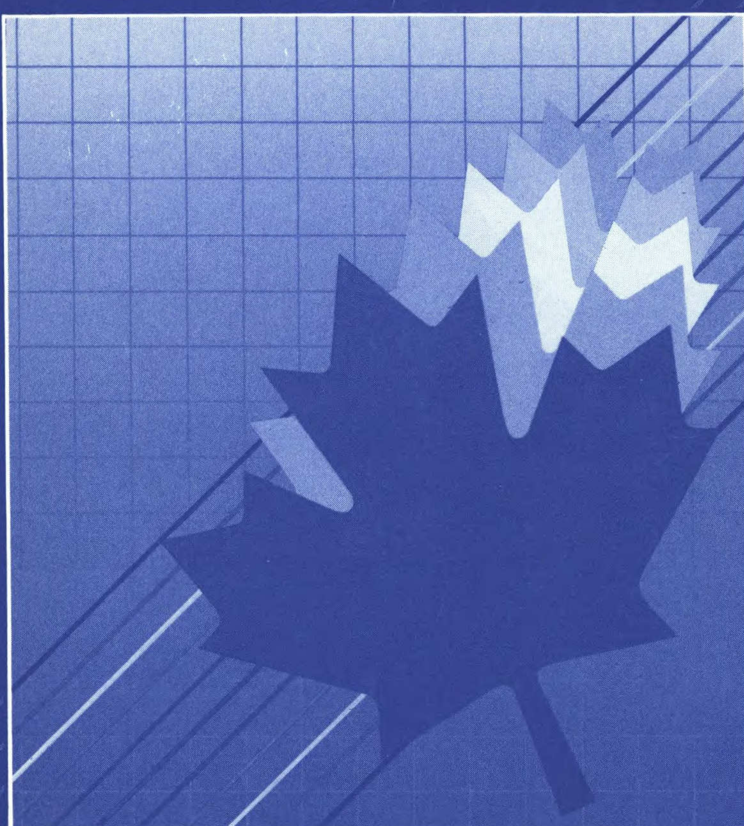
cience and
y Canada

Industrie, Sciences et
Technologie Canada

Science and Technology Resource Allocation Statistics



Canada

INNOVACTION

Science and Technology Resource Allocation Statistics

Prepared by:

S&T Statistics and Analysis Division
Economics and Statistics Directorate
Policy Sector
Industry, Science and Technology Canada
Ottawa, Ontario, Canada
K1A 1A1

Telephone: (613) 954-3477
Facsimile: (613) 954-1894

SEPTEMBER 1988
(Revised November 1988)

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ABRC	-	Advisory Board for the Research Councils (U.K.)
AECL	-	Atomic Energy of Canada Limited
AGR	-	Agriculture Canada
B	-	billion(s)
BE	-	business enterprise
CBC	-	Canadian Broadcasting Corporation
CC	-	Canada Council
CCPC	-	Canadian-controled Private Corporation
CFS	-	Canadian Forestry Service
CIDA	-	Canadian International Development Agency
CMHC	-	Canada Mortgage and Housing Corporation
COMM	-	Communications
EMR	-	Energy, Mines and Resources
ENV	-	Environment Canada
F&O	-	Fisheries and Oceans
FRG	-	Federal Republic of Germany (West Germany)
GDP	-	gross domestic product
GERD	-	gross expenditures on research and development
HQP	-	highly qualified personnel
IDRC	-	International Development Research Centre
ISTC	-	Industry, Science and Technology Canada
ITC	-	investment tax credit
M	-	million(s)
MOSST	-	Ministry of State for Science and Technology
MRC	-	Medical Research Council
NCR	-	National Capital Region
NDEF	-	National Defence
NHW	-	National Health and Welfare
NLC	-	National Library of Canada
NRC	-	National Research Council
NSE	-	natural sciences and engineering
NSERC	-	Natural Sciences and Engineering Research Council
OECD	-	Organisation for Economic and Co-operative Development
PNP	-	private non-profit organization
PRO	-	provincial research organizations
PY	-	person-year
R&D	-	research and development
RIE	-	Regional Industrial Expansion
RSA	-	related scientific activities
RSE	-	research scientists and engineers
S&T	-	science and technology
SRED	-	Scientific Research and Experimental Development Program
SRTC	-	Scientific Research Tax Credit

SSC	-	Supply and Services Canada
SSH	-	social sciences and humanities
SSHRC	-	Social Sciences and Humanities Research Council
STC	-	Statistics Canada
STIID	-	Science, Technology and Industry Information Division (OECD)
TPT	-	Transport Canada
U.K.	-	United Kingdom
U.S.	-	United States

LIST OF TABLES AND FIGURES

<u>NOTE</u>: All negative figures are shown in parentheses.

INTRODUCTION

The Science and Technology Resource Allocation Statistics (STRAS) is a compendium of S&T statistics issued by the S&T Statistics and Analysis Division of Industry, Science and Technology Canada (ISTC). The purpose of STRAS is to provide a sourcebook of S&T statistics for both quantitative and qualitative analysis. While the bulk of the material reviews the S&T and R&D resource allocation of the Government of Canada, national and international data are also provided in order to place the federal figures into context and provide comparative analyses.

S&T and Economic Analysis

The primary impetus for measuring S&T spending comes from the notion that the innovative capacity of domestic economies depends, to a considerable extent, on the rate of technical advance or progress.[1] In fact, the most recent Nobel prizewinner in economics, Robert Solow, was awarded that honour on the basis of his pioneering work which proved that technology, not capital, was the key factor in making economies grow. The relationship between the level of technological investment (especially in basic research) and the productivity gains made by mature industrial economies now forms an integral part of economic theory.

S&T policy analysis borrows from several academic disciplines including political economy, operations research and organizational theory. Because it is interrelated and interdisciplinary by nature, S&T policy analysis at a bare minimum, requires the development of systematic data to form the foundation for policy deliberation.

> Trying to follow a science policy, to choose objectives and to count the cost of alternative objectives, without such statistics, is equivalent to trying to follow a full employment policy in the economy without statistics on investment or employment. It is an almost impossible undertaking. The chances of getting rational decision making are very low without such statistics.[2]

A Framework for S&T Expenditure Analysis

S&T expenditures can be divided into two major areas: Research and Development (R&D) and Related Science Activities (RSA). As defined in the "Frascati Manual", the OECD document accepted as the international standard, R&D is:

---

1 Mansfield, E. *R&D's Contribution to the Economic Wealth of the Nation*, Research Management 15:31-46, 1972.

2 Freeman, C. *Science and Economy at the National Level*, Problems of Science Policy, OECD, Paris, 1968, p. 58.

> an activity which is carried out throughout the economy but which has certain special characteristics which distinguish it from the larger family of science activities and from the economic activities of which it is a part.[3]

R&D is composed of basic research, applied research and experimental development. All three of these activities and, in particular the latter, are important contributors to the innovation process. Because of this importance, R&D constitutes the primary focus of government's attention and, correspondingly, is the major instrument in its overall S&T strategy.

RSA refers to those activities which complement or extend R&D by contributing to the generation, dissemination and application of S&T knowledge. But, unlike R&D, RSAs are not creative activities. Most of the costs of these activities are for data collection, processing and the dissemination of information. This information is used for a wide variety of purposes in both the public and private sectors. These include economic, financial and business planning, and natural resources and environmental management.

RSA, by itself, does not lead to the creation of new wealth. Because of its effect on the innovation process and its perceived importance, R&D constitutes the primary focus of governmental attention and, correspondingly, is made a major instrument in the government's overall S&T policy.

In order to understand R&D activity and its role in S&T policy making, one must examine it both in terms of the organizations funding and performing R&D (institutional classification) and in terms of the nature of the R&D programs conducted (functional distribution). While the institutional classification system allows analysts to observe the differentiation of roles, the functional distribution system focuses on the character of R&D itself. Yet, R&D is only <u>one</u> of the steps in the complete innovation process. As such, limitations are imposed on the utility of indicators designed to measure R&D's impact on the innovation process.

The federal government, private industry and universities constitute the dominant players in the R&D system. Besides being the largest single funder of R&D expenditures, the federal government indirectly funds R&D activity through the provision of tax expenditures. In addition to the dominant players, provincial governments, provincial research organizations, private non-profit institutes and foreign performers are statistically significant entities.

<u>S&T Indicators</u>

The simplest method of measuring S&T activities is to measure the human and financial resources devoted to it. While these are the most common measures, they suffer from the fact that they do not reflect the quality of the work done, or allow for weighted comparisons between different countries.

---

[3] <u>The Measurement of Scientific and Technical Activities 'Frascati Manual'</u>, OECD, Paris, 1981, p. 13.

While it might be advantageous to treat S&T policy as a distinct subset of economic activity, it is difficult to correlate S&T inputs with S&T outputs. Because it is difficult to apply numerical values to S&T outputs and since the "value" of the final product is the result of a combination of many inputs of which scientific research is only one, "science accounting" should be thought of more in terms of the ways resources are allocated over different categories of science expenditures rather than in "input/output" terms.

> Indicators provide indirect information of the phenomena or events to which they are applied. An indicator is a measure of one item used to provide information about another, immeasurable item. For example, statistics on the number of scientists and engineers, and on their levels of training, are indicators of the quality and quantity of S&T knowledge available. Expenditures on R&D are indicators of the levels and sites of the indigenous generation of S&T knowledge. Patent statistics are indicators of the intensity, direction and location of inventive activity.[4]

Consequently, different series of indicators must be developed in order to gain the fullest understanding of the S&T "enterprise".

1. GERD/GDP

Arguably the best-known S&T indicator, the GERD/GDP ratio measures the Gross Expenditures on Research and Development to the Gross Domestic Product. An indicator of the creation and exploitation of S&T, the GERD/GDP ratio is a summary statistic used in the planning framework of the governments of a number of countries, including Canada.

Two factors provide the rationale for the widespread use of GERD/GDP. First, it is easy to calculate; secondly, this indicator acknowledges the relationship R&D has to the economy.

Much attention has been given to Canada's relatively low GERD/GDP ratio compared to those of other OECD nations. In their submission to the Standing Senate Committee on National Finances, Drs. Palda and Pazderka[5] outlined four reasons why the level of R&D activity in Canadian industry is low compared to that of other countries. These included the following:

---

4 Quoted by Stead, H. in Science and Technology Indicators in Canada and the United States of America, Statistics Canada, Ottawa, December 1985.

5 Palda, Dr. K.S. and Pazderka, Dr. B. Report of the Standing Senate Committee on National Finance - Federal Government Support for Technological Advancement: An Overview, (Doody Committee), 1984, pp 12-13.

(a) industrial structure;
(b) defence R&D;
(c) market size; and
(d) foreign ownership.

Each of these factors, the brief argued, gave the appearance of a poorer performance than might otherwise be judged. Hence, in using summary statistics, prudence dictates the manner in which indicators are to be used for comparative analyses.

On a strictly econometric basis, it can be demonstrated that GERD is a non-linear function of GDP, an exponential function, whose exponent is greater than one. This suggests that the GERD/GDP ratio is different for different sizes of economies, and that the larger the economy, the greater the percentage of resources devoted to R&D. This implies that R&D expenditures are discretionary, and that R&D spending is a product of economic activity. This view is in contrast to the synergistic relationship suggested by Freeman and others. For a free-market economy with Canada's GDP, the GERD/GDP ratio should be about 1.7 per cent. The difference between this figure and the actual figure may be explained by the factors suggested by Palda and Pazderka.

2. R&D Capital Stock

Recently, a new indicator has been introduced that treats R&D, not as an operating cost, but as a capital cost which can be depreciated over a set period as the R&D becomes part of the common base of knowledge.[6] It is calculated by treating annual R&D expenditures as payments into a sinking fund, depreciated over a fixed period. What makes this indicator valuable are the inferences that can be drawn from the trends in the capital stock estimates. In policy terms, the measurement of capital stock provides an indication of management policies and a determination of whether policy decisions taken by management have had the desired effect.

3. Trade in High-Technology Products

Some products, such as computers, embody a greater degree of technology than do others, such as lumber. Thus, import/export statistics for high-technology products give an indication of comparative technological advantage. If expenditures on R&D are not fulfilling the desired effects of increased productivity and real increases of per capita income, a country may have to "buy" technology today in order to improve productivity in the future.

Determination of which commodities are "high-tech" is somewhat arbitrary. However, the OECD has proposed a list[7] which provides a basis for

---

[6] Stead, H. A Note on R&D Capital Stock Estimates, (ST-87-15), Statistics Canada, Science, Technology and Capital Stock Division, Ottawa, November 1987.

[7] Ibid., 1987.

international comparisons. This list is used by Statistics Canada. The list does not include any services.

Because many high-technology commodities are capital goods, it can be argued that an expanding economy could support an increased high-technology trade deficit if the deficit were caused solely by the increased demand for capital goods. Therefore, a deficit is not necessarily a "bad" thing and may simply be taken as a loss in the current account.[8]

4. Technology Balance of Payments (TBP)

The TBP registers the flow of proprietary knowledge and know-how into and out of a country. It consists of money paid or received for the use of patents, licences, trademarks, designs, inventions, know-how and technical assistance, etc. However, measurement problems impair the universality of this indicator and, thus, it should be considered only as a partial measure of international technology flows.[9]

Canada, as with most of the smaller OECD countries, is in the situation where it has both a negative TBP and a deficit in high-technology trade. This is, in effect, the phase where the national economy is investing in technology by acquisition in the expectation that it will be used to increase productivity and competitiveness in the future.

5. Scientific Literature and Patent Statistics

The results of R&D are difficult to quantify and even more so is its value to the economy or to society as a whole. As a result, scientific literature and patent indicators are used as surrogate measures of R&D outputs. Interest in these indicators has grown substantially in the last three to five years and major studies have been completed or are in progress in the U.K., the U.S., Japan and the Netherlands.

Scientific literature is one of the major direct outputs of research. Scientific and technical findings are generally published in professional journals and thus add to the body of world scientific knowledge, since scientists and engineers of all countries generally have access to this body of knowledge. Thus, although they do not indicate the importance of individual publications, publication counts have long been accepted as output indicators of basic and applied research. Nowadays, these are usually complemented by citation indicators. These are used to measure the influence and quality of the research effort and are based on the assumption that the most significant literature will be more frequently cited than the less important literature. Similarly, patent counts are used as indicators of technological activity. These are complemented

---

[8] Ibid., 1987.

[9] The Technological Balance of Payments: Main Issues for Discussion Regarding the Proposed Standard Practices for the Collection and Interpretation of Technology Balance of Payments Data, (STIID 6847S), OECD, Paris, November 1987.

by indicators of technological quality that are based on the number of times a patent is cited in subsequent patents.

6. Highly-Qualified Personnel (HQP)

The fundamental requirement for any work in S&T is qualified personnel: scientists, engineers and technologists. Thus, numbers of HQP in the workforce and HQP as a percentage of the total workforce are indicators of levels of technological activity. Both the supply and demand of HQP are important inputs into both Granting Council policies and the overall management of human resources in S&T. However, international comparisons can be difficult because of variations in the definitions of occupations and levels of training.

* * *

A. HOW THE GOVERNMENT OF CANADA SPENDS ITS S&T BUDGET

The federal government is the largest single funder and performer of science and technology in Canada and, as a result, its expenditure decisions influence S&T spending in Canada. Although S&T expenditures are not managed as an envelope in the Cabinet committee system, the S&T Decision Framework has been designed to ensure that expenditures are considered as a co-ordinated whole rather than as a series of unrelated decisions. This process is an important one, for S&T plays a significant role in federal expenditures. The aggregate expenditures on S&T are larger than either the external affairs and aid envelope or the services to government envelope in the 1988/89 Main Estimates.

1. Federal S&T Expenditures

Federal S&T expenditures in 1988/89 will total $4.41 billion, about double their level in 1980/81. Table A-1 shows the growth of federal S&T expenditures since 1980/81, in actual as well as in constant 1981 dollars. Federal S&T expenditures have grown at an average real rate of about 3.2 per cent per annum from 1980/81 to 1988/89. S&T expenditures represent about 4 per cent of total federal expenditures and about 11 per cent of the non-statutory portion of the Main Estimates. The non-statutory portion is that part of the Estimates not set by other legislation and, therefore, more likely to be subject to the processes of government review and restraint.

TABLE A-1
FEDERAL S&T EXPENDITURES

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89
	(billions of dollars)								
Actual dollars	2.27	2.74	3.08	3.48	3.87	3.93	4.18	4.17	4.41
1981 dollars	2.51	2.75	2.83	3.05	3.29	3.22	3.33	3.18	3.23
Per cent real growth from previous year	2.9	9.6	2.9	7.8	7.9	(2.1)	3.4	(4.5)	1.6
Per cent of non-statutory expenditures	10.6	9.8	10.1	10.2	10.5	10.7	11.2	11.0	10.8

Sources: Statistics Canada, Federal Scientific Activities 1986/87, Catalogue No. 88-204, December 1987.
Treasury Board, Main Estimates, Part I, 1988/89.
Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

2. Federal S&T Expenditures: R&D and RSA

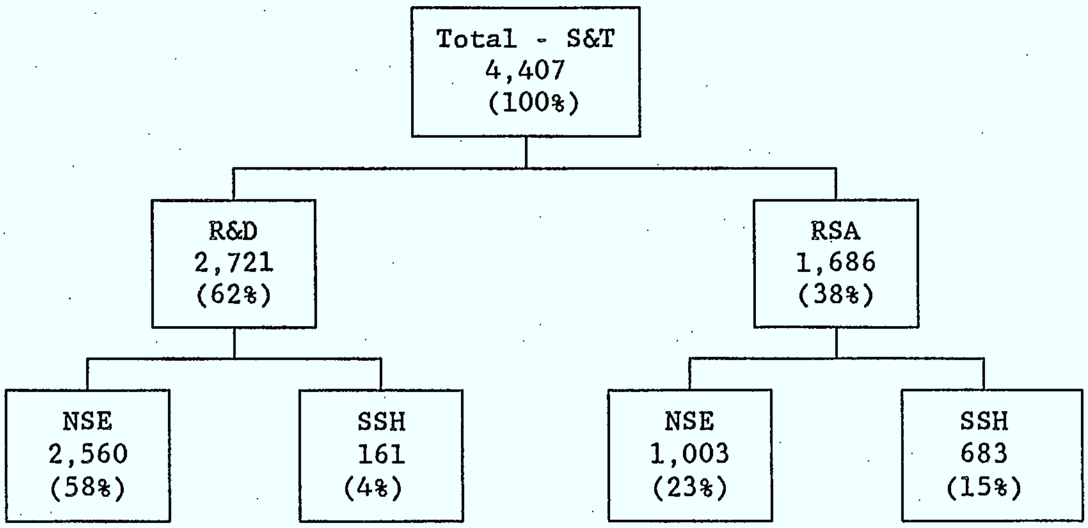
Federal expenditures on R&D will total $2.72 billion in 1988/89 and account for 62 per cent of the federal S&T budget. Because R&D is central to the policy process, federal R&D expenditures represent a major instrument for the implementation of S&T policy.

The $1.7 billion in RSA expenditures account for 38 per cent of the total S&T budget. Unlike the macro-economic concerns that shape the debate over R&D policy, the policy issues in RSA are usually quite specific to the types of services provided and often reflect strong client perceptions of the level of government involvement in that economic or social activity.

S&T expenditures are also divided by subject area into the natural science and engineering (NSE) and the social sciences and humanities (SSH). While activity in NSE tends to be tied to economic development objectives, SSH activity includes social development as well as economic objectives.

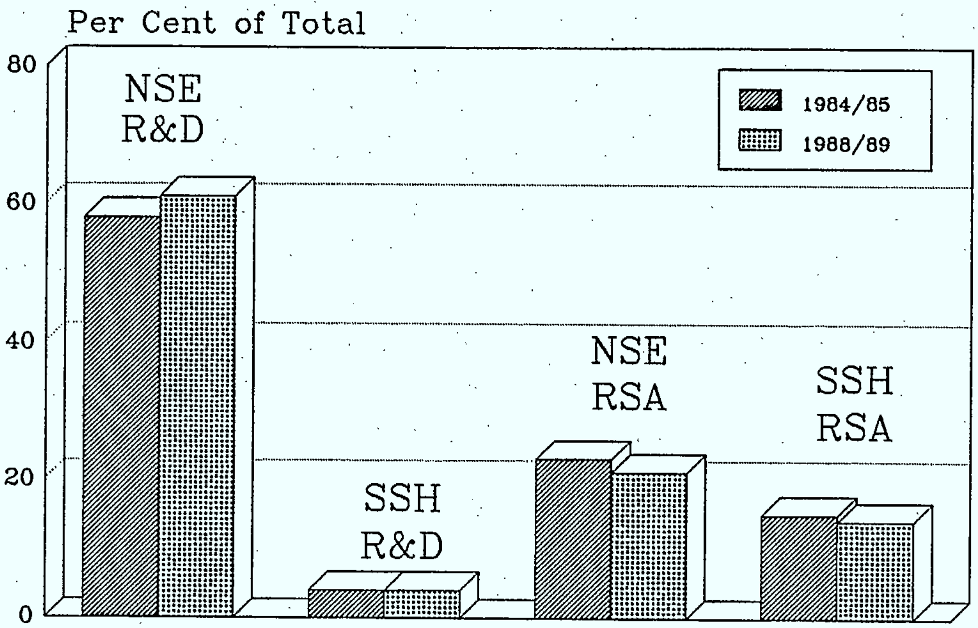
Figure A-1 shows the division of federal S&T expenditures for 1988/89 into these categories. Figure A-2 compares 1984/85 percentages of federal S&T expenditure to those of 1988/89.

FIGURE A-1
FEDERAL S&T EXPENDITURES, 1988/89 (MILLIONS OF DOLLARS)



Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

FIGURE A-2
FEDERAL S&T EXPENDITURES, 1984/85 AND 1988/89



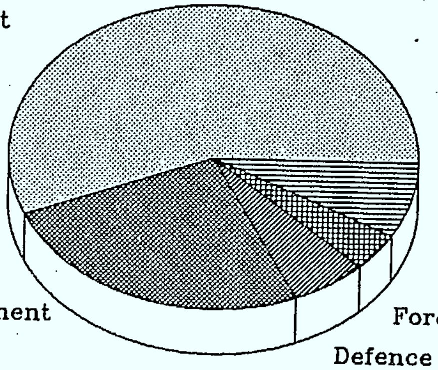
Sources: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.
Statistics Canada, Federal Science Expenditures and Personnel, 1986/87, March 1986.

In addition to the direct expenditures on R&D, it is estimated that the federal government provided a tax relief in the form of Investment Tax Credits (ITC) of another $770 million of R&D through the tax system. ITCs are, however, taxable and therefore the net relief is somewhat less than $770 million. While this issue is discussed further in Section 10 of Part A, the size of the expenditures underscores the government's strategy of using R&D expenditures to further economic development.

3. S&T Expenditures by Policy Envelope

Figure A-3 shows the distribution of S&T expenditures by Cabinet envelope. As suggested by Figures A-1 and A-2 above, R&D expenditures, comprised predominantly of NSE activity, tend to fall in the economic and regional development envelope, while RSA are more evenly distributed between economic and social development envelopes. The concentration of R&D in the economic and regional development envelope is demonstrated by the fact that 71 per cent of federal R&D expenditures and 57 per cent of all federal S&T expenditures are contained in that envelope. The S&T in the government services envelope is almost entirely attributed to Statistics Canada.

FIGURE A-3
FEDERAL S&T EXPENDITURES BY ENVELOPE, 1988/89



$4.41 BILLION FEDERAL S&T EXPENDITURES
(DOES NOT INCLUDE $770 MILLION IN TAX EXPENDITURES)

Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

4. S&T Expenditures by Department

The federal S&T effort is highly fragmented among 77 programs and 53 organizations that report to 25 Ministers. Of these organizations, as shown in Table A-2 and Figure A-4, 16 have S&T expenditures greater than $50 million/year and account for about 91 per cent of the total S&T budget. Of these 16 departments, five have S&T expenditures greater than $300 million in 1988/89. These five, AGR, EMR, ENV, NRC and NSERC, account for 45 per cent of the total S&T budget.

In terms of growth, the three departments and agencies with the greatest average annual real growth from 1984/85 to 1988/89 are RIE, CIDA and NDEF, with growth rates of 8.9, 8.3 and 4.7 per cent respectively. In contrast, the growth rate of SSHRC remained constant and that of nine others declined.

Although NHW and NDEF are big S&T spenders, their S&T expenditures are a small proportion of their total program expenditures. On the other hand, research organizations such as NRC, the Granting Councils and IDRC spend all or almost all of their budget on S&T. STC, as a major RSA performer, also has its total expenditures allocated to S&T. Some departments may have S&T expenditures greater than their voted estimates due to the inclusion of S&T activities which are cost-recovered from outside the government.

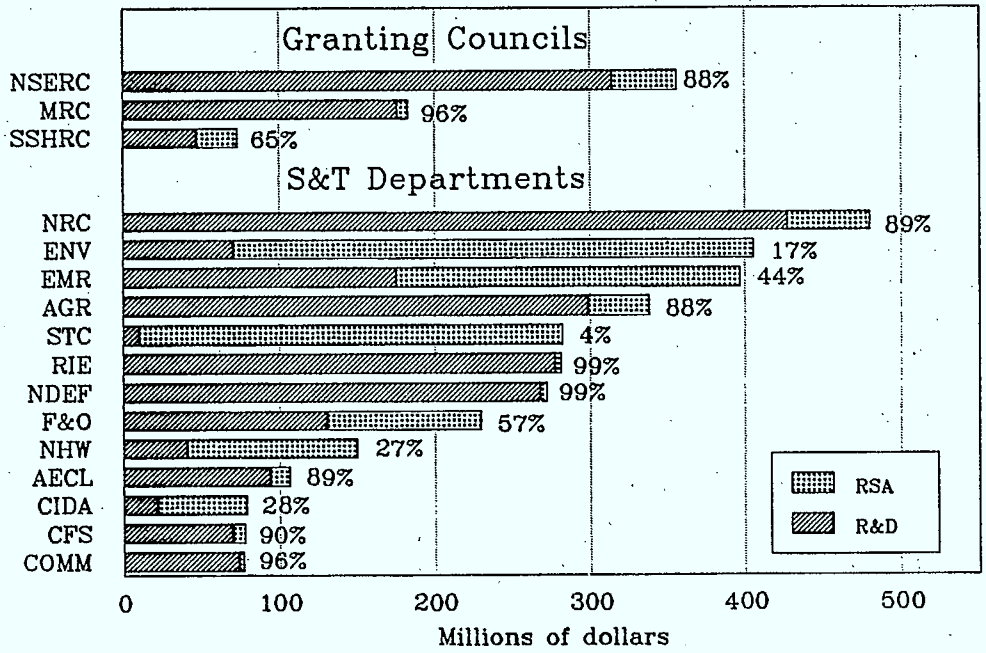
TABLE A-2
FEDERAL S&T EXPENDITURES BY DEPARTMENT, 1988/89[1]

Department/ Agency	R&D	RSA	Total S&T	Real Average Annual Growth Rates 1984/85 to 1988/89
	(millions of dollars)			(per cent)
NRC	427	52	480	(3.8)
ENV	71	335	405	(0.6)
EMR	175	222	397	0.9
NSERC	314	41	356	(0.4)
AGR	299	39	338	(1.9)
STC	10	271	282	(0.1)
RIE	277	4	281	8.9
NDEF	268	4	272	4.7
F&O	131	98	229	(7.1)
MRC	176	7	183	0.2
NHW	41	109	150	2.3
AECL	95	12	107	(11.5)
CIDA	22	57	79	8.3
CFS	70	7	78	(2.7)
COMM	74	3	77	(8.4)
SSHRC	48	26	73	0.0
Others	223	399	622	n.a.
Totals	2,721	1,686	4,407	(0.4)

1. Columns may not add due to rounding.

Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

FIGURE A-4
FEDERAL S&T EXPENDITURES BY DEPARTMENT, 1988/89[1]



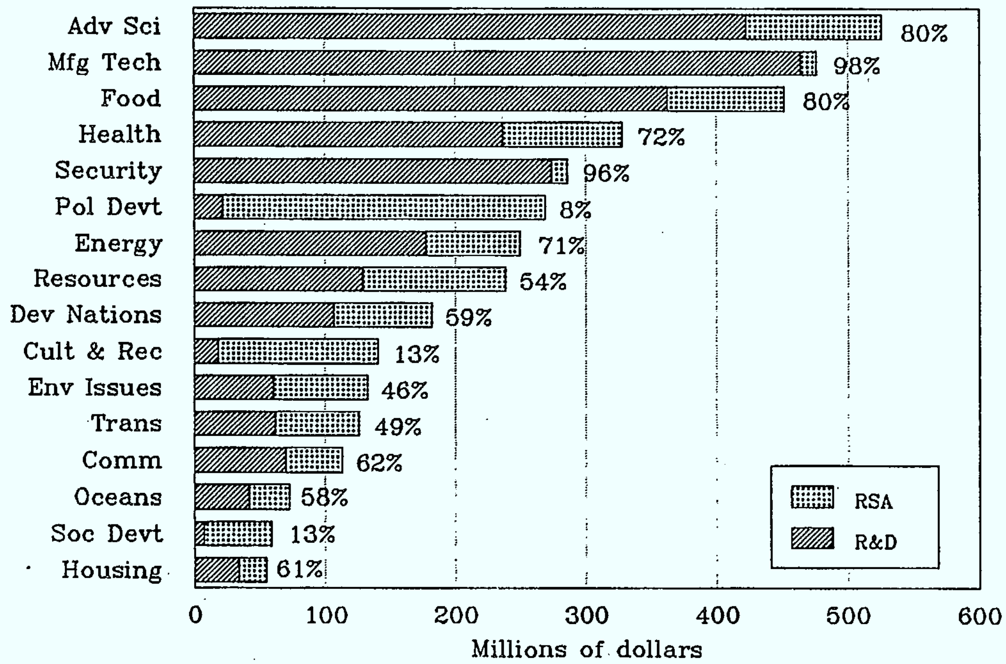
1. The figure beside each bar represents the percentage of R&D relative to total S&T expenditures for each department or agency.

Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

5. S&T Expenditures by Areas of Application

It is possible to divide federal S&T activities into subject areas simply by looking at the resources allocated by the various departments and their mandates. Thus, Agriculture for example, has a clear requirement to carry out S&T programs as part of its mandate to support the food industry, and the Granting Councils support university R&D. However, S&T is interdisciplinary and it is useful to know what the total effort is in any given area of application. Thus, Agriculture or the Granting Councils may support work in transportation while fulfilling their respective mandates. Figure A-5 shows the extent of federal S&T expenditures by area of application. A more detailed representation of the areas of application, along departmental lines, is seen in Table A-3 (page 8). From Figure A-5, it can be observed that the areas of application in which S&T expenditures exceed $300 million -- advancement of science, manufacturing technology, food and health -- are also the major areas of application for R&D spending.

FIGURE A-5
FEDERAL S&T EXPENDITURES BY AREA OF APPLICATION, 1988/89[1]



1. The figure beside each bar represents the percentage of R&D relative to total S&T expenditures for each area of application.

Source: Based on data from Statistics Canada, Main Estimates Science Addendum, 1988/89, March 1988.

TABLE A-3
FEDERAL S&T EXPENDITURES BY AREA OF APPLICATION AND BY DEPARTMENT, 1988/89

	AGR	AECL	CIDA	COMM	EMR	ENV	F&O	IDRC	MRC	NHW	NRC	NSERC	NDEF	NLIB	NMC	RIE	MOSST	SSHRC	STC	TRANS	OTHER	TOTAL
Adv Sci-Basic				3.1	2.4	0.5					112.8	322.6					1.5	72.3			1.5	516.7
Adv Sci-Strat				0.9		0.4											7.8				0.0	9.1
Comm				60.6								5.3		36.2					0.4		10.5	113.0
Cult & Rec				0.4		7.7									103.6				2.3		26.6	140.5
Dev Nations			78.5					103.2													0.0	181.7
Energy	2.9	101.2			110.0	6.4	5.7				8.7	2.2							0.8	0.1	11.0	249.3
Env Issues					34.6	63.9	18.3				4.8	3.1									7.9	132.6
Food	300.0				0.3	0.8	106.8				28.0	3.7							9.7		2.2	451.6
Health		5.4			3.6				182.6	110.6	19.4								5.9		0.3	327.8
Housing					0.9	6.3					25.8								3.2		18.9	55.1
Mfg Tech				3.4	3.5						181.6					279.8	7.8				0.0	476.1
North Devt					6.3																4.3	10.6
Oceans					1.1	27.6	40.0					1.8									2.1	72.6
Pol Devt				0.2	0.4					7.5							13.3		201.4	0.1	45.8	268.7
Resources	68.2				117.1	46.6															6.6	238.5
Security					0.4						4.8		269.2								11.3	285.7
Soc Devt										15.4									17.9		25.8	59.1
Space				5.0		7.0					32.9						7.3				1.1	53.3
Trans							50.9				33.6								4.9	33.9	2.7	126.0
Other					72.3	203.3						15.9									63.5	355.0
Total	371.0	106.6	78.5	73.6	352.9	370.5	221.7	103.2	182.6	133.5	452.4	354.5	269.2	36.2	103.6	279.8	37.7	72.3	246.5	34.1	242.5	4123.2

Note: This table excludes non-program costs.
Source: Statistics Canada, Main Estimates Science Addendum, PYs and Applications, 1988/89.

6. Federal S&T by Performer

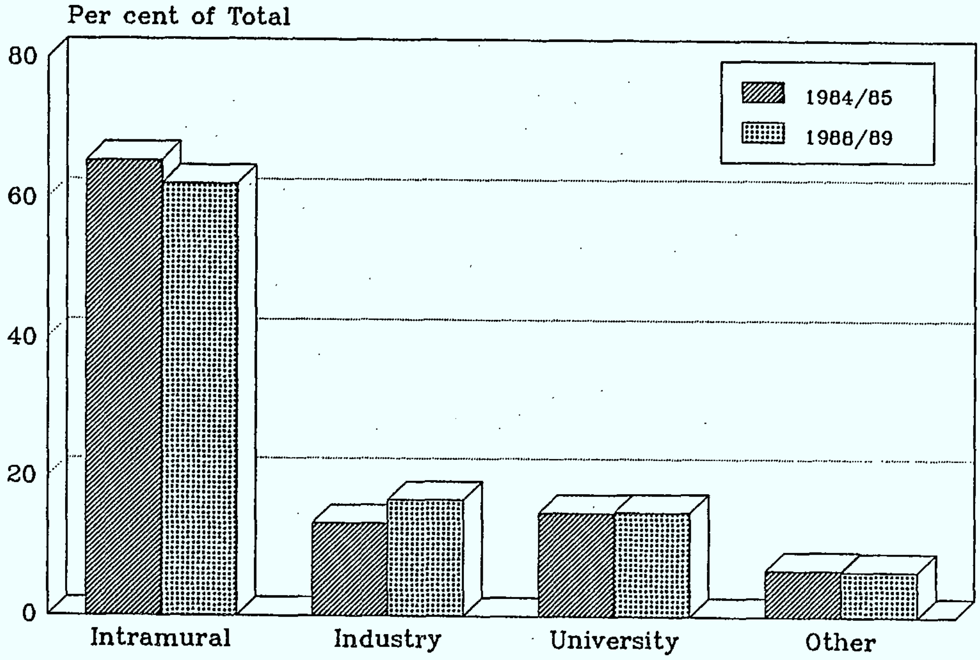
There are three major performers of federally funded S&T: federal laboratories, industry and Canadian universities (Table A-4 and Figure A-6). The federal scientific establishment is by far the largest performer and in 1988/89 will spend 62 per cent of the total. The next largest share, 17 per cent, will be spent in the industry sector. Canadian universities will receive 15 per cent of all federal funding.

TABLE A-4
FEDERAL GOVERNMENT EXPENDITURES BY PERFORMING SECTOR, 1982/83 TO 1988/89

Sector of Performance	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89e
	(millions of dollars)						
Intramural	2,039	2,278	2,531	2,544	2,761	2,697	2,734
Industry	402	452	515	559	575	588	734
Universities	460	530	592	592	604	628	658
Non-Profit Institutions	24	40	37	35	37	39	40
Other	54	76	77	70	69	74	80
Foreign	96	108	122	129	135	142	161
Total	3,075	3,484	3,874	3,929	4,181	4,168	4,407

Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

FIGURE A-6
FEDERAL S&T EXPENDITURES BY PERFORMER, 1984/85 AND 1988/89

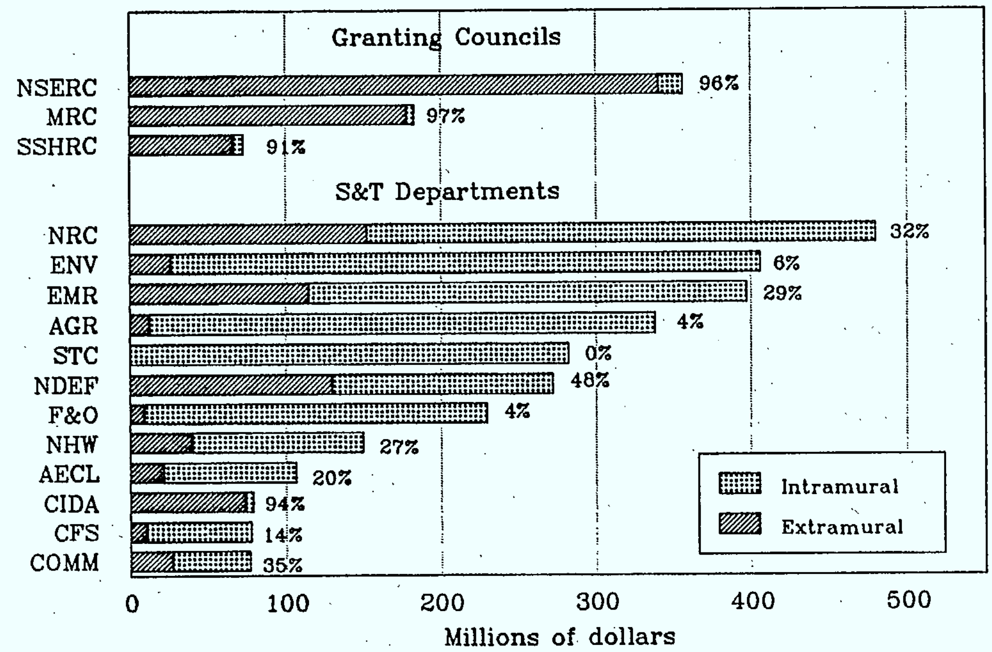


Sources: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.
Statistics Canada, Federal Science Expenditures and Personnel, 1986/87, March 1986.

The distribution of performance shares varies with the field of science (NSE or SSH), the type of activity (R&D or RSA), and the mission of the funding department or agency. As a general rule, the intramural share is greatest in SSH and for related scientific activities such as data collection, scientific information, museum services, operations and policy studies. The extramural programs are heavily oriented towards R&D (industry 85 per cent, universities 89 per cent) while the intramural programs are more evenly split between R&D and RSA (48 per cent) due to the service element of intramural S&T activities.

Figure A-7 shows federal extramural S&T expenditures by department for 1988/89. Spending on R&D contracts has increased at a faster rate than expenditures on intramural R&D. R&D contracts grew by about 5 per cent between 1987/88 and 1988/89, while intramural spending on R&D declined.

FIGURE A-7
FEDERAL EXTRAMURAL PERFORMANCE, 1988/89[1]



1. The figure beside each bar represents the percentage of extramural performance.

Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

More than half of federal R&D is performed in the extramural sector (Table A-5). This extramural share will increase from 50 per cent in the previous year to 57 per cent in 1988/89. Most of this increase is due to a 29 per cent growth in payments to industry; these payments will grow from $480 million to $622 million. As a result, industry's share of federally-funded R&D will rise from 18 per cent in 1987/88 to 23 per cent this year.

TABLE A-5

TOTAL FEDERAL S&T EXPENDITURES BY ACTIVITY, 1987/88 AND 1988/89

Activity	1987/88 Millions of dollars	1987/88 Per Cent of Total	1988/89 Millions of dollars	1988/89 Per Cent of Total	Real Rate of Change
Extramural					
R&D contracts	270.4	6.5	283.3	6.4	0.6
R&D grants	902.3	21.6	1,073.6	24.4	14.3
R&D fellowships	40.2	1.0	43.8	1.0	4.6
Related science activities	259.2	6.2	272.6	6.2	1.0
Total Extramural	1,472.1	35.3	1,673.4	38.0	9.2
Intramural					
Intramural R&D	1,122.9	26.9	1,040.0	23.6	(11.0)
Intramural RSA	1,192.0	28.6	1,282.3	29.1	3.0
Capital	260.9	6.3	286.9	6.5	5.6
Administration	120.5	2.9	124.4	2.8	(0.9)
Total Intramural	2,696.3	64.7	2,733.6	62.0	(2.6)
Total S&T	4,168.4	100.0	4,407.0	100.0	1.5

Source: Statistics Canada, Science, Technology and Capital Stock Division.

During the last ten years, the overall trend has been towards a greater centralization of intramural S&T activities within a relatively small number of departments and agencies. The five largest intramural programs (AGR, ENV, NRC, EMR, STC) now account for 60 per cent of the total expenditures as compared with 53 per cent in 1976. The top ten will spend 85 per cent, a gain of four percentage points over the period.

Federal laboratories are important sources of Canadian inventions. Between 1978 and 1984, more than 480 Canadian patents were granted to federal laboratories. NDEF, NRC and AECL are the major patentees. NDEF was granted almost half of all federal patents, NRC about one-fifth, and AECL nearly one-sixth. Between 1978 and 1984, the federal government received as many patents for Canadian inventions as Northern Telecom, and three times that of the next largest corporate patentee, Canadian General Electric.

Support for R&D in industry is highly concentrated among three departments and agencies. In 1988/89, for example, RIE will provide approximately 35 per cent of the funds, NRC 15 per cent and NDEF 15 per cent (Table A-6).

TABLE A-6
FEDERAL S&T EXPENDITURES BY DEPARTMENT AND BY PERFORMER, 1988/89

Department/ Agency	Intramural	Industry	University	Non-Profit Institutions	Provincial Government	Foreign	Other	Total by Department
	(millions of dollars)							
AGR	392.0	14.1	4.7	1.8	0.5	1.1	1.2	415.4
AECL	84.8	20.1	0.9	0.1	..	0.2	0.5	106.6
CIDA	4.6	50.7	2.3	..	..	21.4	0.1	78.9
COMM	49.6	16.5	1.0	..	..	9.4	0.2	76.6
EMR	281.8	55.4	8.7	2.0	19.2	24.5	5.4	397.0
ENV	379.0	9.7	2.1	2.3	3.7	0.9	7.6	405.3
F&O	220.2	6.9	1.5	0.2	..	..	0.5	229.3
IDRC	31.3	0.4	5.7	0.3	..	64.7	0.8	103.2
NDEF	141.8	112.0	12.3	0.7	0.5	4.4	..	271.7
NHW	109.8	2.8	17.6	13.5	2.1	1.1	2.7	149.6
NRC	327.2	111.3	29.7	0.5	..	6.1	4.9	479.7
RIE	17.7	253.8	3.1	..	3.6	..	3.0	281.2
STC	281.8	..	..	..	..	..	..	281.8
NSERC	15.3	4.8	326.6	0.5	..	6.7	1.8	355.7
MRC	4.6	..	171.7	0.6	..	5.5	0.6	183.0
SSHRC	6.7	..	55.0	5.2	..	6.3	0.1	73.1
Others	385.4	75.1	15.5	12.5	14.8	8.6	7.0	518.9
Totals	2,733.6	733.6	658.4	40.2	44.4	160.9	35.9	4,407.0

Source: Statistics Canada, Federal Science Expenditures & Personnel, 1988/89, April 1988.

Federal support for sponsored research is concentrated in the larger universities. In 1986/87, for example, the top ten received about three-fifths of the total grants and the top sixteen more than three-quarters. Ontario had four universities in the top ten and Quebec three. Table A-7 shows the top sixteen recipients of federal grants for sponsored university research.

TABLE A-7
FEDERAL R&D GRANTS TO CANADIAN UNIVERSITIES, 1986/87

Universities	Grants --($ M)--	Total Funding ---(per cent)--
Toronto	59.1	11.3
British Columbia	51.8	9.9
McGill	43.0	8.4
Alberta	25.5	4.9
Montreal	24.1	4.6
Manitoba	21.8	4.2
Waterloo	21.5	4.1
McMaster	21.5	4.1
Laval	21.4	4.1
Western Ontario	19.5	3.7
Queen's	17.4	3.3
Calgary	17.0	3.3
Saskatchewan	16.5	3.2
Guelph	16.2	3.1
Dalhousie	15.9	3.0
Ottawa	15.2	2.9
Total funding to all Canadian universities	520.6	100.0

Source: Canadian Association of University Business Officers, Financial Statistics of Universities and Colleges, 1986/87, March 1988.

7. Regional Distribution of Federal S&T

In 1986/87, the latest year for which regional data are available, the Government of Canada spent $2.4 billion on R&D and $3.7 billion on S&T in total. Because of the way the statistics are collected, in a separate survey of regional institutions, the total of federal expenditures for 1986/87, by region, does not add up to the total $4.2 billion. The difference lies mainly in unallocated overhead costs and foreign S&T expenditures.

Table A-8 shows the regional distribution of federal S&T financial resources, with the National Capital Region shown as a separate entity. In 1986, more funds were spent in the National Capital Region (37 per cent) than in any other region. Ontario had the second highest level of expenditures (20 per cent), and Quebec the third (15 per cent).

As a result of their dominance in extramural S&T, Ontario and Quebec were the only two regions in which less than half of federal expenditures were allotted to intramural performers. The NCR, P.E.I., Manitoba and Nova Scotia, on the other hand, were very dependent on federal intramural activities. Each of these regions had more than three-quarters of federal expenditures earmarked for intramural programs.

Although the NCR continued to receive the largest proportion of NSE funds, in the period 1981 to 1986, its share decreased from 32 per cent to 28 per cent. Conversely, Quebec saw its portion increase by almost the same amount, from 13 per cent to 18 per cent. In the other regions of the country, expenditure distribution remained constant.

TABLE A-8

FEDERAL S&T EXPENDITURES BY REGION AND BY PERFORMER, 1986/87

Region	Intramural	Extramural: Canadian Industry	Extramural: Canadian Universities	Extramural: Other Canadian Performers	Total	Per Cent of Total[1]
	(millions of dollars)					
Newfoundland	50	4	9	3	66	2
P.E.I.	9	5	1	1	16	0
Nova Scotia	118	16	20	4	158	4
New Brunswick	32	17	8	9	66	2
Que. (ex. NCR)	229	177	142	20	568	15
NCR	1,258	81	22	13	1,374	37
Ont. (ex. NCR)	351	163	208	22	744	20
Manitoba	111	12	22	6	151	4
Saskatchewan	48	9	20	4	81	2
Alberta	101	16	46	3	166	4
B.C.	148	40	86	7	281	8
Yukon and NWT	23	..	..	1	24	1
Canada	2,478	540	584	93	3,695	100

1. Due to rounding, this column does not add up to 100%.

Source: Statistics Canada, Science Statistics, Cat. No. 88-001, Vol. 12, No. 7, July 1988.

Please note that the distribution of R&D as shown in Figure A-8 differs substantially from the distribution of S&T due to the concentration of RSA in the NCR.

TABLE A-9

FEDERAL R&D FUNDING BY REGION AND SECTOR OF PERFORMANCE, 1986/87

Region	Intramural	Industry	University	All R&D[1]	Per Cent of Total[1]
	(millions of dollars)				
West	277	70	160	517	22
Ont. (ex. NCR)	195	142	185	535	23
NCR	529	72	19	625	26
Que. (ex. NCR)	148	168	127	459	20
Atlantic	132	39	35	217	9
Total	1,282	492	526	2,355	100

1. Rows and columns may not add due to rounding. "All R&D" includes "other performers" as well as intramural, industry and universities.

Source: Statistics Canada, Science Statistics, Cat. No. 88-001, Vol. 12, No. 7, July 1988.

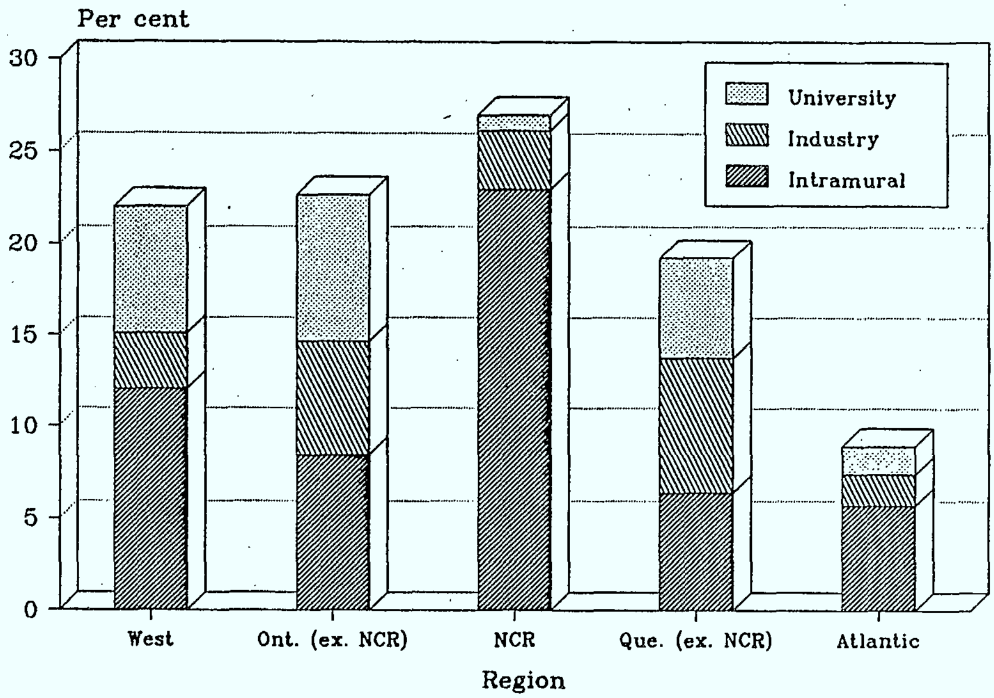
TABLE A-10
GOVERNMENT OF CANADA GRANTS AND CONTRACTS FOR R&D TO INDUSTRY, 1986/87
(in millions of dollars)

Region	Grants	Per Cent	Contracts	Per Cent	Grants & Contracts	Per Cent
Atlantic	28.3	9.0	11.1	6.4	39.5	8.1
Quebec	153.5	48.7	14.5	8.3	168.0	34.3
NCR	16.9	5.4	54.1	31.0	71.0	14.5
Ontario	80.2	25.4	61.0	34.9	141.2	28.8
West & NWT	36.3	11.5	33.8	19.4	70.1	14.3
Total[1]	315.4	100.0	174.6	100.0	490.0	100.0

1. Columns may not add due to rounding.

Source: Statistics Canada, Science Statistics, Catalogue No. 88-001, Vol. 12, No. 7, July 1987.

FIGURE A-8
FEDERAL R&D FUNDING BY REGION AND SECTOR OF PERFORMANCE, 1986/87



Sources: Statistics Canada, Estimates of Canadian R&D Expenditures by Region, 1979 to 1985, July 1987.
Statistics Canada, Science Statistics, Cat. No. 88-001, Vol. 12, No. 7, July 1987.

8. Public Service Personnel in Federal S&T Activities

The Government of Canada employs over 30,000 public servants in S&T activities. As a percentage of total PYs, S&T personnel account for 13 per cent of public servants. The largest public service S&T employers with controlled PYs are AGR, ENV, NRC and STC. The distribution of person-years, by department, is shown in Table A-11. AGR is by far the largest R&D employer, followed by NRC and EMR. STC is the largest RSA employer followed by ENV and NHW. Of the 16,510 employees in the RSA and Administration categories, 1,455 are engaged in the administration of external programs. Although RSA accounts for only 38 per cent of S&T expenditures, it consumes 54 per cent of S&T PYs.

TABLE A-11
PUBLIC SERVANTS ENGAGED IN S&T BY DEPARTMENT, 1988/89

Department/Agency	R&D	RSA and Administration (person-years)	Total S&T
Agriculture	4,399	583	4,982
Statistics Canada	113	4,112	4,225
Environment Canada	758	3,129	3,887
National Research Council	2,888	577	3,465
Energy, Mines and Resources	795	1,960	2,755
Fisheries and Oceans	1,288	1,051	2,339
National Defence	1,812	105	1,917
National Health and Welfare	270	1,132	1,402
National Museums of Canada	225	771	996
Communications	330	53	383
University Granting Councils - Total	..	310	310
All Others	104	3,091	3,195
Total S&T public servants[1]	12,982	16,874	29,856
S&T public servants as a per cent of total PYs	5.7	7.3	12.9

1. Does not include employees of AECL, IDRC, CC, CMHC or CBC personnel.
Source: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.

The total number of S&T person-years in the public service, and excluding military personnel, in 1988/89 is 29,856 PYs. Given the distribution of PYs by category, as reported by Statistics Canada, with average salaries as shown below in Table A-12, the average salary for an S&T person year is $39,102.

Public service employment in S&T has been decreasing by about 2 per cent per year since 1984/85.

TABLE A-12
S&T WORKERS IN THE PUBLIC SERVICE, 1988/89[1]

Salary Category	Number (person-years)	Estimated Average (thousands of dollars)
Executive	809	69.3
Professional	9,827	49.3
Admin. and foreign service	3,385	41.6
Technical	7,818	34.1
Admin. support	5,581	24.3
Operational	2,437	25.8
Total	29,856	38.0

1. Does not include employees of AECL, IDRC, CC, CMHC, CBC, or military personnel.

Sources: Statistics Canada, Federal Science Expenditures and Personnel, 1988/89, April 1988.
Treasury Board, Main Estimates, Part III, 1988/89, February 1988.

Table A-13 adds the regional dimension to the personnel engaged in S&T activities. As shown below, over one half of the people (52 per cent) are employed in the NCR. 1986/87 is the latest year for which regional data are available.

TABLE A-13
PERSONNEL ENGAGED IN SCIENTIFIC ACTIVITIES,
BY REGION AND BY SELECTED DEPARTMENTS, 1986/87

Region	AGR	AECL	EMR	ENV	F&O	NRC	STC	Other	Total
	(person-years)								
Newfoundland	96	..	..	67	257	60	76	30	586
P.E.I.	110	..	..	11	8	1	..	12	142
Nova Scotia	149	..	141	227	831	89	64	227	1,728
New Brunswick	290	..	1	93	109	3	..	13	509
Quebec (ex. NCR)	509	..	1	540	161	214	218	800	2,443
NCR	1,428	..	2,225	257	207	2,645	3,499	6,897[1]	17,158
Ontario (ex. NCR)	726	1,692	28	1,301	182	27	199	596	4,751
Manitoba	359	911	3	236	127	9	158	15	1,818
Saskatchewan	372	..	6	188	..	110	..	8	684
Alberta	581	..	212	431	..	2	69	200	1,495
B.C.	411	..	75	358	554	96	133	171	1,798
Yukon & N.W.T.	..	..	..	113	..	..	..	47	160
Canada	5,027	2,603	2,713	3,822	2,436	3,256	4,416	9,066	33,272

1. Includes 1,310 person-years for National Health and Welfare, 530 person-years for the National Library of Canada and 1,073 person-years for National Museums of Canada.

Source: Statistics Canada, Science, Technology and Capital Stock Division.

9. R&D Capital Stock

R&D capital stock, the sum of investments (discounted over time) in R&D, is an indicator of the stock of knowledge derived from research and development. The stock is calculated from the amount of R&D expenditures incurred, in constant dollars. For federal intramural R&D expenditures, an eight-year life-cycle is considered appropriate and, thus, the stock is depreciated over an eight-year period.

The capital of R&D was calculated for eight major departments in constant 1981 dollars. Corrections were made for organizational changes. Although the absolute value of the stock depends upon the discount rate, the changes over time provide a good indicator of policy direction. Thus, the growth (or lack of it) is used as a measure of R&D performance.

Table A-14 provides average annual growth rates for the period 1980-1984 and 1984-1988.

TABLE A-14
AVERAGE ANNUAL GROWTH RATES OF R&D CAPITAL STOCK

Department/Agency	1980-1984	1984-1988
	(per cent)	
Agriculture	4.4	4.3
Communication	4.5	(6.9)
Energy, Mines and Resources	11.4	3.8
National Defence	3.0	3.1
AECL	1.6	(1.4)
NRC	9.3	3.1
Fisheries & Oceans	10.3[1]	2.4
Environment	(9.3)[1]	(7.6)

1. Between 1982 and 1984.
<u>Source</u>: MOSST calculations.

It can be argued that federal S&T programs should, in the long term, have growth rates that approximate the growth of the economy. Thus, those departments which show growth rates in excess of 3 per cent are experiencing a real expansion of their programs. Those with growth rates in the 0-3 per cent range have grown with the economy, but have had no major change in their programs. Those departments with negative growth rates have suffered real cutbacks and appear to be under long term pressure to reduce the R&D effort in those fields.

10. <u>R&D Tax Expenditures</u>

R&D tax incentives are intended to promote and enhance R&D in Canada and to improve the technological competitiveness of Canadian industry. Tax expenditures represent an important and efficient mechanism for stimulating industrial R&D in Canada. They are also an integral part of the Government of Canada's overall strategy to encourage a stronger industrial R&D base.

The use of Scientific Research Tax Credits (SRTCs), which provided a tax incentive to investors who financed the cost of R&D, was discontinued in

1985. SRTCs were replaced by an enhanced Investment Tax Credit (ITC) regime which permits tax credits to be earned at varying rates depending on the type and size of taxpayer and the location in Canada where the R&D is performed.

Expenditures qualifying as R&D for tax purposes are outlined in the definition of Scientific Research and Experimental Development (SRED). Revenue Canada's guidelines for determining what activities constitute SRED are contained in its *Information Circular 86-4R2*, which is similar to the definition of R&D used by the OECD, i.e. the "Frascati Manual". In accordance with the recommendations contained in the "Frascati Manual", R&D expenditures for statistical purposes are to be recorded net of any corresponding tax incentives, hence, only the net amount is included in the R&D statistics compiled by the Government of Canada.

Present Tax Structure

SRED expenditures in Canada, which may be of current or capital nature, are fully deductible in computing taxable income. If the deduction for SRED expenditures is not used in the year in which the expenditures are incurred, it may be carried forward indefinitely to future years. Generally SRED expenditures also qualify for ITCs. ITCs are generally earned at a rate equal to 20 per cent of the eligible SRED expenditures, with eligible SRED expenditures in the Atlantic Provinces and the Gaspé Peninsula qualifying for a special rate of 30 per cent. A Canadian-controlled private corporation (CCPC), as defined in *The Income Tax Act*, earns ITCs at a preferred rate of 35 per cent on the first $2 million of SRED expenditures, provided the taxable income of the CCPC and its associated corporations for the immediately preceding year did not exceed $200,000.

The deductions related to R&D expenses must be reduced by the amount of related ITCs in accordance with the treatment of other forms of government assistance.

Qualifying CCPCs, individuals and certain trusts are eligible to receive a refund in respect of their unused ITCs. ITCs earned at the 35 per cent rate of a CCPC in respect of current SRED expenditures are fully refundable. Other R&D-related ITCs earned by CCPCs, including ITCs earned by individuals and certain trusts, may be refundable at a rate equal to 40 per cent of their stated value. The non-refundable portion of ITCs may be carried forward and claimed against tax payable in future years.

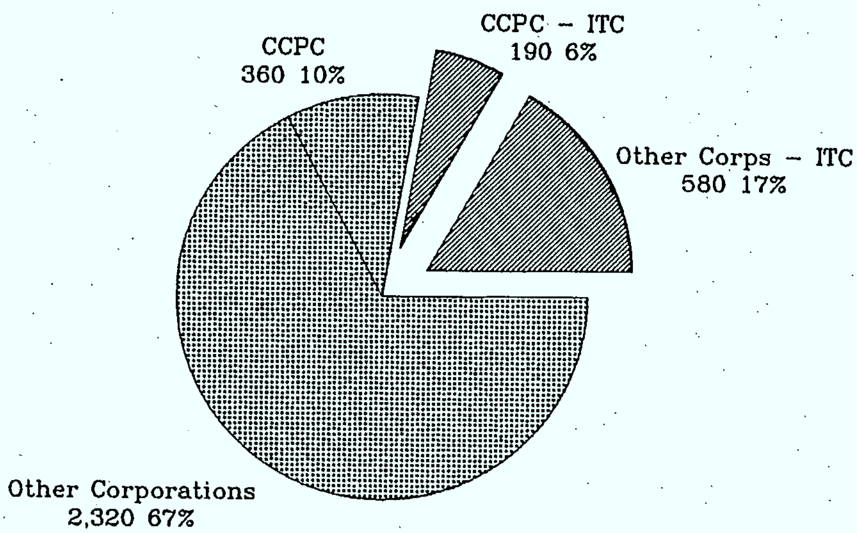
Prior to implementation of Tax Reform, medium and large-sized corporations could obtain a partial refund of their unused ITCs equal to 20 per cent of the stated value. This option was eliminated effective December 31, 1987, one year earlier than it had been scheduled to expire. Under Tax Reform, the carrying forward of unused ITCs for use in other years has been increased from seven to ten years. Also, the use of ITCs to offset federal income tax has been limited to 75 per cent of federal tax otherwise payable in the year, exclusive of the surtax.

CCPCs and individuals have been afforded relief with regard to the new 75 per cent restriction. For CCPCs, the tax payable with respect to $200,000 of taxable income ($24,000 of income tax at current rates) is not subject to the

75 per cent restriction. With respect to individuals, up to $24,000 of federal tax may be offset without being subject to the 75 per cent limitation.

Enhanced refundability provisions for ITCs related to R&D were introduced in May 1985. This is the latest year for which taxation data are virtually complete but, because of the changes in the R&D tax structure during that year, the figures are anomalous. Data for 1986 are about 80 per cent complete. Figure A-9 shows the results based on MOSST projections of Revenue Canada data.

FIGURE A-9
INVESTMENT TAX CREDITS, 1986



<u>Source</u>: Revenue Canada data.

ITCs as a percentage of industrial R&D have increased manyfold over the last ten years, from 3 per cent in 1977 to almost 23 per cent in 1986. It is estimated that, for 1986, tax credits of approximately $770 million will have been earned on the full $3.5 billion of industrial R&D for that year. Since ITCs reduce eligible deductions for tax purposes and since not all ITCs that are earned will be claimed in the year, the cost of the foregone revenue to the Government of Canada would be somewhat lower than the $770 million attributed to the ITCs.

* * *

B. THE NATIONAL R&D ENVIRONMENT

Preceding sections have focused on the S&T and R&D expenditures of the Government of Canada. These expenditures must also be viewed in the context of national levels of R&D spending. As stated before, the federal government is the largest single funder and performer of R&D in Canada, so that its expenditure decisions act as signals for and influence the R&D community as a whole. It is not possible to demonstrate that federal R&D expenditures lead national R&D expenditures, in that large percentage increases in federal spending in one year are not followed by increases in national spending. However, the fact that the federal government funds about 10 per cent of all industrial R&D (see Table B-3 on page 23), provides it with a policy tool to increase industrial R&D performance at the margin.

1. Gross Expenditure on R&D

Gross Expenditure on R&D (GERD) is a measure of the level of the national effort on R&D. Relative to GDP, Canada's GERD has increased in most years since 1979.

TABLE B-1
NATIONAL GERD

	1979	1980	1981	1982	1983	1984	1985	1986	1987p
Millions of actual dollars	2,939	3,507	4,331	5,090	5,412	6,089	6,806	7,185	7,631
Millions of constant 1981 dollars	3,602	3,888	4,331	4,683	4,743	5,160	5,592	5,734	5,825
Per cent real growth	3.7	7.8	11.5	8.1	1.3	8.8	8.4	2.7	1.6
GERD/GDP (per cent)	1.06	1.13	1.22	1.36	1.33	1.37	1.42	1.41	1.38

p. Projected.
Sources: Statistics Canada, Science Statistics, Cat. No. 88-001, Vol. 12, No. 6, June 1988.
Bank of Canada, Bank of Canada Review, April 1988.

2. Funders and Performers

Over the past decade, industry has steadily increased its share of both the funding and performance of Canada's R&D effort (Table B-2). For 1988, it is estimated that industry will perform about 56 per cent of GERD and fund 43 per cent, a substantial increase over the 1977 values of 37 and 31 per cent, respectively. Concurrently, the federal funding and performance shares have declined to 30 per cent and 17 per cent respectively.

TABLE B-2
GERD BY FUNDING AND PERFORMING SECTORS (NSE + SSH)

Year	Federal Government	Provincial Government[1]	Business	University	Other
	Funder shares, per cent of GERD				
1977	39	7	31	17	6
1979	35	7	37	15	6
1981	34	7	42	11	6
1983	37	7	39	10	7
1985	34	6	41	9	10
1987p	32	6	42	10	10
	Performer shares, per cent of GERD				
1977	26	3	37	31	2
1979	23	3	43	29	2
1981	21	3	49	25	2
1983	23	3	48	25	2
1985	20	2	53	22	2
1987p	18	2	54	23	2

1. Does not include PROs.
p. Projected.
Source: Statistics Canada, Science, Technology and Capital Stock Division.

Table B-3 is the estimated funder-performer matrix for the year 1988; it demonstrates that there are substantial shifts of funds from the two levels of government to industry and universities. The provincial governments, however, transfer a much higher percentage of their R&D funding to extramural performers than does the federal government.

TABLE B-3
EXPENDITURES ON R&D BY FUNDING AND PERFORMING SECTORS (NSE AND SSH), 1988p

Funder	Federal	Provincial	PRO	BE	University	PNP	Total
	Performer (millions of dollars)						
Federal	1,320	..	8	445	604	30	2,407 (30%)
Provincial	..	154	45	51	238	22	510 (6%)
PRO	..	..	1	..	..	..	1 ..
BE	..	..	18	3,336	61	3	3,418 (43%)
EPF = University (GUF)	..	..	..	..	814 (GUF)	..	814 (10%)
PNP	..	..	..	..	163	47	210 (3%)
Foreign	..	..	2	595	13	..	610 (8%)
Total	1,320 (17%)	154 (2%)	74 (1%)	4,427 (56%)	1,893 (24%)	102 (1%)	7,970

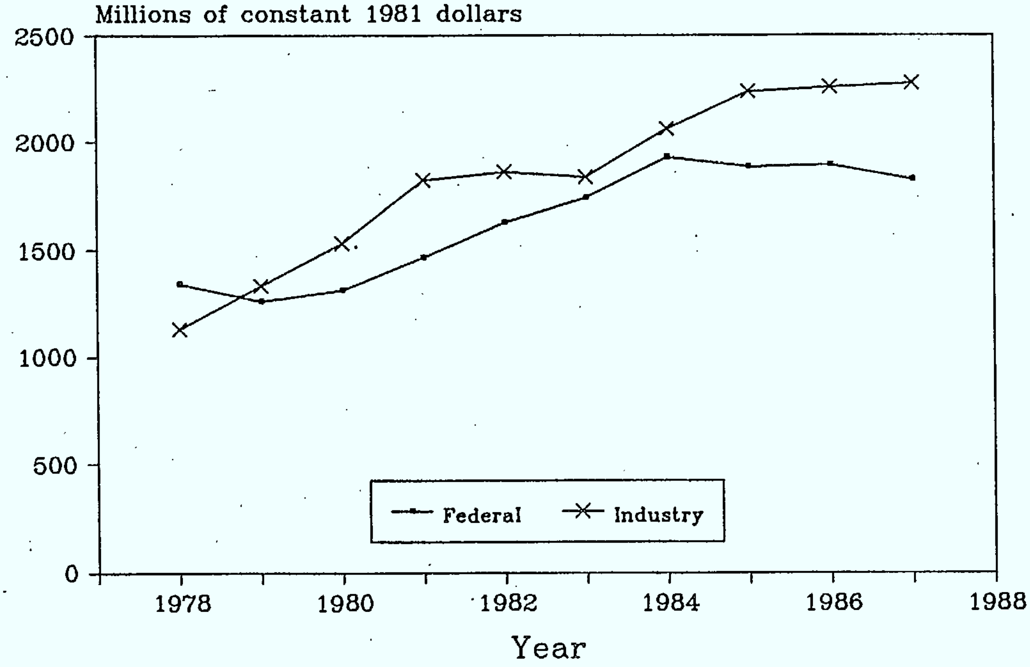
p. Projected.
Source: Statistics Canada, Science, Technology and Capital Stock Division.

After substantial increases during the first half of the 1980s, there has been little or no real growth in industrial or federal support for R&D since

1985 (Figure B-1). For the last three years, Canada's GERD has grown slowly in constant dollar terms, at about 2 per cent per annum, less than the real growth of GDP, with the result that the GERD/GDP ratio has fallen.

Although most of the R&D performed in the industrial sector is self-financed, the federal government is nevertheless an important funding source (Table B-4). During the 1980s, direct federal support has increased on average about twice as fast as industry's own funding. Nonetheless, the federal share is still relatively small, varying between 10 and 11 per cent during most of this decade.

FIGURE B-1
R&D FUNDING BY CANADIAN INDUSTRY AND THE GOVERNMENT OF CANADA



Source: Statistics Canada, Science and Technology Indicators, 1987.

TABLE B-4
YEAR-OVER-YEAR CHANGE IN FEDERAL FUNDING OF INDUSTRIAL R&D
(millions of 1981 dollars)

Year	Federal Funding		Industrial Funding		Total Industrial R&D[1]	
		Per cent change		Per cent change		Per cent change
1979	132	(2.2)	1,274	14.8	1,551	14.4
1980e	132	0.0	1,463	14.8	1,741	12.2
1981	190	43.9	1,726	18.0	2,125	22.0
1982	245	28.9	1,748	1.3	2,288	7.7
1983	246	0.4	1,604	(8.2)	2,264	(1.0)
1984	285	15.8	1,763	9.9	2,537	12.0
1985	315	10.5	2,193	24.3	2,973	17.2
1986	326	3.5	2,242	2.2	3,053	2.7
1987e	319	(0.2)	2,360	5.3	3,173	3.9

1. All sources of funding.
e. Estimate.
Source: Statistics Canada, Science, Technology and Capital Stock Division.

3. Industrial R&D in Canada

In Canada, as elsewhere, R&D spending is heavily concentrated within a very few industrial sectors. These R&D-intensive industries depend on innovation to maintain their competitive edge. Generally their expenditures amount to at least 3 per cent of sales (Table B-6). On the other hand, resource-based and other industries, which compete mainly on the basis of price and availability, perform relatively little R&D.

TABLE B-5
CONCENTRATION OF INDUSTRIAL R&D AMONG INDUSTRIES, 1982 TO 1988

Industry	1982	1983	1984	1985	1986	1987p	1988p
	(per cent of total intramural expenditures)						
Telecommunications equipment	14	18	18	17	16	19	19
Aircraft and parts	12	11	9	9	10	11	11
Oil and natural gas producers	13	9	10	8	5	4	4
Drugs and medicines and other chemical products	7	7	7	7	7	7	7
Electronic parts and components and other electronic equipment	6	7	7	8	8	8	8
Business machines	5	5	6	5	6	7	7
Engineering and scientific services	4	6	7	8	8	7	7
Other industries	39	37	36	38	40	37	37
Total	100	100	100	100	100	100	100

p. Projected.
Source: Statistics Canada, Science, Technology and Capital Stock Division.

In the last seven years, seven major industries have maintained a dominance of industrial R&D activity (Table B-6). In particular, the share of total R&D carried out by firms in the telecommunications equipment industry has grown to 19 per cent of the total industrial R&D performance.

TABLE B-6

CURRENT R&D EXPENDITURES AND SALES BY INDUSTRY, 1986

Industries	R&D --(millions of -- dollars)	Sales by R&D Performers -----(billions of ---- dollars)	Average R&D/Sales ---(per cent)---
	x,xxx	xxx,x	x,x
MINING AND OIL WELLS			
Mining	49	6.0	0.8
Crude petroleum and natural gas	37	5.0	0.7
TOTAL MINING AND OIL WELLS	86	11.0	0.8
MANUFACTURING			
Telecommunication equipment	621	3.0	20.7
Aircraft and parts	368	2.4	15.3
Business machines	228	5.3	4.3
Refined petroleum and coal products	147	24.6	0.6
Drugs and medicine	103	2.2	4.7
Food, beverages and tobacco	88	18.2	0.5
Primary metals (non-ferrous)	88	6.3	1.4
Pulp and paper	87	15.7	0.6
Machinery	86	3.6	2.4
Scientific and professional equipment	50	1.3	3.8
Textiles	36	3.0	1.2
Metal fabricating	33	2.3	1.4
Electronic parts and components	30	0.4	7.5
Primary metals (ferrous)	27	6.6	0.4
Wood	22	0.5	4.4
Rubber and plastic products	20	2.2	0.9
Non-metallic mineral products	16	2.6	0.6
Other electronic equipment	290	2.0	14.5
Other chemical products	162	10.2	1.6
Other transportation equipment	111	31.4	0.4
Other electrical products	72	4.7	1.5
Other manufacturing industries	40	1.9	2.1
TOTAL MANUFACTURING	2,724	150.1	1.8
SERVICES			
Engineering and scientific utilities	313	1.1	28.5
Computer services	198	1.1	18.0
Electrical power	180	15.5	1.2
Transportation and other utilities	142	30.9	0.5
Other non-manufacturing industries	185	16.9	1.1
TOTAL SERVICES	1,018	65.5	1.6
TOTAL ALL INDUSTRIES	**3,828**	**226.6**	**1.7**

Source: Statistics Canada, Science Statistics, Cat. No. 88-001, Vol. 12, No. 5, June 1988.

TABLE B-7

MAJOR INDUSTRIAL R&D PERFORMERS, 1986 (millions of dollars)

Rank of Performers	Total R&D Expenditures (millions of dollars)	Total R&D Expenditures (per cent)	Sales of Performers (millions of dollars)	Sales of Performers (per cent)	Average R&D/Sales (per cent)
Top 5	982	26	17,009	8	5.8
Top 10	1,291	34	29,731	13	4.3
Top 15	1,538	40	33,464	15	4.6
Top 20	1,692	44	57,612	25	2.9
Top 25	1,811	47	64,777	29	2.8
Top 50	2,194	57	80,909	36	2.7
Top 75	2,410	63	97,691	43	2.5
Top 100	2,566	67	115,664	51	2.2
All Firms	3,828	100	226,573	100	1.7

Source: Statistics Canada, Science, Technology and Capital Stock Division.

Most industrial R&D in Canada is performed by a small number of firms. Out of ~~3,828~~ 3,414 companies which reported performing R&D in 1986, 25 accounted for almost half the R&D performed. The concentration of R&D can have dramatic effects on expenditures. The decisions of a few firms can significantly alter overall R&D expenditures and particularly industry totals.

Foreign-controlled companies are generally less R&D-intensive than their Canadian-controlled competitors. The difference is most noticeable in sectors such as machinery, transport equipment, electrical and electronic products -- sectors which in other industrial nations are very R&D-intensive. Most of the foreign-controlled firms are subsidiaries of large multinationals whose parents are based in the U.S. or the U.K. Since these corporations can transfer technology fairly easily, they tend to centralize their R&D function at corporate headquarters from whence they supply most of the R&D requirements of their branch plants.

TABLE B-8

R&D AS A PERCENTAGE OF SALES BY INDUSTRY AND COUNTRY OF CONTROL, 1986

Industry	Canadian	Foreign	Total
	(per cent of sales)		
Mining and oil wells	0.72	0.58	0.68
Chemical-based	0.59	0.97	0.79
Wood-based	0.33	0.22	0.32
Metals	0.90	0.68	0.86
Machinery & transport equipment	3.72	0.97	1.36
Electrical & electronic products	14.00	3.54	6.65
Other manufacturing	1.26	0.69	1.00
Services	1.40	0.60	1.24
All Industry	1.50	1.18	1.42

Source: Statistics Canada, Science, Technology and Capital Stock Division.

4. Highly-Qualified Personnel

Table B-9 indicates a substantial growth in the numbers of higher-degree holders in all professional occupations. The numbers have doubled in almost every occupation and in many the growth has exceeded that in total employment. As a result, the proportion of highly-qualified personnel in the experienced labour force has increased from 2.5 per cent in 1981 to 3.0 per cent in 1986.

TABLE B-9
EXPERIENCED LABOUR FORCE 15 YEARS AND OVER BY HIGHEST DEGREE OBTAINED

			Master's & Doctoral Degrees			
	Total		Number of Employees		Per cent of Total	
Occupation	1981	1986	1981	1986	1981	1986
	(thousands)		(thousands)			
Managers, admin. & related occs.	814.0	1,009.0	53.3	75.2	6.5	7.4
Physical sciences	40.5	40.8	6.9	6.8	17.1	16.9
Life sciences	28.3	31.3	5.2	6.1	18.2	19.3
Architects & engineers	266.4	268.9	20.7	22.5	7.8	8.4
Mathematicians & systems analysts	67.7	109.0	5.2	7.5	7.7	6.9
Soc. sci, soc. work, law & religion	220.9	271.7	35.7	44.3	16.1	16.3
University teachers	33.6	36.9	27.6	28.6	82.1	77.5
Other teaching occupations	455.6	490.7	43.4	52.2	9.5	10.6
Medicine & health[1]	519.2	599.2	64.9	73.2	12.5	12.2
All other occupations	9,820.8	9,925.7	40.4	54.6	0.4	0.6
All occupations	12,267.1	12,783.5	303.4	384.4	2.5	3.0

1. Includes first professional degrees (M.D.s, D.D.S.s, D.V.M.s, etc.) with master's and doctoral degrees.

Source: Statistics Canada, Census data.

5. Public Awareness

Canadians are well aware of the importance of remaining competitive in high-technology. According to a recent Decima Research study of public attitudes towards science and technology, 98 per cent of Canadians feel that it is important for Canada to develop its own technology. Further, Canadians overwhelmingly agree that keeping up with the technological advances of other nations is important (96 per cent). As Table B-10 indicates, the most important reasons for spending money on science and technology are perceived to be developing cures for illnesses and diseases (34 per cent) and to increase employment (30 per cent). Thus, while respondents regard enhanced industrial competitiveness (92 per cent) as a good or very good reason for increased investment in science and technology, they tend to show greater interest in social rather than economic benefits. When replying to questions designed to test the public's perception of S&T, people readily associated medical research and space programs with S&T but other technologies did not appear to have a high public impact.

TABLE B-10
REASONS FOR INCREASING EMPHASIS ON SCIENCE AND TECHNOLOGY

	Good Reason	Very Good Reason	Most Important Reason
	(per cent)		
To see new cures	31	64	34
To increase overall employment	35	60	30
To harvest Canada's natural resources more efficiently	43	49	14
To compete more effectively in international markets	44	48	21

Source: Decima Research, Report to MOSST on Public Attitudes Towards Science and Technology, January 1988.

6. Manufacturing Technology

Despite concerns about a slow rate of adoption of new technologies, there are little data on the rate of diffusion of technology in Canadian industry. Statistics Canada has surveyed 4,687 large and medium-sized establishments regarding the use and planned use of eighteen key industrial technologies in five technology groups. These establishments accounted for 51 per cent of the estimated value of 1986 shipments for manufacturers. The most striking feature of the results is that, while only 50 per cent of the responding establishments used at least one of the technologies, they were responsible for 81% of the value of 1986 shipments of all respondents. This suggests that the larger establishments are more likely to adopt advanced technologies.

The dominant technology group was communication and control (Table B-11) followed by inspection, sensor and testing equipment, if the shipment measure is used, or fabrication and assembly equipment if the decision is based on the number measure. By both measures, the programmable controller was the leading single technology. The results show that programmable controllers have widely penetrated the manufacturing industry and are used by almost all the larger responding establishments in the transportation equipment and primary metal industries.

Ontario led all provinces in terms of the percentage of establishments using at least one of the selected technologies; the number of responses by province tended to reflect the distribution of medium- and large-scale enterprises across the country.

TABLE B-11
PERCENTAGE USAGE OF SELECTED ADVANCED TECHNOLOGIES

Technology Group	Shipment Measure[1]	Establishment Measure[2]
Design & engineering	45	22
Fabrication & assembly	50	27
Automated material handling	23	7
Inspection, sensor and testing equipment	54	17
Communications & control	73	35
At least one of the above	81	50

1. Percentage of 1986 shipment from responding establishment which came from establishment using at least one of the technologies in the technology group.
2. Percentage of responding establishment which used at least one of the technologies in the technology group.

Source: Statistics Canada, Survey of Manufacturing Technology - Final Report, Classification Systems Branch, June 1987.

7. Regional Expenditures on R&D

Canada's R&D efforts are not spread evenly across the country. R&D expenditures tend to be concentrated in Ontario and Quebec and tend to mirror the distribution of population and industry in the country.

Although Ontario has 36 per cent of the nation's population and 39 per cent of the GDP, it has 54 per cent of the total GERD as shown in Table B-12. Quebec, an industrialized province like Ontario, with 26 per cent of the nation's population and 23 per cent of its GDP, has 21 per cent of federal GERD.

Even greater disparities exist with the Atlantic and the Western provinces. Different levels and types of R&D are required for each region to match the relative strengths of their industrial and resource sectors of the economy.

Besides having the largest share of federal GERD, Ontario also has the highest ratio of R&D to provincial GDP. With a GERD/GDP of 1.9 per cent in 1986, Ontario was one of two provinces where this proportion was higher than the national average of 1.41 per cent; however, the Ontario figures include most of the federal R&D spending in the NCR. Four provinces had GERD/GDP ratios of less than 1 per cent: Newfoundland, New Brunswick, Saskatchewan and British Columbia.

TABLE B-12

TOTAL EXPENDITURES ON R&D, GDP AND POPULATION BY PROVINCE, 1986

Province	GERD (NSE + SSH)	GDP	Population[1]	GERD/GDP	GERD/Population
	---(millions of dollars)---		--(thousands)--	--(per cent)--	--(dollars per capita)--
Newfoundland	59	6,784	568	0.87	105
P.E.I.	25	1,470	127	1.70	197
Nova Scotia	174	12,578	873	1.38	199
New Brunswick	82	9,833	709	0.83	116
Quebec	1,497	119,439	6,532	1.25	229
Ontario	3,879	204,411	9,102	1.90	426
Manitoba	202	19,098	1,063	1.06	190
Saskatchewan	157	17,195	1,010	0.91	155
Alberta	601	58,265	2,366	1.03	254
B.C.	506	56,496	2,883	0.90	176
Canada[2]	7,185	507,808	25,309	1.41	284

1. Population as of June 1, 1986.
2. Including the Yukon and Northwest Territories.

Source: Statistics Canada, Science Technology and Capital Stock Division and Income and Expenditure Accounts Division, 1986 Census.

The Quebec and Ontario figures include R&D expenditures in their respective portions of the NCR. If the NCR is removed from the provincial statistics, there is little change to the Quebec figures, but Ontario's GERD/GDP drops to about 1.4 per cent and its GERD per capita to about $300 per capita.

Industry-financed R&D is even more regionally centralized, with Ontario performing about 61 per cent and Quebec 23 per cent (Table B-13). This heavy concentration of industrial spending was, to some measure, counterbalanced by the somewhat wider regional dispersion of the funds from other sources and, in particular, the federal government and the university sector.

TABLE B-13

REGIONAL DISTRIBUTION OF R&D FUNDING, 1986

Province	Total	Industry	Federal Government	University	Others[1]
	----------	----------	---(per cent)---	----------	----------
Newfoundland	0.8	0.2	1.5	2.3	0.2
P.E.I.	0.3	0.2	0.5	0.6	0.3
Nova Scotia	2.4	0.7	4.9	3.4	1.0
New Brunswick	1.1	0.7	1.7	1.7	0.8
Quebec	20.8	22.6	17.1	15.8	27.0
Ontario	54.0	61.0	52.7	42.4	46.1
Manitoba	2.8	0.8	4.7	5.7	2.1
Saskatchewan	2.2	1.4	2.8	2.4	2.8
Alberta	8.3	5.7	6.1	19.1	13.0
B.C.	7.0	6.5	8.0	6.7	6.6
Canada: Per cent[2]	100	100	100	100	100
Millions of dollars	7,185	2,924	2,384	703	1,174

1. Includes funding of $528 M from the foreign sector, almost all of which is transfers within foreign multinationals, from provincial governments ($464 M) and private non-profit organizations ($180 M).
2. Totals do not add to 100 per cent due to rounding.

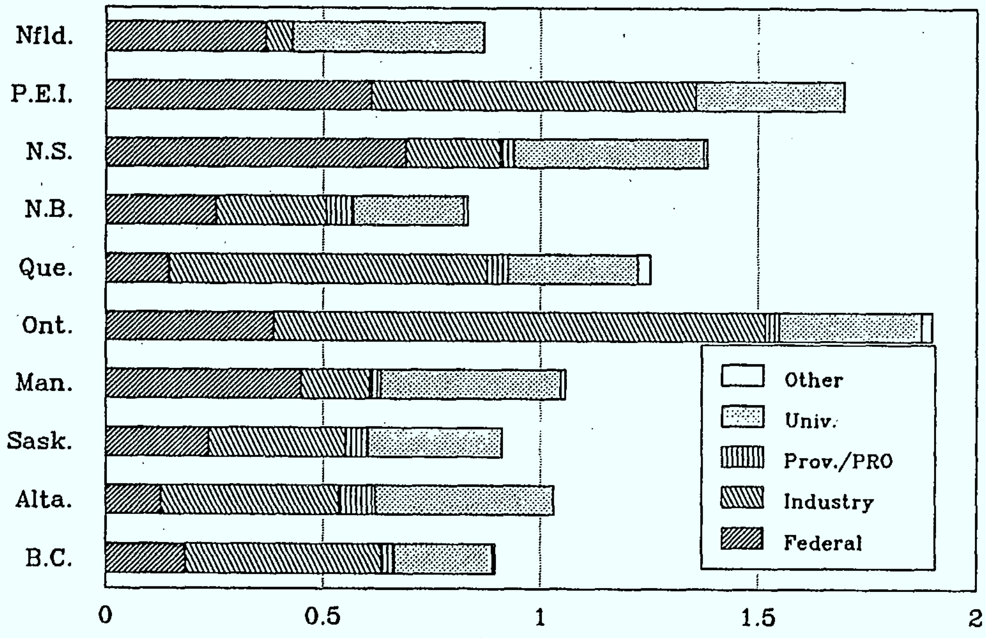
Source: Statistics Canada, Estimates of Canadian Research and Development Expenditures by Region, 1979 to 1986, July 1988.

Figure B-2 provides a comparison of the regional importance of the various funding sources. As expected, industry is the principal funding source in both Ontario and Quebec, where it supports about 50 per cent of provincial R&D. In seven of the ten provinces, the federal government is the major contributor, its share varying between 40 per cent in British Columbia to 78 per cent in P.E.I. Only in Alberta and Quebec does the provincial government fund more than 10 per cent of regional R&D.

Provinces where the federal government bears the largest share of R&D expenditures generally have a relatively weak manufacturing base. Hence, as explained earlier, industry is not a very significant source of R&D spending. In these provinces, most of the federal funds are directed towards resource-enhanced management and exploitation of the resource sector. In Nova Scotia, for example, more than one-half of the expenditures was provided for R&D related to agriculture, fisheries and offshore oil and gas exploration. Similarly, in British Columbia, at least one-half of federal R&D spending was in support of agriculture, fisheries and forestry.

FIGURE B-2

FUNDING OF R&D (NSE AND SSH) AS A PERCENT OF PROVINCIAL GDP, 1986



Sources: Statistics Canada, Estimates of Canadian Research and Development Expenditures by Region, 1979 to 1986, June 1988.
Statistics Canada, Income and Expenditure Accounts Division.

Table B-14 shows the regional distribution of Canada's R&D performance. At the national level, industry is by far the largest performer with a 53 per cent share, followed by universities (23 per cent) and federal laboratories (20 per cent). The picture is, however, quite different at the regional level. Only in half of the provinces is industry the major performer. In the other half, it is the federal government or the university sector that performs the largest share. Once again, as with funding, these are provinces whose economies are largely resource-based and the federal performance is oriented towards enhancement of that base.

TABLE B-14
REGIONAL R&D BY PERFORMER, 1986

Province	Industry	University	Federal Government	Provincial Government	PNP	Total
	(per cent)					(millions of dollars)
Newfoundland	6.7	50.8	42.4	..	..	59
P.E.I.	44.0	20.0	36.0	..	..	25
Nova Scotia	15.5	31.6	50.0	2.3	0.6	174
New Brunswick	30.5	30.5	30.5	7.3	1.2	82
Quebec	58.2	23.8	11.7	3.9	2.3	1,497
Ontario	59.6	17.2	20.3	1.7	1.2	3,879
Manitoba	14.9	39.1	42.6	2.5	1.0	202
Saskatchewan	34.4	33.8	26.1	5.7	..	157
Alberta	39.6	39.8	12.5	8.2	..	601
B.C.	50.2	25.1	20.6	3.4	0.8	506
Canada[1]	53.3	22.8	19.7	3.0	1.2	7,185

1. Includes the Yukon and Northwest Territories.

Source: Statistics Canada, Estimates of Canadian Research and Development Expenditures by Region, 1979 to 1986, June 1988.

In each province, the university sector is an important cog in the R&D system. It performs more than 20 per cent of the R&D in all provinces other than Ontario and P.E.I. and, in eight of the ten, it is the largest or second largest performer. About two-fifths of total university R&D is self-funded from general university grants (which themselves are supported through the federal post-secondary education program) and one-third is supported by the federal government directly (Table B-15). This, however, varies considerably from province to province. Nonetheless, it is Ontario's universities that receive the largest share of federal funds (39 per cent), followed by Quebec's (24 per cent).

TABLE B-15
UNIVERSITY R&D BY SOURCE OF FUNDS, 1986

Province	Total[1]	University	Federal Government	Provincial Government	PNP	BE
	(millions of dollars)					
Newfoundland	30	16	11	..	2	1
P.E.I.	5	4	1	..	..	..
Nova Scotia	55	24	26	1	3	1
New Brunswick	25	12	10	1	1	1
Quebec	357	111	127	70	36	10
Ontario	667	298	205	67	60	33
Manitoba	79	40	24	4	8	1
Saskatchewan	53	17	18	11	5	2
Alberta	239	134	44	45	13	3
B.C.	127	47	58	6	12	2
Canada	1,637	703	524	205	140	54

1. Includes funds from abroad.

Source: Statistics Canada, Estimates of Canadian Research and Development Expenditures by Region, 1979 to 1986, June 1988.

* * *

C. CANADIAN SCIENCE AND TECHNOLOGY: INTERNATIONAL COMPARISONS

The purpose of this section is to provide a comparison of Canada's performance in science and technology with that of other major industrial nations. The indicators used for this comparison include: R&D expenditures, the number of research scientists and engineers, trade in high-technology products, publications and patents. The last two are indicators of the "output" of the system and, as such, complement the information provided by an "impact" indicator (trade in high-technology products) and the "input" of expenditures and HQP. These indicators are, however, all incomplete measures. Nevertheless, while each has inherent weaknesses, as a group they provide a fair assessment of Canada's competence in S&T relative to that of its major international competitors.

1. R&D Expenditures

As a per cent of GDP, Canada's R&D expenditure ranks eleventh amongst the twenty-four nations of the OECD and is considerably lower than that of almost all G-7 countries. This position is unchanged even after adjusting for the large defence R&D budgets of some of the major industrial nations.

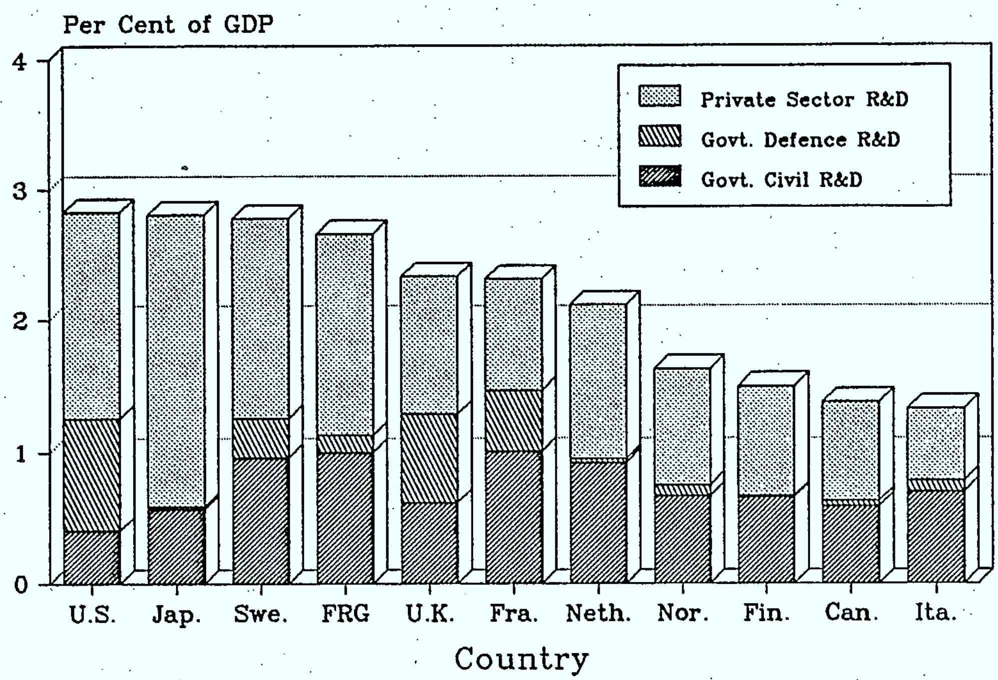
TABLE C-1
SELECTED INTERNATIONAL COMPARISONS OF GERD, 1985,
IN ORDER OF DESCENDING GERD/GDP[1]

Country	GERD/GDP	Civil GERD/GDP	GERD	GERD per Capita
	(per cent)	(per cent)	(billions of US dollars)	(US dollars)
U.S.	2.83	1.98	111.8	420
Japan	2.81	2.79	40.1	324
Sweden	2.78	2.48	2.9	361
FRG	2.66	2.53	19.8	318
U.K.	2.33	1.66	14.4	239
France	2.31	1.85	14.6	284
Netherlands	2.11	2.08	3.4	236
Norway	1.63	1.55	0.9	244
Finland	1.50	1.49	0.8	163
Canada	1.38	1.34	5.3	214
Italy	1.33	1.25	7.1	125

1. OECD data for Canada may differ from those of Statistics Canada due to differences in definitions of GDP and the use of earlier GERD figures.

Source: OECD, Main Science and Technology Indicators, Recent Results, 1979-1987, November 1987.

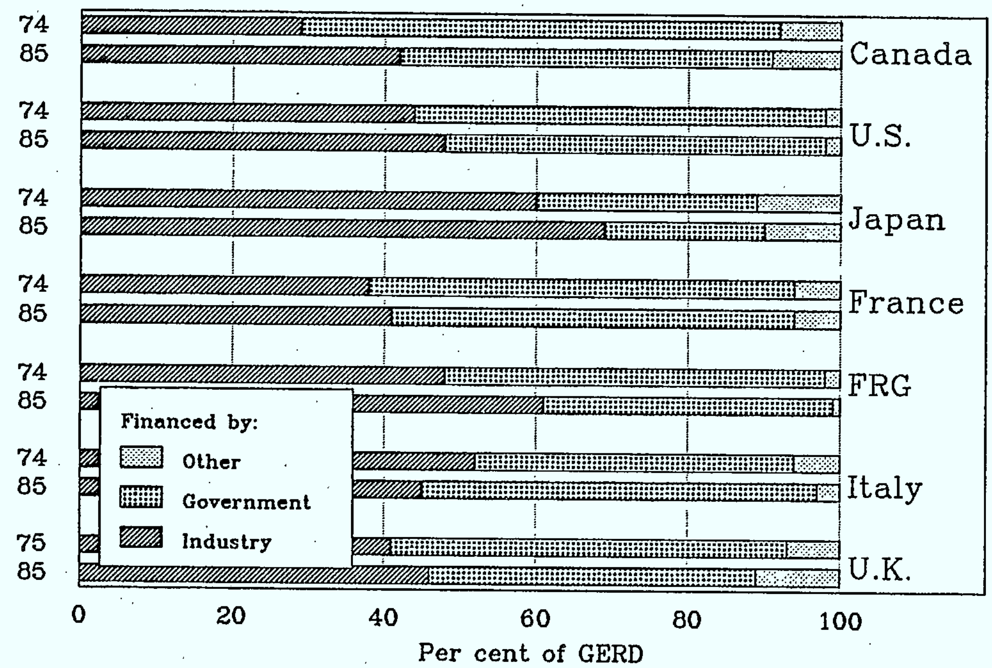
FIGURE C-1
GERD/GDP, 1985



Source: OECD, Main Science and Technology Indicators, Recent Results, 1979-1987, November 1987.

Figure C-2 gives the percentage of GERD financed by industry and government. Over the 1974-1985 period, the share of GERD funded by Canadian industry increased by 45 per cent, substantially exceeding the growth in other G-7 nations.

FIGURE C-2
PERCENTAGE OF GERD FINANCED BY INDUSTRY AND BY GOVERNMENT, 1974 AND 1985[1]



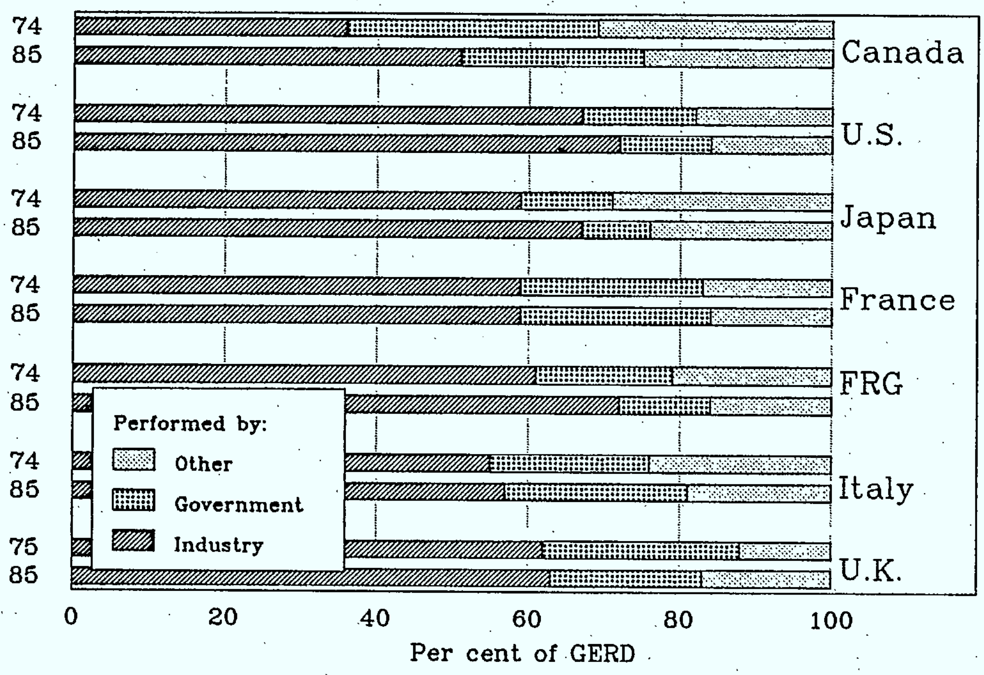
1. As 1974 data are not available for the U.K., 1975 data were used instead.

Sources: OECD, Main Science and Technology Indicators, Recent Results, 1979-1987, November 1987.
OECD, S&T Statistical Indicators, GERD, 1969-1982, 1983.

As can be seen from Figure C-3, the industrial sector in Canada performs a smaller proportion of GERD than in other G-7 nations. As is the case with industrial funding, the share performed by Canadian industry has increased significantly since 1977.

With the growth in industrial performance, the government's share of Canada's R&D effort has decreased, but is still higher than average for the G-7 countries. Similarly, with regard to funding, the Canadian government's share has declined and is now approaching the G-7 average.

FIGURE C-3
INDUSTRY-PERFORMED AND GOVERNMENT-PERFORMED R&D AS A PERCENTAGE OF GERD, 1974 AND 1985[1]



1. As 1974 data are not available for the U.K., 1975 data were used instead.

Sources: OECD, Main Science and Technology Indicators, Recent Results, 1979-1987, November 1987.
OECD, S&T Statistical Indicators, GERD, 1969-1982, 1983.

2. Research Scientists and Engineers (Highly-Qualified Personnel)

Canada ranks below the median of OECD countries in both total R&D personnel and numbers of research scientists and engineers (RSE) per thousand of the labour force (Table C-2). In terms of these measures, the U.S. and Japan are substantially ahead of all other nations.

TABLE C-2
TOTAL R&D PERSONNEL AND RESEARCH SCIENTISTS AND ENGINEERS (RSE)[1]
PER THOUSAND LABOUR FORCE, 1983

Country	R&D Personnel	RSE	Change in RSE from 1979
	(per thousand workers)		(per cent)
FRG	13.5	4.8	9
Japan	12.1	7.4	20
France	11.0	3.9	27
Sweden	10.5	3.9	45
Netherlands	9.9	3.7	17
Norway	7.9	4.1	17
Finland	7.9	3.7	27
Denmark	6.6	2.8	28
Canada	5.9	2.7	31
Italy	4.9	2.7	36
United States	..	6.4	18

1. RSE in some countries consists of only university graduates in science and engineering.

Source: OECD, Main Science and Technology Indicators, Recent Results, 1979-1987, November 1987. The OECD notes that the Japanese data are likely over-estimated. No data are available for the U.K.

The growth since 1979 in the number of Canadian research scientists and engineers has been slightly higher than the median for the OECD area. Overall in the OECD as a whole, the number of research scientists and engineers increased by 19 per cent as compared with a 31 per cent increase in Canada.

3. Trade in "R&D-intensive" Products

There is no standard definition for "high-technology" products. Nevertheless, it is common practice to identify high-technology products based on the level of R&D expenditure associated with the product. In most such cases, the R&D expenditure is at least 4 per cent of either sales or value added.

A number of different lists of products deemed to be "R&D-intensive" have been developed by various countries and organizations. There are, however, certain core products which are common to all existing lists. The common products are aircraft, computers, electronic and telecommunications equipment, scientific instruments, drugs and medicines. In addition to these, selected electrical and non-electrical machinery, and chemical products are included in the group of "R&D-intensive" products.

The volume of trade in these products has been increasing over the last few years. In 1987, "R&D-intensive" exports were 11 per cent of total exports whereas "R&D-intensive" imports were 18 per cent of the total. Table C-3 shows Canada's high-technology trade from 1980 to 1987.

TABLE C-3
TRADE IN "HIGH-TECHNOLOGY" PRODUCTS, 1980-1987

Year	Imports	Exports	Deficit Current Dollars	Deficit 1981 Dollars	Exports/Imports
	(millions of dollars)				(per cent)
1980	10,501	5,911	4,590	4,745	0.56
1981	12,888	7,441	5,447	5,447	0.58
1982	11,953	7,723	4,230	3,909	0.65
1983	13,518	8,415	5,103	4,654	0.62
1984	17,621	11,222	6,399	5,381	0.64
1985	18,443	12,059	6,384	4,960	0.65
1986	19,885	12,874	7,011	4,983	0.65
1987	20,730	13,564	7,166	5,681	0.65

Sources: Statistics Canada, Science Statistics, Cat. No. 88-001, Vol. 12, No. 3, May 1988.
Bank of Canada, Bank of Canada Review, April 1988.

The rising high-technology trade deficit in current dollars during the eighties confirms that Canada is a unvarying net importer of high-technology products. However, the slight decrease of the import coverage ratio indicates that the importance of exports of high-technology products relative to imports has slowly increased during the eighties.

R&D-intensive products tend to be capital goods; the magnitude of imports merely indicates that Canadian industries are investing heavily in high-technology capital goods and presumably are forecasting a positive return on their investments.

More than 75 per cent of our trade in high-technology products is with the U.S. Over the last five years, exports to the U.S. have increased from 68 per cent to 76 per cent while imports declined from 83 per cent to 77 per cent. In 1987, the deficit with the U.S. was 80 per cent of the total. Trade in computers and related equipment accounted for one-third of Canada's deficit, while 80 per cent occurred in just three areas: computers, scientific instruments and non-electrical machinery.

Table C-4 provides a product group analysis of Canada's high-technology trade balance.

TABLE C-4
HIGH-TECHNOLOGY TRADE DEFICIT BY PRODUCT GROUP, 1986

Product Group	Total -(millions of dollars)-	-(per cent)-	With the U.S. -(millions of dollars)-	-(per cent)-
Computers and related equipment	2,680	37	2,390	42
Non-electrical machinery	1,468	20	783	14
Scientific instruments	1,393	19	909	16
Electronic equipment	1,115	16	947	17
Electrical machinery	669	9	461	8
Chemicals (including drugs)	215	3	322	6
Telecommunications equipment	36	1	(164)[1]	(3)[1]
Aerospace	(410)[1]	(6)[1]	84	1
Total[2]	7,166	100	5,731	100

1. Positive trade balance.
2. Columns may not add to totals due to rounding.

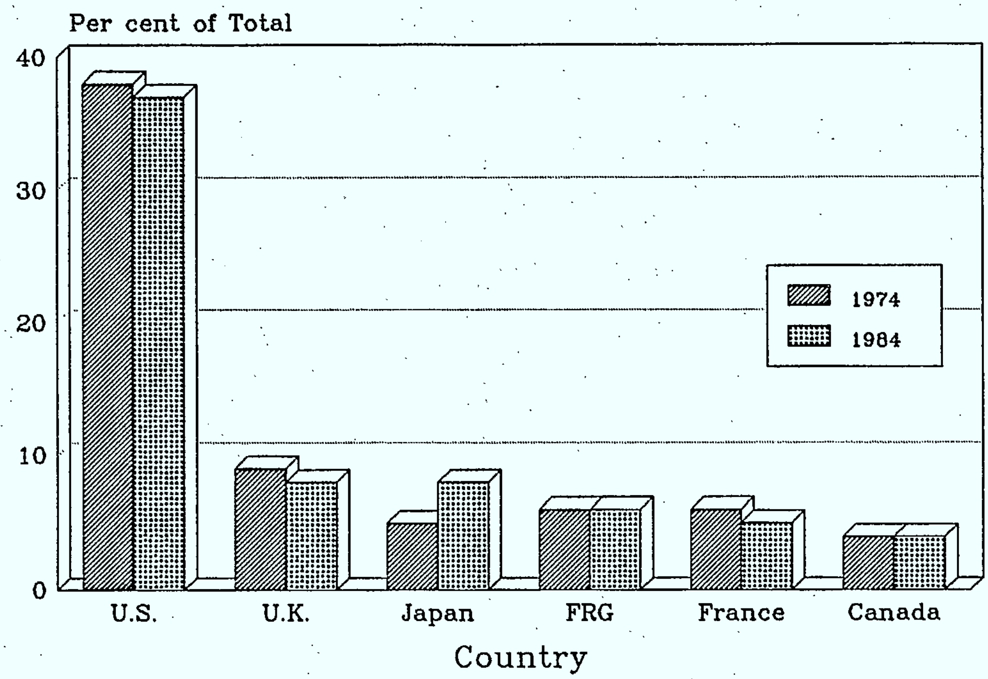
Source: Statistics Canada, Science, Technology and Capital Stock Division.

4. Scientific Literature (Bibliometrics)

Scientific literature is one of the major direct outputs of the research system and can be considered as both an intermediate and a final product. The direct output of basic research, for example, is typically the published paper and, hence, the analysis of publications is a reasonable way of assessing the performance of the basic research system. Other areas of research are, however, more problematic since they produce other outputs in addition to papers and since commercial or military considerations may impede open publication.

According to an analysis of the papers published in a set of over 2,100 highly-cited and influential scientific and technical journals, Canadians author about 4 per cent of the world's research papers, a share which ranks Canada sixth among all OECD nations (Figure C-4). Not unexpectedly, the U.S., which provides nearly half of the OECD's total expenditures on R&D and more than one-third of the inputs into university research, also accounts for the largest number of papers. Also, not surprisingly, Japan, which has had the greatest increase in R&D expenditures, recorded the largest growth in its publication output, increasing its share from 5 per cent in 1973 to 7 per cent in 1984 and raising Japan from fifth to third position in the OECD.

FIGURE C-4
COUNTRY SHARES OF THE WORLD'S RESEARCH PAPERS



Source: ABRC, ABRC Science Policy Studies No. 1, Evaluation of National Performance in Basic Research, 1986.

Changes in the distribution pattern of published outputs within individual countries may provide insights into the extent to which policy decisions affect the actions of researchers or the allocations of resources to different kinds of scientific activities. In recent years, practically every OECD country has announced new priorities for research. Almost invariably, these priorities include biotechnology, microelectronics and advanced materials. Hence, the success of government efforts to re-orient priorities in these directions should, to some measure, be evident in an examination of the publication outputs in the targeted areas (Table C-5).

TABLE C-5
CHANGES IN THE NUMBER OF PUBLICATIONS IN SELECTED AREAS OF S&T, 1975-1984

Country	All Areas	Biotechnology Relevant	New Materials Relevant	Micro-electronic Relevant
	(per cent change)			
Finland	56	37	35	73
Japan	55	94	57	39
Netherlands	41	64	10	34
Italy	27	59	18	58
Sweden	19	12	13	53
Norway	18	(1)	(8)	7
Canada	9	15	1	20
U.S.	8	23	5	10
Switzerland	5	35	4	41
FRG	3	11	14	(5)
France	(5)	39	14	30
U.K.	(7)	2	26	(20)
OECD Total	11	27	9	13
World Total	10	23	12	17

Source: OECD, The Research System in Transition, SPT(87)13, June 1987.

The publication data clearly show that the OECD as a whole has substantially increased its output of biotechnology-relevant papers. In almost every country, the papers in this category have grown at a much faster rate than total publications and, hence, the shares of biotechnology-relevant papers in national outputs have also risen in most countries. However, among the basic sciences relevant to biotechnology, the trends were much more diverse. In Canada, for example, the share of national output increased in immunology, virology and pharmacology but decreased in chemical engineering and biochemistry. In Japan, on the other hand, the output shares increased for all of the biotechnology-relevant sub-areas except microbiology.

With respect to new materials and microelectronics, the publication data provide no evidence to suggest an OECD-wide focusing of effort in these key areas of research. Whereas, in some countries such as Japan and France, the shares of national publications grew for all research fields related to new materials and microelectronics, in most the share of national outputs remained stable or actually decreased. This suggests that Japan and France are the countries that have best succeeded in re-orienting their research priorities in accordance with their stated policy goals. Other countries have either been less successful or, having adopted their priorities at a much later date, did not have sufficient time by 1984 to implement their research policy.

These figures, however, mask substantial differences in the orientation of the various national programs, differences which result in shares that vary according to the field of science (Table C-6). Thus, in terms of shares of published papers, U.S. dominance is greatest in the earth and space science, in biology and in clinical medicine and is weakest in chemistry and physics. Canada, on the other hand, has a 9 per cent share of the world's research papers in biology, a 6 per cent share in earth and space science and only 3 per cent shares in chemistry and physics.

TABLE C-6
PUBLICATIONS BY MAIN FIELD OF S&T, 1984

Field	U.S.	U.K.	Japan	FRG	France	Canada	Rest of World
	(per cent)						
Clinical medicine	42	10	6	6	5	4	27
Chemistry	21	6	12	6	5	3	46
Biomedical research	40	8	7	6	5	5	29
Physics	29	6	9	7	6	3	40
Engineering & technology	41	8	9	8	3	5	27
Biology	42	10	7	4	3	9	25
Earth & space science	44	8	3	4	4	6	31
Mathematics	37	7	6	7	8	4	31
All fields	37	8	8	6	5	4	33

<u>Source</u>: Statistics Canada, <u>Indicators of Canadian Research Output, 1984</u>, March 1988.

Unlike publication counts which are merely an indicator of quantity, citations reflect the relevance, influence or quality of the research output. Table C-7 shows there has been a decrease in the international influence of Canadian-authored papers. Nevertheless, these have remained more influential than French- or Japanese-authored papers in each major field of research. It is interesting to note that, while Canada produces a higher than average number of papers in biology, it is in chemistry -- a field in which Canada has had two Nobel prizewinners -- that Canada has had the greatest influence.

TABLE C-7
INTERNATIONAL CITATIONS TO CANADIAN PAPERS[1]

Field	1973	1977	1981
	(relative citation ratio[2])		
Clinical medicine	0.90	0.82	0.75
Biomedical research	0.67	0.61	0.57
Biology	0.80	0.60	0.53
Chemistry	1.19	1.08	0.88
Physics	0.77	0.69	0.63
Earth and space science	0.77	0.57	0.50
Engineering and technology	0.94	0.82	0.65
Mathematics	0.56	0.61	0.63

1. International citations are citations made to Canadian-authored papers by non-Canadian-authored papers.
2. A citation ratio of 1.00 reflects no over- or under-citing of Canadian S&T literature, whereas a higher ratio implies a greater impact or use than would have been expected from the number of Canadian papers produced for that year.

Source: Statistics Canada, Indicators of Canadian Research Output, 1984, March 1988, from Science Literature Indicators Data Bank, Computer Horizons, Inc., Haddon Heights, New Jersey, 1987.

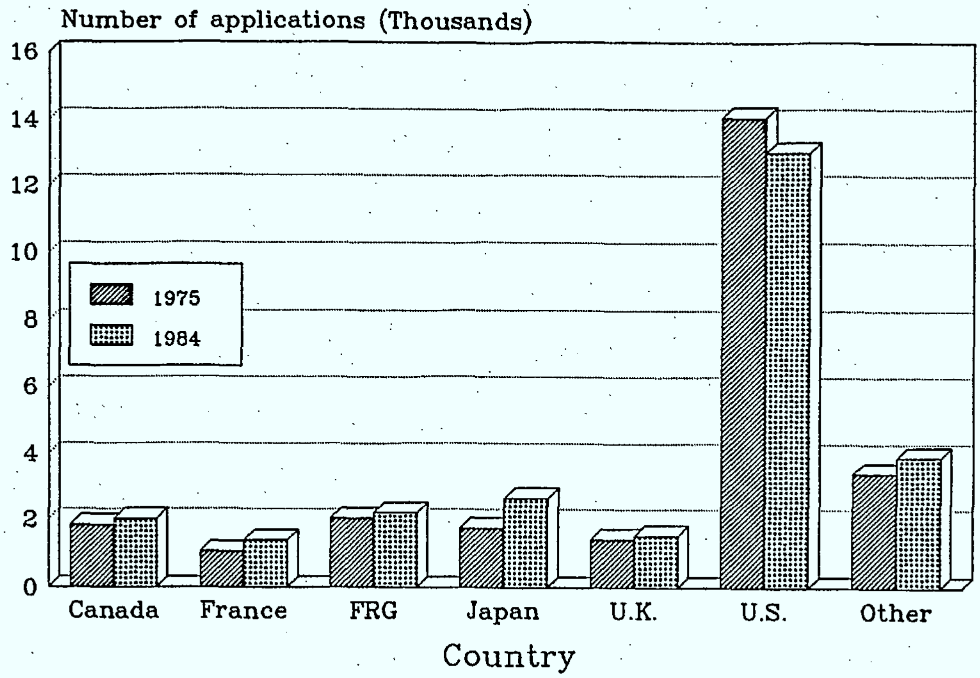
The bibliometric data also show that there is a large and growing degree of co-operation in Canadian research. During the period 1981-1984, for example, about half of the Canadian papers had two or more authors. In about 44 per cent of these cases, the second author was a non-Canadian. The degree of co-authorship was greatest in clinical medicine and earth and space science, where at least six out of every ten papers were co-authored, and least in biology and mathematics. Foreign co-authorship was greatest in "big" science fields such as physics (high-energy particles) and space science. The recent expansion of programs designed to encourage networking and create stronger university-industry-government linkages should lead to a larger share of co-authored Canadian papers.

5. Patents

Patent data can be used to gain some useful insights into the relative positions of the various countries as producers of technology. Moreover, patent statistics can give an indication of a nation's contribution to the international dissemination of technology.

Canadian patenting activity is largely dominated by foreign nationals. As shown in Figure C-5, American residents account for at least half of the patent applications. Over the period 1975 to 1984, Canada's share of patent applications has remained essentially constant at 7 per cent, a proportion which is unusually small even for the smaller OECD economies. In Spain, for example, indigenous inventions account for about 16 per cent of the total applications, in Denmark 19 per cent, and in Belgium 24 per cent.

FIGURE C-5
PATENT APPLICATIONS FILED IN CANADA BY COUNTRY OF INVENTOR, 1975-1984



Source: World Intellectual Property Organization, Industrial Property Statistics, Geneva, various issues.

The dominant feature in Canadian patenting has been the strong growth in the number of patents filed on Japanese inventions. The number has increased by more than one-half and Japan's share of Canadian patent applications has grown from 7 per cent in 1975 to 10 per cent in 1984. A similar trend is noticeable in the U.S. where Japanese inventions account for almost 17 per cent of the patents granted in 1984, up from about 9 per cent in 1975. Moreover, according to recent studies by F. Narin *et al.*, published in CHI Research in an article entitled *Identifying Areas of Strength and Excellence in U.K. Technology* (February 20, 1987), the patents awarded to Japanese inventors are by far the most frequently-cited and the citation gap between Japan and other nations appears to be broadening. This suggests that Japan's position in patented technology is strong, growing and based on high-quality, leading edge technology.

6. Science Education

According to a recent international study of science achievement, Canadian Grade 12/13 students rank near the bottom of the class. The study, conducted by the International Association for the Evaluation of Educational Achievement, tested students on their knowledge of basic concepts of biology, chemistry and physics. The results, showing England and Hong Kong near the top of the rankings and Canada and Italy near the bottom, are summarized in Table C-8 below.

TABLE C-8
RANK ORDER OF COUNTRIES FOR SCIENCE ACHIEVEMENT

Country	Grade 12/13 Science Students		
	Biology	Chemistry	Physics
England	2	2	2
Hong Kong	5	1	1
Singapore	1	3	5
Hungary	3	5	3
Japan	10	4	4
Norway	6	8	6
Australia	9	6	8
Sweden	8	9	10
Finland	7	13	12
U.S.	13	11	9
Canada	11	12	11
Italy	12	10	13
Total Number of Countries	13	13	13

Source: U.S. National Science Foundation, Science Achievement in Seventeen Countries, 1988.

In general, the tests showed that the difference in the science achievement between boys and girls is still large is most countries. Boys outperformed girls in all subjects except biology in nearly every country. Only in Australia, Hong Kong and Sweden did girls score slightly better than boys.

The failure of its students to master scientific concepts in Grade 12/13 probably accounts for Canada's relatively low shares of science and engineering degrees at the undergraduate and graduate levels. Whereas in the U.K., for example, 54 per cent of the full-time undergraduate students are enrolled in natural sciences and engineering programs, in Canada the comparable figure is only 30 per cent. The differences are less substantial at the graduate level with 51 per cent of the U.K. students enrolled in natural sciences and engineering faculties as compared with 47 per cent in Canada. However, at both the undergraduate and graduate levels, Canada's share of students in engineering is relatively low.

* * *

DATE DUE - DATE DE RETOUR

ISTC 1551 (2/90)