999 was greater than that allocated to all R&D (GERD) in 1989.

Canada showed many of the same patterns of change seen in the high R&D performance counties, just to a lesser extent. The proportion of R&D activities done by business did increase but to a level that remained lower than in the high R&D performance countries. Canada's R&D in institutions of higher learning was closer to the higher end of the range amongst the high performance countries, and compared to all OECD countries generally. Business R&D as a proportion of total GDP did increase, but not at the high rates reported by the high R&D performers. Canada's performance can be characterized as more consistent with the high R&D performers than with the other members of the G-7, with the exception of the United States. The United States also reported increases in business R&D, both as a proportion of GDP and as a percentage of total R&D.

Section 4: Who is funding business R&D?

Given the significance of business R&D as a key component of all R&D activities, it is worth asking about the sources of funding for business R&D. Funding for business R&D can come from any one of four sources: domestic business, government, other national institutions (for example charities funding medical research) and abroad. "Abroad" is composed of foreign institutions, foreign businesses and foreign subsidiaries of domestic businesses. Thus, this category provides an indicator of globalization of business R&D.

Table 4.1 - Sources of Funding of Business R&D, 1999 and 1989

Country	1989 Business	Government	Other National	Abroad	1999 Business	Government	Other National	Abroad
Austria	89	6	0.0	5	64[a]	0	--	30[a]
Denmark	83	12	2.1	3	89	4	0.6	6[a]
Finland	96	3	0.0	1	94	4	0.0	1
Iceland	85	11	0.0	4	77	2	0.0	21[a]
Ireland	89	7	0.1	4	85	4	0.0	11
Korea [b]	--	--	--	--	94	6	0.2	0
Sweden	85	13	0.0	2	89	8	0.1	3
Canada	**73**	**10**	**0.0**	**17**	**69**	**4**	**0.0**	**27**
France	70	19	0.1	11	81	10	0.1	9
Germany	86	11	0.3	3	90	8	0.2	2
Italy	77	16	0.0	6	79	13	0.3	8
Japan	99	1	0.1	0	98	2	0.2	1
United Kingdom	69	17	0.0	13	67	10	0.0	23
United States	72	28	0.0	--	88	12	0.0	--
Total OECD	**80**	**18**	**0.0**	**--**	**88**	**9**	**0.0**	**--**

-- not available or applicable
[a] 1998
[b] 1995 most recent data available
Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

The majority of business R&D is financed by domestic business in Canada and in all of the high R&D performance countries (for that matter, in all OECD countries). There are, however, differences between countries and there have been shifts in the sources of funds since 1989.

Amongst the high R&D performing countries, funding from government is a small component of total business R&D funding and contributions from other national institutions are negligible for all high R&D performance countries. Rates of government funding of business R&D ranged from 2.4% in Iceland to 7.8% reported by Sweden. Canada falls in the middle of this range at 3.7%. In all cases except Finland, the proportion of business R&D funded by government declined sharply between 1989 and 1999. This was also true in Canada, were government funding of business R&D declined from 10% to 4%. In some cases, such as Sweden and Denmark, the downward shift in the proportion of funding by government was largely matched by an upward shift in domestic business R&D funding. In other cases, most notably Austria, but also Iceland and Ireland, there was a decrease in the proportion of funds coming from domestic industry and a sizable increase in the proportion from abroad.

The picture is different for the members of the G-7. Government funding did fall but it remained higher than for the high R&D performing countries. The most significant shifts were reported by the United States and France, where the proportion of funding from government dropped, to be made up by similar increases in the proportion funded directly by business. The United Kingdom reported shifts that were very similar to Canada's and, indeed an overall distribution of funding that was very similar to Canada's. Overall, at the OECD level, there was a decrease in the proportion of business R&D funded by government which was mirrored in a corresponding increase in funding from business. The shift was more noticeable amongst the G-7 than the high R&D performing countries perhaps because their proportion of business R&D funded by business was already quite high in 1989.

Table 4.2 - Percentage shifts in funding of BERD, 1989 to 1999

Country	Business	Government	Other National	Abroad
Austria	-25	0	--	25
Denmark	6	-7	-2	3
Finland	-2	1	0	1
Iceland	-8	-8	0	17
Ireland	-4	-3	0	7
Korea [b]	--	--	--	--
Sweden	3	-5	0	1
Canada	**-3**	**-6**	**0**	**10**
France	11	-9	0	-2
Germany	4	-3	0	-1
Italy	1	-3	0	2
Japan	-1	1	0	0
United Kingdom	-2	-7	0	9
United States	16	-16	0	--
Total OECD	**8**	**-9**	**0**	**--**

-- not available or applicable

[a] 1989 to 1998

[b] 1995 most recent data available

Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Those OECD countries reporting less than 85% of funding coming from domestic business also report more than 10% of BERD funding coming from abroad. The proportion of Canadian business R&D financed by domestic businesses dropped slightly from 72% to 69%, while the proportion of funding from foreign companies increased by 10%, from 17% to 27%. In 1989, none of the high R&D performance countries had a rate of funding from abroad higher than 5%. By 1999, Canada had been joined by Austria, Iceland and Ireland, with rates over 10%, while Finland, Korea and Sweden continued to have very low levels of funding from abroad.

Section 5: R&D Growth by Industry Sector

Which industries are performing R&D?

Six industry sectors have been identified by the OECD as being of interest in terms of business R&D. Tables are provided showing the percentage of total business R&D performed by each industry[18]. These industry sectors are: aerospace, electronics, computers and office machinery, pharmaceuticals, instruments and services. Each country has a distinct profile with different industries accounting for a different proportion of business R&D, but looking at the countries with high R&D performance, in each case the most R&D intensive area is either the electronics industry or the service sector[19]. These two areas combined account for half of business R&D, except in Denmark and Sweden, both of which have strong pharmaceutical R&D efforts. In all of the high R&D performance countries, electronics, services and pharmaceuticals account for over half of all

[18] OECD, Main Science and Technology Indicators (MSTI) database, July 2002

[19] The services sector can encompass a broad range of activities (including contract R&D, software design, computer services, communications, finance and transportation and storage). Note also that there may be issues with respect to the comparability international data on R&D in services, see F.D. Gault (1997) *Research and Development in a Service Economy*, Statistics Canada, Catalogue No. 63F0002XPB No. 12, p. 10.

industrial R&D. This also holds true for Canada. Unlike all of the high R&D performance countries, Canada also has strong aerospace R&D sector.

Table 5.1 - Percentage of total business R&D by selected industries, 1999

Country	aerospace	electronics	office machinery and computers	pharmaceuticals	instruments	services	all other
Austria [a]	--	26.6	0.2	5.7	2.2	22.4	42.8
Denmark [a]	0.0	6.6	0.4	20.2	4.5	36.7	31.7
Finland	0.0	47.5	0.3	4.1	2.0	11.7	34.4
Iceland [c]	0.0	0.1	--	2.5	5.8	70.8	20.9
Ireland [b]	0.3	30.4	5.1	14.4	5.1	12.8	32.1
Korea [d]	3.0	39.8	5.5	2.0	0.7	13.3	35.8
Sweden	2.9	23.4	0.7	16.5	5.7	12.8	38.0
Canada	**11.6**	**27.1**	**4.8**	**6.4**	**1.3**	**29.2**	**19.6**
France	11.8	12.5	1.9	13.2	6.7	9.1	44.9
Germany	6.6	10.5	2.2	6.4	4.8	5.4	64.2
Italy	11.2	20.2	0.9	8.6	2.9	18.7	37.4
Japan	1.0	17.9	10.7	6.5	4.6	2.7	56.6
United Kingdom	10.9	7.7	1.0	22.4	4.2	17.4	36.4
United States	7.9	9.7	5.1	6.7	10.7	31.2	28.7

-- not available or applicable

[a] 1998

[b] 1997

[c] electronics 1997, pharmaceuticals 1988

[d] aerospace 2000

Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Iceland, Finland and Korea report the highest degree of concentration of R&D. In Iceland 71% of R&D is done in the service sector. For Finland and Korea the area of concentration is electronics - in Finland almost one half of all business R&D is focussed on electronics; in Korea 40%.

Amongst G-7 countries, the selected industries represented a slightly lower proportion of all business R&D spending. These countries also tended to have a more equal mix of R&D spending amongst the selected industry categories. This may well be due to the fact that their economies are larger rather than to any conscious strategy. The odd-men out are Sweden, which has a degree of diversity in R&D that is similar to the majority of G-7 members and Canada, which is more comparable to the high R&D performers with respect to the importance of R&D in electronics and services.

Canada's business R&D efforts are somewhat more diversified than many of the high R&D performers. The top category is services, which account for 29% of R&D, with electronics close behind at 27% and aerospace at 12%. Canada has not relied on electronics to the same degree as Finland, but the impact of changes to the telecom sector (a key component of the electronic category) will likely be felt as data for 2001 and beyond become available. [20]

[20] In Canada, telecom component manufacturers were some of the largest business R&D performers. The major companies in the sector reported decreases in R&D in 2001. The overall level of business R&D decreased in 2001 if they are included, but it increased if they were excluded. See "Canadian R&D Flat in 2002", *The Ottawa Citizen*, September 5, 2002, p. D2. See also *Industrial Research and Development, 2002 Intentions*, Statistics Canada, Cat. No. 88-202-XIB.

Table 5.2 – Shifts in R&D in selected industries, 1989 to 1999

Country	aerospace	electronics	office machinery and computers	pharmaceuticals	instruments	services
Austria	--	10	-6	2	2	18
Denmark	0	0	-2	4	-4	12
Finland	0	33	-4	-1	-1	4
Iceland	0	-1	--	-6	-3	63
Ireland	0	2	1	5	0	4
Korea [a]	1	8	4	1	0	6
Sweden	-2	2	-2	6	4	5
Canada	**1**	**4**	**-1**	**3**	**0**	**6**
France	-7	4	-2	6	-8	5
Germany	-1	-8	-1	1	3	3
Italy	0	6	-5	-5	2	11
Japan	0	2	1	1	1	3
United Kingdom	0	1	-6	10	0	2
United States	-14	-1	-6	1	5	17

-- not available or applicable
[a] 1995-1999
Source OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Austria and Finland both reported significant shifts between 1989 and 1999, toward more R&D in the electronics sector. Iceland actually reported a decrease in electronics R&D to virtually zero, while Denmark reported steady levels around 7%. In all of the other high R&D performance countries, it remained steady, accounting for at least 20% of all industrial R&D throughout the 1990s. None of the G-7 countries reported significant increases in the proportion of electronics R&D and its overall proportion was lower than in the high R&D performance countries; Germany, in fact, reported a significant drop in the proportion of business R&D allocated to electronics.

The service sector reported increases in its proportion of total business R&D between 1989 and 1999 in all high R&D performance countries[21]. In Iceland, R&D within this sector increased 63%. Austria and Denmark also reported significant increases, while the other high R&D performance countries reported smaller shifts. As with the high R&D performers, R&D in services increased amongst all G-7 members.

Sweden and Ireland reported smaller increases in the proportion of business R&D in the pharmaceutical industry, while almost all high R&D performance countries reported declines in the proportion of R&D done in the office machinery and computer sector. The G-7 countries also reported small but consistent decreases in the proportion of business R&D in office machinery and computers. The proportion of R&D in instruments was down generally, with the exception of Sweden and Austria.

Aerospace was a very significant component of business R&D for G-7 countries, unlike in the high R&D performers. The United States reported a sizable drop in the proportion of R&D in this sector, which was matched by its increase in R&D in services.

Canada reported fairly minor shifts in its distribution of business R&D spending between 1989 and 1999, with small increases in electronics and services, thus resembling the members of the G-7 rather than the high R&D performance countries.

[21] In fact, services as a percentage of total business R&D increased in all OECD countries for which data were available in 1989 and 1999. OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Section 6: A Discussion of Indicators of R&D Performance

A comparison of GERD/GDP vs. growth in R&D as an indicator

Research and development performance can be measured with a variety of indicators. The most commonly used indicator has been the GERD/GDP ratio. Using this indicator, Canada ranked 15th amongst OECD members in 1999. The use of the GERD/GDP as an indicator can underestimate the extent to which a country has increased its actual R&D expenditures. This can happen when the growth in GDP increases at a greater rate than the increase in R&D expenditures. Similarly, if a country experiences an economic slowdown but continues to commit a set amount to R&D, its GERD/GDP ratio may actually improve. As the growth in GERD/GDP ratio can be affected by many factors, not just the growth in R&D, a significant increase in the investment that a country makes in R&D might not be registered.

An alternative indicator to measure a country's R&D performance is the absolute increase in the proportion of GDP allocated to R&D over a given period of time. This is a measure that more fully reflects the increasing commitment that a country makes to R&D as a proportion of GDP over time. According to this indicator, Canada's increase between 1989 and 1999 ranks 7th out of all members of the OECD.

An indicator of research and development performance that does not include GDP looks simply at the real (after inflation) increase in R&D spending. By comparing data for 1989 and 1999 in inflation adjusted currency the real rate of increase in spending can be calculated. By this measure Canada ranks 13th, ahead of all other G-7 countries, but with a lower the rate of increase in R&D spending than those reported by the countries identified as the high R&D performers.[22]

As rankings are relative measures, changes to the membership of the OECD also affect ranking. Most of the OECD members who joined during the 1990s reported lower levels of R&D as a percentage of GDP, with the exception of Korea. The addition of Korea caused many countries, including Canada, to shift downward one position. If Israel were to join the OECD as a full member, this would cause all countries on the list to drop as it reported a GERD/GDP ratio of 4.40 in 2000. A country seeking to improve its rank it must not only take into account the current membership, but those countries that may join over time. This makes it difficult to establish a relative target.

Indicators of BERD as the key indicators of R&D performance

The increase (or decrease) in the proportion of BERD that comprises the GERD is another alternative indicator to assess the performance of R&D. Behind the shifts in overall R&D spending is a clear trend that applies to virtually all of the OECD member countries – the rate of R&D spending is driven by the rate of business spending on R&D. In the majority of OECD countries the rate of business spending increased, sometimes quite significantly. Business R&D increased most significantly in the high R&D performance countries. Of those countries that reported decreases in business R&D (France, Germany, Italy, the United Kingdom, Switzerland, Norway), all but Norway reported drops in their overall GERD/GDP ratio and most had comparatively high levels of business R&D in 1989. A few countries, most notably the southern European countries of Greece, Portugal and Spain increased overall GERD/GDP ratios by increasing the proportion of GDP allocated to R&D done in institutions of higher learning.

The degree of specialization or diversification of the BERD between different industries is also an interesting indicator. This paper found that a key difference between the majority of the G-7 and the high R&D performers is the degree of diversification in business R&D. For the most part, the members of the G-7 engage in R&D in a broad range of industries, with no two sectors together accounting for more than half of their business R&D. Canada is the exception, with R&D in the electronics/communication and services sectors accounting for more than one half of its efforts. This type of indicator allows for a fine analysis of the underlying structure of business R&D in a given country.

[22] Note that a further measure, R&D per capita, could also be used to measure R&D intensity. Using this measure, Canada ranked 13th in 1999.

This indicator also provides the means to examine in more detail whether a smaller economy such as Canada has concentrated its R&D efforts in a limited number of industries or whether the effort is broad based. Amongst the high R&D performers, which are also smaller economies, all but Sweden report two top categories that account for more than half of their efforts. Specialization may allow smaller economies to develop depth of expertise within a particular field but may expose them to greater uncertainties if economic difficulties occur within their areas of specialization.

Ranking amongst the top five R&D performers amongst OECD members by 2010 is an ambitious target that will require that Canada break out of its position in the middle of the pack and increase its GERD/GDP ratio by a substantial amount. This target is all the more challenging since the EU announced its own target of reaching a GERD/GDP ratio of 3.0% by 2010[23] (and the EU member countries presently account for half of all OECD members).

Over the years between 1989 and 1999, Canada's R&D performance, as measured by its real R&D spending and its GERD/GDP ratio, improved. In fact, Canada's GERD/GDP ratio increased the most of all the G-7 countries and Canada reported the seventh largest absolute increase in GERD/GDP amongst all OECD countries. Its overall improvements in R&D spending were due to increases in R&D spending by business.

[23] OECD Science, Technology and Industry Outlook, OECD, 2002, p.4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Annex 1: Composition of General Expenditures on Research and Development of OECD members

Components of Gross Domestic Expenditures on Research and Development (GERD)
All OECD members, 1989 and 1999

	As a percentage of GDP				As a percent of GERD			As a percentage of GDP				As a percent of GERD		
	1989							**1999**						
	Total	BERD	GOVERD	HERD	BERD %	GOVERD %	HERD %	**Total**	BERD	GOVERD	HERD	BERD %	GOVERD %	HERD %
Australia	1.27	0.52	0.41	0.33	41	32	26	1.51	0.64	0.35	0.44	42	23	29
Austria	1.35	0.79	0.10	0.44	59	7	33	1.83	1.14	0.12	0.53	62	7	29
Belgium	1.64	1.10	0.10	0.42	67	6	26	1.96	1.40	0.06	0.47	71	3	24
Canada	1.47	0.74	0.28	0.44	50	19	30	1.80	1.02	0.22	0.54	57	12	30
Czech Republic	--	--	--	--	--	--	--	1.25	0.79	0.30	0.15	63	24	12
Denmark	1.51	0.83	0.29	0.37	55	19	25	2.09	1.32	0.32	0.42	63	15	20
Finland	1.80	1.11	0.33	0.35	62	18	19	3.22	2.19	0.37	0.63	68	11	20
France	2.29	1.38	0.55	0.34	60	24	15	2.19	1.38	0.40	0.38	63	18	17
Germany	2.86	2.07	0.37	0.41	72	13	14	2.44	1.70	0.34	0.40	70	14	16
Greece	0.37	0.08	0.16	0.13	22	43	35	0.67	0.19	0.15	0.33	28	22	49
Hungary	--	--	--	--	--	--	--	0.69	0.28	0.22	0.15	41	32	22
Iceland	1.01	0.20	0.50	0.25	20	50	25	2.33	1.09	0.70	0.49	47	30	21
Ireland	0.80	0.47	0.14	0.18	59	18	23	1.21	0.88	0.07	0.26	73	6	21
Italy	1.24	0.73	0.27	0.24	59	22	19	1.04	0.51	0.20	0.33	49	19	32
Japan	2.70	2.01	0.23	0.34	74	9	13	2.94	2.08	0.29	0.44	71	10	15
Korea	--	--	--	--	--	--	--	2.47	1.76	0.36	0.30	71	15	12
Mexico	--	--	--	--	--	--	--	0.40	0.11	0.13	0.16	28	33	40
Netherlands	2.04	1.21	0.35	0.44	59	17	22	2.02	1.14	0.33	0.53	56	16	26
New Zealand	0.87	0.28	0.42	0.17	32	48	20	1.11	0.31	0.37	0.48	28	33	43
Norway	1.69	0.96	0.33	0.41	57	20	24	1.70	0.95	0.26	0.49	56	15	29
Poland	--	--	--	--	--	--	--	0.75	0.31	0.23	0.21	41	31	28
Portugal	0.46	0.12	0.13	0.16	25	28	35	0.75	0.17	0.21	0.29	23	28	39
Slovak Republic	--	--	--	--	--	--	--	0.68	0.43	0.19	0.07	63	28	10
Spain	0.72	0.41	0.16	0.15	57	22	21	0.88	0.46	0.15	0.27	52	17	31
Sweden	2.83	1.85	0.11	0.87	65	4	31	3.78	2.84	0.13	0.81	75	3	21
Switzerland	2.83	2.12	0.12	0.56	75	4	20	2.64	1.95	0.03	0.62	74	1	23
Turkey	--	--	--	--	--	--	--	0.63	0.24	0.04	0.35	38	6	56
United Kingdom	2.15	1.49	0.30	0.33	69	14	15	1.88	1.25	0.23	0.37	66	12	20
United States	2.62	1.88	0.29	0.38	72	11	15	2.66	1.99	0.21	0.37	75	8	14
Total OECD	2.26	1.56	0.29	0.36	69	13	16	2.21	1.53	0.24	0.38	69	11	17

Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

BERD – Business Expenditures on R&D
GOVERD – Government Expenditures on R&D
HERD – Higher Education Expenditures on R&D (includes R&D activities in research hospitals)
Private Non-profit Expenditures on R&D are only included in the total R&D figure


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Annex 2: The Frascati Manual Definition of R&D

In order to compare data from various countries, members of the Organization for Economic Cooperation and Development (OECD) established a common framework of understanding for the measure of research and development activities.

The definition established by the OECD defines research and development as "creative work undertaken in a systematic fashion designed to increase the stock of knowledge". [24] Research and development (R&D) activities can fall into three broad categories: basic research, applied research and experimental development. Basic research is defined as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena … without any particular application or use in view". Applied research, by contrast, is "directed towards a specific practical aim or objective". Experimental development involves applying existing knowledge to produce new materials, products or devices, processes, systems or services or to significantly improve those already in produced.

There are, in many cases, fine lines between what is included in R&D and what is not. For example, education and training are not included and nor is specialized medical care, but research projects undertaken in teaching hospitals are included. Personnel who provide support to R&D activities are not included but their costs may be included under R&D overhead.

Activities excluded from R&D and exceptions to exclusions

	Excluded activity	Exceptions (included in R&D)
1	education and training	▪ Independent PhD. and post-doctoral research
2	"other related scientific and technological activities" such as routine data collection, testing and calibration, specialized medical care, legal patent work, routine software development	▪ If done solely for the purpose of R&D support ▪ "advanced medical care" involving research carried out in university hospitals ▪ software which involves scientific or technological advances
3	"other industrial activities" which includes ▪ all other steps necessary for the development and marketing of a manufactured product and the commercial use of a process and equipment ▪ industrial production, pre-production and distribution of goods and services	▪ prototype development ▪ pilot plants
4	Administration and other supporting activities such as: ▪ purely financial activities related to R&D; raising, managing and distributing funds ▪ indirect supporting activities such as: clerical support, transportation, cleaning, repair, maintenance and security activities	▪ costs of such activities (part of overhead expenditures by R&D performers)

[24] Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development (2002), OECD, Section 2

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