Ministry of State
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UNIVERSITY RESEARCH IN CANADA

A Background Paper
for the
National Forum on
Post-Secondary Education

INNOVACTION
The Canadian Strategy for Science and Technology

Canada

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INTRODUCTION

The purpose of this paper is to stimulate informed discussion of university research and its role in helping Canadians move confidently and successfully into the 21st century.

The paper has four parts: first, an overview of the character and funding of university research; second, a perspective on highly qualified personnel; third, a brief sketch of the emerging knowledge, technology and expertise transfer role of the university; and fourth, some of the research and related issues important for the future of universities, and for Canada.

Canada's universities have responded remarkably well to the challenges of the past. Today, they are a rich and diverse resource extending from coast to coast. Collectively, the universities perform three roles essential to Canada's economic, social and cultural progress: teaching; research; and, the transfer of knowledge, technology and expertise to the wider community. Individually, each university responds to the needs and aspirations of its more immediate community and to the policies of its provincial government: education is a constitutional responsibility of the provinces.

Federal government support for post-secondary education takes a number of forms, including: fiscal transfers to the provinces under the Established Programs Financing arrangements; Canada Student Loans programs; special provisions of the Income Tax Act; and, direct support of university research and research training, mainly through the three federal research Granting Councils.

University research, in particular natural sciences and engineering, is the primary focus of this paper: the broader cultural aspects are recognized, but are beyond the scope of the paper. There are, as well, many interdependent linkages amongst the research, teaching and knowledge/technology transfer functions. All three will become increasingly important to Canada's future as we move, by necessity, towards a more knowledge-intensive society and economy.

Knowledge is becoming a key international commodity and its productive application is increasingly determining the future competitive success, and consequent standard of living, of whole nations.

The universities are, therefore, central to Canada's future. In the years ahead, the universities and university research face even more significant challenges and opportunities than in the past as Canada — like its competitors — transforms itself into a more knowledge-intensive society.

University Research in Canada

- 25% of all research and development in Canada is performed by universities
- since 1977, expenditures on university research have risen from $710 million to an estimated $1.7 billion
- in 1984-85, 40% of university research was in the natural sciences and engineering, 32% was in the health sciences, and 28% was in the social sciences
- the federal government is the largest single funder of university research, providing about 60% of all outside sources of funding
- the proportion of total expenditures on university research provided by governments is increasing significantly, while the proportion provided by universities themselves is declining
- under the current $3.4 billion five-year federal financial plan for university research to 1990-91, including the private sector share under the matching fund policy, funding will increase by 50% compared to the 1981-85 period.

Highly Qualified Personnel in Canada

- Canada has relatively few research scientists and engineers, tied with Italy in second last place among OECD countries
- the number of higher degree holders (Master's and Ph.D.s) in all professions has been growing, totalling over 300,000 in 1981 or 2.5% of the total workforce. Medicine and health, university teaching and physical and life sciences occupations all experienced a proportionate decline. Engineering, social sciences, and managers/administrators enjoyed the largest proportionate growth
- full-time university enrolments have increased dramatically in recent years, but the proportion of enrolments in the natural sciences, engineering and applied sciences has not grown significantly, accounting for less than one-third of enrolments in 1984-85: the greatest increase has been in the social sciences and humanities
- the number of graduate degrees in the social sciences and humanities has grown twice as fast as in the natural sciences and engineering; the percentage of graduate degrees in these fields has actually declined since 1970
- while women account for roughly half of university enrolments, relatively few women enroll in the natural sciences and engineering, especially at the graduate level: in 1985 women received just over 10% of Masters degrees and 6% of Ph.D. degrees in the engineering and applied sciences
- between 1955 and 1985, the number of research-intensive personnel immigrating to Canada exceeded the number who left for the U.S. by up to 1300% annually: in the 1980-85 period some 10,000 landed immigrants with Master's and Ph.D. degrees entered Canada — equal to about one-half the number of graduate degrees awarded to Canadians by the universities in the same period
- historically, training highly qualified personnel has proven to be a wise investment paying social, economic and cultural benefits: unemployment rates for highly qualified personnel are consistently less than one-half that of the labour force as a whole
- the Economic Council of Canada has projected employment to 1995: in the "professional" categories growth rates are projected to be in the 30-200% range with highest growth in mathematics, statistics and systems analysis. This compares to projections of about 12% for all occupations.

Universities and Technology Transfer

- universities are developing a new role as active agents of progress, through the diffusion of knowledge, technology and expertise to other sectors of society
- interest in university-industry collaboration is growing: in 1984-85 industry spent $45 million on contract research in universities, compared to $17 million in 1979-80; contract research with universities by non-profit organizations grew from $70 million in 1979-80 to $160 million in 1984-85
- private sector funding of sponsored research in universities ranges from 18-25 per cent in all regions of Canada
- early indication is that the federal matching grants policy will substantially increase research collaboration between universities and the private sector.

Issues for the Future

- as Canada adapts to a rapidly changing, knowledge-intensive economy, what is the appropriate balance between a university's roles in teaching, research and technology transfer?
- how should universities identify and manage their research priorities, given the need to:
  - develop centres of excellence to focus scarce resources on key areas of leading-edge research;
  - encourage the multidisciplinary research required to advance new areas of science and technology;
  - maintain the vital interaction between basic and applied research; and
  - allocate research resources between research areas where indirect costs are relatively low, and areas which are increasingly cost-intensive such as natural sciences and engineering?
- what kind of highly qualified people should universities provide to meet Canada's future needs, given:
  - the difficulty in predicting those needs accurately;
  - the rapidly increasing knowledge and technological-intensity of the economy;
  - an aging population of university teachers;
  - key areas of opportunity where demand does not precede, but is created by, the supply of qualified personnel; and
  - the need to encourage more women to enter research-intensive careers?
- how can universities cooperate more effectively with the private sector in their research efforts, recognizing:
  - the vital importance of transferring knowledge and technology from the university to the market place;
  - the divergent objectives and "cultures" which have separated industry and university research in the past;
  - the need to safeguard university traditions of independence and scholarship; and
  - the key role universities can play in regional development?

An Overview of University Research in Canada

1. The Contribution of Universities to the National R&D Effort

University-based research accounts for an estimated 25 per cent ($1.7 billion) of all research and development ($7 billion) that will be performed in Canada in 1987. The universities themselves fund about 40 per cent of the R&D they perform.

The universities rank second to business in the amount of R&D they perform, while they are third after business and the federal government in terms of their own expenditures on R&D.

TABLE 1
Gross Expenditure on R&D (GERD) by Funder and Performer by Percentage (NSE+SSH)*

Year	Federal Government	Provincial Government	Business	University	Other
Funder Shares, % of GERD					
1981	34	7	42	11	6
1983	37	7	39	10	7
1985	35	7	42	9	7
1987**	34	7	43	10	7
Performer Shares, % of GERD					
1981	21	3	49	25	2
1983	23	3	48	25	1
1985	21	3	51	23	2
1987**	20	2	51	25	2

* (Natural Sciences and Engineering & Social Sciences and Humanities).
** Estimate
Source: Statistics Canada, Science Statistics, Vol. 11, No. 1, 1987.

2. Sources of Funding for University Research

In 1987, the value of all R&D performed in universities is estimated to be $1.7 billion: an increase from some $710 million in 1977. As noted above, the universities themselves fund $680 million or about 40 per cent of that amount. The federal government, however, is the single largest external funder — providing almost $600 million for directly sponsored research: 35 per cent of all university research or about 60 per cent of all outside sources of funding. In addition, federal transfers to provinces under the Established Programs Financing arrangements are, in part, allocated by provinces and universities to support research.

TABLE 2
Total Expenditures on R&D (NSE and SSH), 1987 (Estimates)

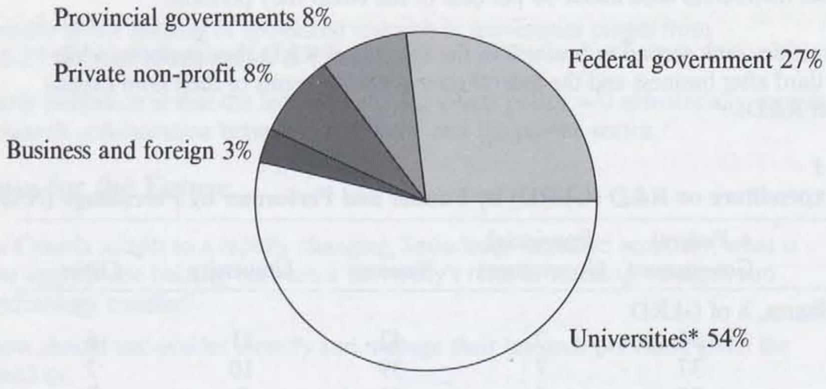
	PERFORMER						
FUNDER	FED	PROV	PRO	BE	UNIV	PNP	TOTAL
	(millions of dollars)						
FED	1,380	—	10	375	592	28	2,385 (34%)
PROV	—	138	44	57	205	25	469 (7%)
PRO	—	—	6	—	—	—	6 —
BE	—	—	16	2,888	70	6	2,980 (42%)
UNIV	—	—	—	—	680	—	680 (10%)
PNP	—	—	—	—	186	38	224 (3%)
FOREIGN	—	—	2	316	10	—	328 (5%)
TOTAL	1,380 (20%)	138 (2%)	78 (1%)	3,636 (51%)	1,743 (25%)	97 (1%)	7,072

PRO = Provincial Research Organization BE = Business Enterprise PNP = Private Non-Profit Organization

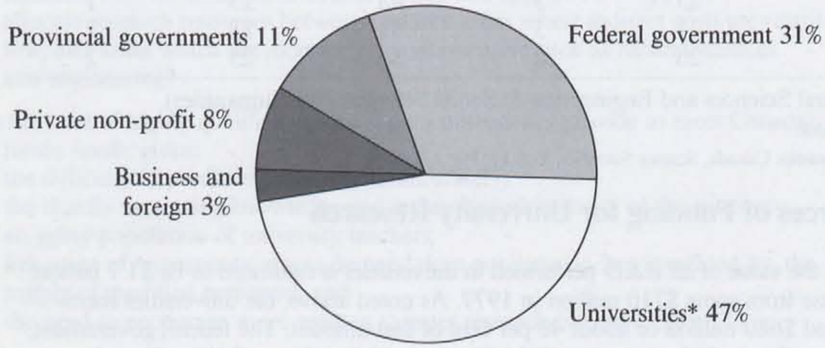
Source: Statistics Canada, Science, Technology and Capital Stock Division.

In the 1977-1987 period, governments increased their share of university research expenditures from 35 to 46 per cent. Over the same period, the universities reduced their own share of expenditures on research from 54 to 39 per cent.

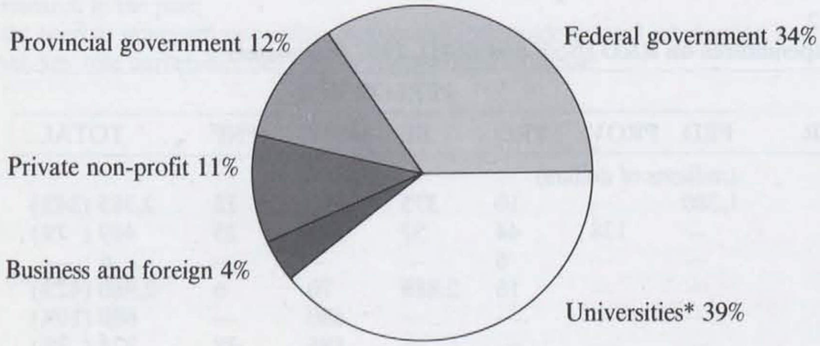
TABLE 3
Sources of Funds for University R&D 1977, 1982 and 1987



1977



1982



1987

* Costs of unsponsored R&D and of sponsored R&D not covered by direct funding.

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

3. University Research by Field of Study and Funding Sector

1984-85 is the latest year for which estimates are available to indicate how expenditures are distributed across the three broad fields of university research: forty per cent was devoted to engineering and other natural sciences; 32 per cent to health sciences research; and, 28 per cent to the social sciences.

As the single largest external source of funding for university research, the federal government supported 35 per cent of all health sciences research, 53 per cent of natural sciences and engineering and 14 per cent of social sciences research. By comparison, the universities themselves funded almost an equal share (33%) of health sciences as did the federal government, but less than half (21%) of the proportion of natural sciences and engineering research funded by the federal government. The greatest difference is in social sciences research where the universities funded five times (70%) the share funded by the federal government at 14 per cent.

TABLE 4
University Research by Field of Study and Funding Sector, 1984-85

	Health Sciences		Engineering and Other Natural Sciences		Social Sciences		Total	
	($M)	(%)	($M)	(%)	($M)	(%)	($M)	(%)
Total Federal Government	159	(35)	303	(53)	55	(14)	517	(36)
- SSHRC (1)	—		—		30	(8)	30	(2)
- NHW & MRC (2)	150	(33)	—		—		150	(10)
- NSERC (3)	9	(2)	240	(98)	—		249	(18)
- Other (4)	—		63	(11)	25	(6)	88	(6)
Provincial Governments	28	(6)	91	(16)	49	(12)	168	(12)
Industry	8	(2)	29	(5)	9	(2)	46	(3)
Private Non-Profit (5)	105	(23)	23	(4)	7	(2)	135	(10)
Higher Education (6)	150	(33)	117	(21)	280	(70)	547	(38)
Foreign	5	(1)	6	(1)	—		11	(1)
Total	455	(100)	569	(100)	400	(100)	1424	(100)

Source: Statistics Canada, Science and Technology Statistics Division.

Notes:
1. Social Sciences and Humanities Research Council
2. Includes Health and Welfare and Medical Research Council funding.
3. Natural Sciences and Engineering Research Council.
4. Includes all other federal R&D grants and contracts performed in institutions of higher education.
5. Includes charities, foundations, etc.
6. Includes funding for higher education by the federal and provincial governments under EPF, as well as funding from higher education institutions.

Note: Table 4 is a preliminary estimate by Statistics Canada which is currently reviewing its methodology. Thus, the data should be used with some caution.

4. Federal Support of University Research

Indirect federal support is provided through: the provisions of the Income Tax Act (e.g. tuition fee and charitable donation deductions and R&D tax credits to businesses who contract eligible research to universities); fiscal transfers to provinces under the Established Programs Financing arrangements; and assistance to students under the Canada Student Loans program.

The direct federal support of university research is channelled mainly through the three research Granting Councils:

- the Natural Sciences and Engineering Research Council;
- the Medical Research Council; and,
- the Social Sciences and Humanities Research Council.

The three Councils operate at arm's length from the government under authority of special Acts of Parliament. They fund and promote research, research training and related activities located mainly at universities.

The Councils administer about 80 per cent of all direct federal funding of university research. The balance is provided by a number of other federal departments and agencies in the form of contracts and grants to support specific departmental needs for research.

The $582 million budget of the three Councils in 1987-88 is distributed based on peer-adjudicated grants to cover the direct costs of the research and related activity being supported.

The Granting Councils' support can be considered as a three stage pyramid of assistance:

Support for the Broad Research Base: support of the broad university research base through a large number of relatively small operating grants and scholarships to individual professors and students. This consumes some 70 per cent of total budgets.

Strategic Grants: a system of grants to focus and target research on areas of national importance. About 10 per cent of the budgets is spent on strategic grants.

University-Private Sector Research Collaboration: given a major stimulus by the matching funding policy announced by the federal government in 1986, some 8 per cent of Councils' budgets are currently spent on furthering research collaboration between the universities and the private sector. This is the fastest growing component of Granting Councils' budgets.

The balance of Councils' budgets supports a variety of other activities, including funding of scientific and learned societies, workshops, seminars and administrative costs (the latter ranging from under 4 per cent to about 8 per cent of total budgets amongst the three Councils).

Federal support, Granting Councils and other departments and agencies included, is concentrated in a relatively small number of universities. The top five universities received 43 per cent of 1984/85 federal funding, the top ten 63 per cent and the top fifteen universities received almost 80 per cent.

TABLE 5
Top 15 University Recipients of Federal Funding, 1984-85

Universities	Grants	Total Funding
	(millions of dollars)	(percentage)
Toronto	67.3	14.7
McGill	40.2	8.9
British Columbia	38.5	8.4
Alberta	24.6	5.4
Montreal	24.5	5.4
McMaster	21.5	4.7
Manitoba	19.7	4.3
Western	19.0	4.2
Waterloo	18.2	4.0
Laval	15.9	3.5
Queen's	15.9	3.5
Calgary	14.5	3.2
Saskatchewan	13.9	3.0
Dalhousie	13.5	3.0
Ottawa	12.2	2.7
Total Funding to All Canadian Universities	457.2	100.0

Source: NRC, Canada Institute for Scientific and Technical Information, Directory of Federally Supported Research in Universities, Volume 1, 1984/85.

In the February 1986 Budget, the federal government announced a $3.4 billion five-year financial plan for university research, including a new policy to encourage and support university-private sector research collaboration — (the matching funding policy). The government augmented the five-year plan in August 1987 by announcing an $18 million increase to the Councils' budgets as part of InnovAction, the Canadian strategy for science and technology.

TABLE 6
The Federal 5-Year Financial Plan for University Research, 1986-91
($ Millions)
Total of Three Granting Councils

	1986-87	1987-88	1988-89	1989-90	1990-91	Total 1986-1991
Base Budgets of Councils	562.0	537.7	538.7	538.7	538.7	2715.8
Federal Matching of Private Sector Contributions, Maximum	—	44.5	69.7	110.3	155.7	380.2
Total Federal Funding	562.0	582.2	608.4	649.0	694.4	3096.0
Anticipated Private Sector Contributions	—	44.5	69.7	110.3	155.7	380.2
Total Available Funding for University Research (federal government and private sector)	562.0	626.7	678.1	759.3	850.1	3476.2

Source: Ministry of State for Science and Technology.

Under the five-year plan, funding for university research to 1990-91 will increase by over $1 billion or 50 per cent compared to the 1981-85 period.

TABLE 7
UNIVERSITY RESEARCH — GRANTING COUNCILS
Comparison of 1981-85 with 1986-91 Period
($ millions)

Total Funding — Three Councils	1981-82/1985-86	1986-87/1990-91
Parliamentary Main Estimates Provision	2125.3	3078.0
Parliamentary Supplementary Estimates	186.0	18.0*
Sub Total	2311.3	3096.0
Private Sector Share of Matching Policy	nil	380.2
TOTAL	2311.3	3476.2

* Announced August 19, 1987
Source: Ministry of State for Science and Technology.

5. Some International Comparisons

Canada's universities performed almost 25 per cent of the nation's R&D in 1983, (the last year for which international data are available) compared to Australia (30%), Sweden (27%), France and Germany (15%) and the U.S.A. and the U.K. (13%).

By a different measure, i.e. higher education R&D as a per cent of Gross Domestic Product, Canada's .34 compares to the U.S.A. (.36), U.K. (.31) and Sweden (.66).

TABLE 8
Expenditure on R&D in the Higher Education Sector International Comparisons, 1983

	HERD[1]/GERD[2] per cent	HERD/GDP[3] per cent
Australia	30.5	0.29
Sweden	27.0	0.66
Iceland	26.5	0.20
Norway	25.9	0.37
Netherlands	25.3	0.51
Canada	24.7	0.34
Japan	23.0	0.59
Finland	21.4	0.28
Italy	19.3	0.22
Spain	17.7	0.08
Ireland	17.4	0.12
Switzerland	17.4	0.40
France	15.8	0.34
Germany	15.6	0.40
United Kingdom	13.8	0.31
United States	13.4	0.36

1. Higher Education R&D Expenditures
2. Gross Expenditures on R&D
3. Gross Domestic Product

Source: Organization for Economic Co-operation and Development.

An Overview of Highly Qualified Personnel in Canada

1. The Scientific and Engineering Intensity of the Labour Force

A country that has a strong ability to invent has the prerequisite foundation for an equally strong ability to exploit. These abilities are primarily embodied in people — i.e. highly qualified personnel, mainly graduates of our universities. Judged by the number of research scientists and engineers in our labour force, Canada has a relatively weak ability to invent and exploit, compared to other countries. Growth in the number of research scientists and engineers in Canada from 1979 to 1983 was slightly higher than the median for other OECD countries, but that growth rate was lower than in France, Sweden, Italy and the USA. Canada continues to rank below the median of OECD members, per thousand of research scientists and engineers in its labour force, tied with Italy in second last place. Canada ranks third last of OECD countries in respect of R&D personnel, ahead of only Austria and Italy.

TABLE 9
Total R&D Personnel and Research Scientists and Engineers (RSE) Per Thousand Labour Force, 1983

Country	R&D Personnel	RSE	Change in RSE from 1979
	(per thousand)		(percentage)
FRG	13.5	4.8	7
Japan	12.1	7.4	14
Switzerland ('79)	11.8	3.4	—
France	11.0	3.9	26
Sweden	10.5	3.9	39
Netherlands	9.9	3.7	6
Norway	7.9	4.1	11
Finland	7.9	3.7	23
Canada	5.9	2.7	17
Austria ('81)	5.6	2.0	—
Italy	4.9	2.7	29
United States	—	6.4	21

Note: RSE in some countries consists of all university graduates in science and engineering.

Source: OECD, Recent Results, 1979-1986. The OECD notes that the Japanese data are likely over-estimated. No data are available for the U.K.

A second broad measure of Canada's ability to invent and exploit is the proportion of the labour force holding a Master's or Doctorate degree. Between the two census periods 1971 and 1981, there was an 88 per cent growth in the numbers of higher degree holders (i.e. highly qualified personnel) in all occupations: from 161,000 in 1971 to over 303,000 in 1981. In 1981 some 2.5 per cent of the Canadian workforce held Master's or Doctorate degrees compared to 1.8 per cent in 1971.

As a share of all Master's and Doctorate degree holders, those experiencing declines between 1971 and 1981 included: medicine and health (-10.0%); university teachers (-3.1%); physical sciences (-1.0%); and life sciences (-0.2%). Occupations whose shares grew over the decade included: architects and engineers (2.1%); managers and administrators (2.0%); social sciences, social work, law and religion along with "other teaching occupations" (1.5 %). Mathematicians and systems analysts grew by only one-half of one per cent as a share of the total workforce with Master's and Doctorate degrees.

TABLE 10
1971/1981 Census
Experienced Labour Force 15 Years and Over by Highest Degree Obtained

Occupation	Total All Education 1971	Total All Education 1981	Master's & Doctorate Degrees 1971	Master's & Doctorate Degrees 1981	Percent of Total 1971	Percent of Total 1981
	(thousands)				(percentage)	
Managers & Admin. & Related Occs.	372.2	814.0	23.5	53.3	6.3	6.5
Physical Sciences	34.3	40.5	5.3	6.9	15.3	17.1
Life Sciences	19.1	28.3	3.1	5.2	16.4	18.2
Architects & Engineers	154.5	266.4	7.9	20.7	5.1	7.8
Mathematics & Systems Analysts	26.2	67.7	2.0	5.2	7.7	7.7
Soc. Sci, Soc. Work, Law & Religion	102.6	220.9	16.6	35.7	16.2	16.1
University Teachers	23.5	33.6	19.6	27.6	83.7	82.1
Other Teaching Occupations	325.8	455.6	20.6	43.4	6.3	9.5
Medicine & Health**	326.6	519.2	50.0	64.9	12.3	12.5
All Other Occupations	7,428.5	9,820.8	22.3	40.4	0.3	0.4
All Occupations	8,813.3	12,267.1	161.0	303.4	1.8	2.5

** Includes first professional degrees (M.D.s, D.D.S.s, D.V.M.s, etc.) with Masters's and Doctorates.

Source: Statistics Canada, 1971/1981 Census (Special Run).

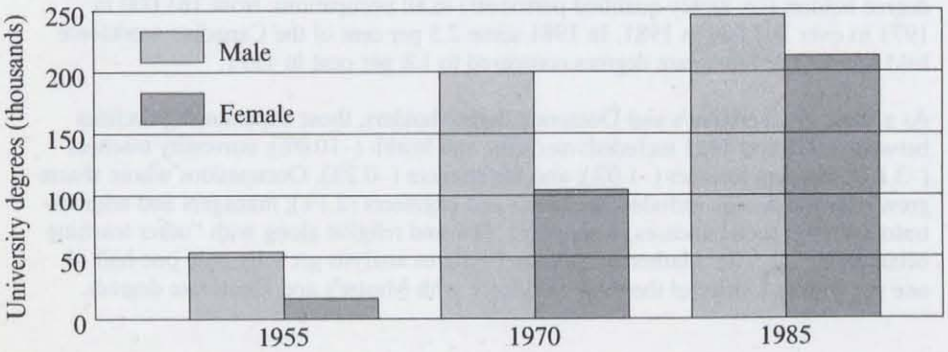
2. The Quantity and Kind of Highly Qualified Personnel Produced by Canada's Universities

a) Trends in Enrolments

The educational and training role of universities is intricately linked to the research role. The educational function has been characterized by increasing specialization and differentiation of program offerings in response to the evolution of scientific fields, the professionalization of work, and the demands of student enrolment. While the education role is performed mainly at the undergraduate level, education at the graduate level is of particular significance for the research function and to the training of highly qualified personnel for the country.

Canada is second only to the United States in the proportion of people in the 18-24 age group attending university (13.5% compared to the U.S. 18.5%). Full-time university enrolment increased dramatically from 1955 to almost one-half million in 1985, with women now accounting for one-half of enrolments.

TABLE 11
Full-time University Enrolment by Sex, 1955, 1970 and 1985



Source: Statistics Canada, Education, Culture and Tourism Division.

The distribution of university enrolments by field of study is illustrated in Table 12. Enrolment in natural sciences and engineering has not experienced any significant growth as a proportion of total enrolments — 31.9 per cent in 1984-85. In the engineering/applied sciences, the growth rate was still slower (9.7 per cent in 1970-71, compared to 10.6 per cent in 1984-85). By contrast, the proportionate share of enrolments in social sciences and humanities increased from 46 per cent to over 52 per cent.

On the basis of absolute numbers, enrolments in natural sciences and engineering increased 61 per cent over the 1970-1985 period compared to 67 per cent for social sciences and humanities.

TABLE 12

Full-Time University Enrolment[1] by Field of Study, Canada

	1970-1	1975-6	1980-1	1984-5
Natural Sciences and Engineering	**84,317**	**93,963**	**106,982**	**135,700**
(1970 = 100)	(100)	(111)	(127)	(161)
%	28.8	27.6	30.3	31.9
Engineering/Applied Sciences	28,395	31,727	39,235	44,976
	(100)	(112)	(138)	(158)
%	9.7	9.3	11.1	10.6
Mathematics/Physical Sciences	20,471	17,226	22,406	36,331
	(100)	(84)	(109)	(177)
%	7.0	5.0	6.3	8.5
Agriculture/Bio Sciences	19,529	23,791	22,059	28,198
	(100)	(122)	(113)	(144)
%	6.7	7.0	6.2	6.6
Health Professions	15,922	21,219	23,287	26,195
	(100)	(133)	(146)	(164)
%	5.4	6.2	6.6	6.2
Social Sciences and Humanities	**133,703**	**166,682**	**181,880**	**223,455**
(1970 = 100)	(100)	(125)	(136)	(167)
%	45.7	48.9	51.5	52.5
Education	35,479	44,942	38,076	42,853
	(100)	(127)	(107)	(121)
%	12.1	13.2	10.8	10.1
Humanities[2]	37,901	39,882	41,268	51,371
	(100)	(105)	(109)	(136)
%	13.0	11.7	11.7	12.1
Social Sciences	60,323	81,858	102,536	129,231
	(100)	(136)	(170)	(214)
%	20.6	24.0	29.0	30.4
Unclassified	74,328	80,187	64,359	66,135
%	25.4	23.5	18.2	15.6
TOTAL	292,348	340,832	353,221	425,290
	(100)	(117)	(121)	(145)

1 Enrolment in courses not leading to a university degree is excluded

2 Includes Fine and Applied Arts

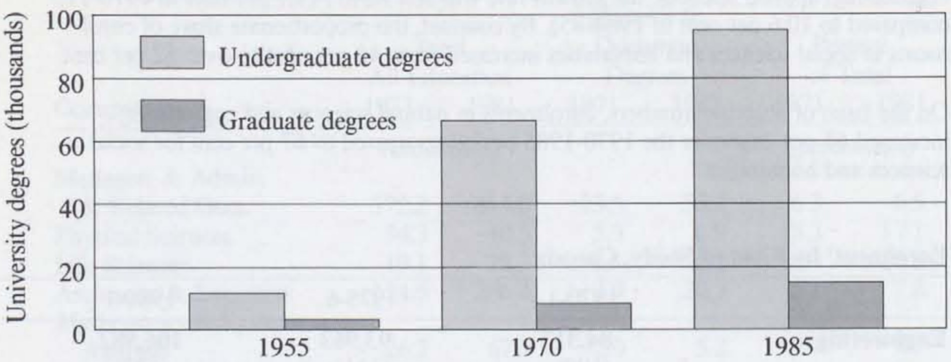
Source: Compilation from unpublished data and from Statistics Canada Universities Enrolment and Degrees, December, 1986.

b) Trends in Degrees Awarded

In 1985, Canadian universities awarded some 97,000 undergraduate and 17,000 graduate degrees.

As a proportion of all degrees awarded, graduate degrees remained virtually unchanged in 1985 compared to 1970: 15 and 14 per cent respectively. The number of graduate degrees awarded, however, increased by 54 per cent between 1970 and 1985 compared to 48 per cent for undergraduate degrees.

TABLE 13
Number of University Degrees Granted, 1955, 1970 and 1985

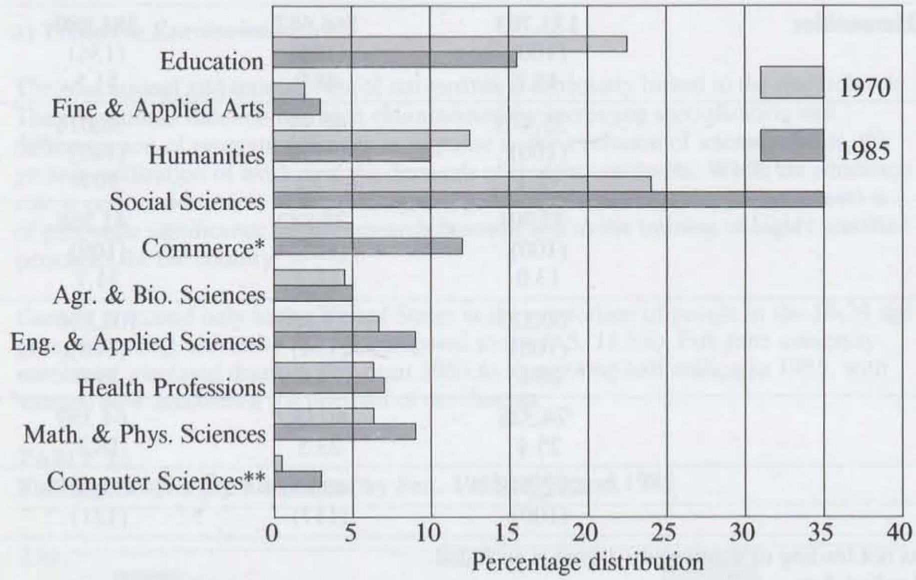


Source: Statistics Canada, Education, Culture and Tourism Division.

Undergraduate Degrees Awarded

At the undergraduate level about 70 per cent of degrees are awarded in the social sciences, humanities, education, and in the fine and applied arts: with education and the humanities losing ground as a proportion of the total between 1970 and 1985. The natural sciences and engineering gained little ground as a share of undergraduate degrees awarded: within mathematics and physical sciences, for example, computer science degrees rose from less than 1 per cent in 1970 to 3 per cent in 1985, while engineering and applied science degrees increased from 7 per cent to 9 per cent only.

TABLE 14
Undergraduate Degrees by Field of Study, 1970 and 1985



* Commerce is a field within the social sciences.
** Computer Science is a field within mathematics and physical sciences.
Source: Statistics Canada, Education, Culture and Tourism Division.

Graduate Degrees Awarded

At the graduate level less than one-third (30%) of all degrees awarded in 1984 were in the natural sciences and engineering compared to 37% in 1970 and 27% in both 1975 and 1980. All sub-fields of natural sciences and engineering, except the health professions, underwent a decline in their share of total graduate degrees awarded over the period. The smallest absolute and proportionate growth between 1970 and 1984 occurred in mathematics/applied sciences. By comparison, the social sciences and humanities experienced absolute growth rates double those for the natural sciences and engineering. The social sciences and humanities increased their share of graduate degrees awarded in 1984 to over two-thirds (68%) from just under 63 per cent in 1970.

TABLE 15
Graduate Degrees Awarded by Field of Study, Canada

	1970	1975	1980	1984
Natural Sciences and Engineering	**3,360**	**3,559**	**3,869**	**5,153**
(1970 = 100)	(100)	(98)	(107)	(142)
% of total	37.1	27.6	27.3	30.0
Engineering/Applied Sciences	1,185	1,190	1,300	1,888
	(100)	(100)	(110)	(159)
%	12.1	9.2	9.2	11.0
Mathematics/Physical Sciences	1,326	1,235	1,101	1,415
	(100)	(93)	(83)	(107)
%	13.5	9.6	7.8	8.2
Agriculture/Bio Sciences	745	709	827	949
	(100)	(95)	(111)	(127)
%	7.6	5.5	5.8	5.5
Health Professions	374	425	641	901
	(100)	(114)	(171)	(241)
%	3.8	3.3	4.5	5.2
Social Sciences and Humanities	**6,156**	**9,299**	**10,289**	**11,691**
(1970 = 100)	(100)	**(151)**	(167)	(190)
%	62.8	**72.0**	72.6	68.0
Education	1,341	**2,333**	3,031	3,133
	(100)	**(174)**	(226)	(234)
%	13.7	**18.1**	21.4	18.2
Humanities[1]	1,931	**2,551**	2,239	2,264
	(100)	**(132)**	(116)	(117)
%	19.7	**19.8**	15.8	13.2
Social Sciences	2,884	**4,415**	5,019	6,294
	(100)	**(153)**	(174)	(217)
%	29.4	**34.2**	35.4	36.6
TOTAL[2]	9,796	**12,908**	14,170	17,194
	(100)	**(132)**	(145)	(176)

1 Includes Fine and Applied Arts
2 Total includes unclassified degrees
Source: Statistics Canada.

As a postscript to the enrolment and degrees awarded data presented above, it is worth noting that foreign university students numbered some 27,000 in 1985 after having risen from 16,000 in 1973 to a peak of about 35,000 in 1983. Apart from the acknowledged benefits to Canada of the presence of foreign students, it is important to recognize that they constitute a significant number of degrees awarded in certain fields. These foreign students normally do not enter the Canadian labour market on graduation.

Foreign students were awarded about 20 per cent of all Master's and Doctorate degrees combined in the 1980-85 period: 17 per cent and 29 per cent respectively. Degrees awarded to foreign students were highest at the Ph.D. level in engineering/applied sciences (40%) and computer sciences and mathematics (35%) and lowest at both degree levels in the health sciences (9% and 15% at the Master's and Doctorate levels respectively).

TABLE 16
Master's and Ph.D. Degrees Awarded (1980-85 totals) in Selected Major Fields of Study: Canadians (including landed immigrants) and Foreign Students

	Master's		(%)	Ph.D.s		(%)	Total		(%)
Field of Study	Can.	Foreign	Foreign	Can.	Foreign	Foreign	Can.	Foreign	Foreign
Agriculture/Bio Sciences	3347	505	(13)	1068	314	(33)	4415	819	(16)
Engineering/Applied Sciences	6208	1586	(20)	759	515	(40)	6967	210	(33)
Health Professions	3293	316	(9)	786	140	(15)	4079	456	(10)
Computer Sciences and Mathematics	1736	451	(20)	294	155	(35)	2030	606	(33)
Physical Sciences	2260	603	(21)	1140	503	(30)	3400	1106	(25)
Total	16848	3461	(17)	4047	1627	(29)	20891	5088	(20)

Source: Estimates by the Ministry of State for Science and Technology, based on: Statistics Canada, enrolment and degrees awarded statistics, special runs.

c) Women in Natural Sciences and Engineering Studies

Women are well represented at the undergraduate level in Canadian universities, where they now account for almost 52 per cent of enrolments compared to 43 per cent in 1972-73. However, they are over-represented in certain fields of study such as education (68%), English (71%) and nursing (96%) and under-represented in engineering/applied sciences (12%), computer science (23%) and physics (14%).

At the graduate level women constitute about 45 per cent of Master's degree enrolments and 34 per cent in Ph.D. programs compared to 27 and 19 per cent respectively in 1972-73. Again, women are over-represented in the traditional female fields at the graduate level and under-represented in, for example, electrical engineering (less than 6 and 3 per cent in Master's and Doctorate programs respectively) and computer science (20% at the Master's level and 12% in Doctorate programs).

TABLE 17
Proportion of Women in Full-time and Part-time University Degree Enrolment, by Selected Field of Study

	Per Cent Female					
	Bachelor's First Professional		Master's		Ph.D.	
Field of Study	1972-73	1985-86	1972-73	1985-86	1972-73	1985-86
Education	59.7	68.0	32.4	62.3	25.5	51.7
Humanities & Related	51.4	62.1	41.0	56.4	32.6	43.9
English	61.9	71.3	49.8	66.6	42.7	57.4
Social Sciences & Related	30.3	51.1	21.5	40.8	22.9	42.1
Business & Commerce	12.5	43.9	4.8	29.3	0.0	30.9
Agriculture & Biological Science	42.9	57.3	27.3	44.7	14.7	30.1
Biology	33.1	51.4	28.9	43.1	15.7	33.1
Engineering & Applied Sciences	2.7	12.4	2.7	11.5	2.6	7.2
Architecture	12.3	31.5	7.7	30.0	—	21.1
Chemical Eng.	4.1	25.2	3.4	18.0	4.2	10.5
Civil Eng.	1.4	12.0	2.6	11.0	1.7	3.5
Electrical Eng.	1.0	6.9	1.9	5.8	2.2	2.8
Mechanical Eng.	0.9	6.9	1.6	6.7	2.7	6.5
Health Professions & Occupations	52.6	69.3	43.5	64.3	20.7	38.1
Medical Science	22.9	42.5	29.9	49.8	20.3	35.9
Nursing	97.9	96.1	93.2	96.8	100.0	100.0
Pharmacy	53.7	66.9	27.1	42.0	24.3	18.3
Mathematics & Physical Sciences	21.6	27.3	14.9	23.0	6.9	15.6
Computer Science	20.2	23.3	13.6	20.5	5.3	12.2
Mathematics	30.5	35.4	21.2	24.6	8.4	17.9
Chemistry	20.4	34.4	19.4	33.2	8.9	20.2
Geology & Related	8.3	21.2	11.0	26.7	3.6	17.9
Physics	8.3	14.0	7.2	11.4	4.4	6.9
TOTAL	42.6	51.8	26.7	44.6	19.5	34.0

Source: Statistics Canada.

Overall, degrees awarded to women have increased in proportion to their gains in total enrolment since 1970. By 1985, women received some 52% of Bachelor's and first professional degrees, 42% of Masters degrees and about 26% of Ph.D. degrees. However, women still tended to be over-represented, relative to these averages, in education, the humanities and in the health sciences particularly at the bachelor/first professional and Master's degree levels. In spite of important progress since 1970, women are still under-represented in business and commerce, engineering and natural sciences, accounting, for example, for some 4 per cent of mechanical engineering degrees at the Ph.D. level, less than 4 per cent at the Master's level in electrical engineering, and, 8 per cent of Ph.D. physics degrees.

TABLE 18
Proportions of University Degrees Granted to Women 1970 and 1985, by Selected Specializations

	Per Cent Female					
	Bachelor's First Professional		Master's		Ph.D.	
Specialization	1970	1985	1970	1985	1970	1985
Education	52.5	71.3	24.0	58.1	20.5	38.3
Humanities & Related	47.0	61.1	35.6	56.2	25.5	41.7
English	60.4	73.2	43.2	58.3	42.0	55.2
Social Sciences & Related	26.8	49.9	21.2	38.7	15.8	32.8
Business & Commerce	6.7	40.9	1.7	27.7	—	19.4
Agriculture & Biological Sciences	38.9	56.0	19.3	38.5	8.5	24.7
Engineering & Applied Sciences	1.6	11.6	1.9	10.5	0.0	6.5
Chemical Eng.	1.9	21.2	4.1	21.0	0.0	14.8
Civil Eng.	0.8	11.4	0.9	10.7	0.0	4.1
Electrical Eng.	1.1	5.7	1.8	3.6	0.0	5.2
Mechanical Eng.	0.5	5.5	0.7	5.4	0.0	4.3
Health Professions & Occupations	51.4	65.6	34.1	61.0	9.2	26.1
Medical Sciences	10.7	40.1	23.2	41.7	6.4	29.5
Nursing	97.3	96.1	96.4	96.6	—	—
Pharmacy	43.8	63.7	28.6	43.3	0.0	0.0
Mathematics & Physical Science	17.5	29.3	7.6	21.8	3.6	17.6
Computer Science	19.6	27.1	6.3	18.9	0.0	15.2
Mathematics	24.6	37.8	9.4	31.5	10.9	32.6
Chemistry	15.6	35.8	12.7	31.3	2.4	21.7
Geology & Related	4.3	21.2	2.4	22.3	0.0	15.1
Physics	7.7	15.5	4.0	6.6	4.1	8.0
TOTAL	38.4	51.9	21.5	42.0	9.3	26.4

Source: Statistics Canada.

3. Immigration and Emigration of Highly Qualified Personnel

Immigrants to Canada have been an important source of supply of highly qualified personnel — reflecting a number of factors, including our history of relatively "open door" immigration policies, the attractiveness of Canada for economic and quality of life reasons, and, as a response to labour market demand for highly qualified personnel that could not be satisfied from domestic supply sources — mainly our universities.

Immigration was a major source of supply of highly qualified personnel for Canada in the 1980-85 period: contributing about one-half as many highly qualified personnel as were graduated by Canada's universities. Over 10,000 landed immigrants entered Canada with Master's and Doctorate degrees compared to almost 21,000 graduate degrees that were awarded to Canadians by our universities (reference Table 16).

TABLE 19

Immigration: Landed Immigrants, by Intended Occupation, Holding Master's and Doctorate Degrees, 1980-1985

Intended Occupation	Master's	Ph.D.	Total
Managers	1314	279	1593
Physical Sciences	411	536	947
Life Sciences	206	382	588
Architects and Engineers	1388	510	1898
Mathematics, Systems Analysts	623	145	768
Social Sciences & Related (excludes Religion)	507	225	732
University Teachers	348	942	1290
Other Teaching Occupations	737	400	1137
Medicine and Health	848	707	1555
GRAND TOTAL	6382	4126	10508

Source: Employment and Immigration Canada, immigration statistics, special run.

There are no comprehensive data available to indicate what proportion of the existing stock of over 300,000 highly qualified personnel in the labour force is of immigrant origin. However, amongst university teachers, who represent more than 10 per cent of total highly qualified personnel in Canada, some 23 per cent were citizens of other countries.

TABLE 20

Full-time University Teachers in Canada, 1981-82

Country of Citizenship	Number	Per cent
Canada	25,791	76.8
United States	3,875	11.5
United Kingdom	1,470	4.4
Other Commonwealth	632	1.9
Belgium and France	420	1.3
Other Europe	577	1.7
Other	488	1.5
Not Reported	347	1.0
Total	33,600	100.0

Source: Statistics Canada, Teachers in Universities (Cat. 81-241).

In an unpublished study, the Science Council of Canada examined immigrants entering Canada over a thirty year period: 1956 to 1985. The Science Council focussed its study on the "Research-Intensive Occupations". In the 1956-1985 period, some 267,000 immigrants came to Canada in these occupations. Over one-half the total arrived in the 1966-1975 decade.

In order to obtain some measure of Canada's net gain in these occupations, after accounting for migration from Canada, the Science Council used data from the United States — the prime destination of Canadians in research-intensive occupations. Over the thirty-year period, immigration to Canada from all countries exceeded emigration to the U.S. by between 100 and 1300 per cent annually: in total Canada gained in quantitative terms by a ratio of some 5:1.

Apart from teachers and technicians, the largest number of immigrants to Canada was in engineering, natural sciences and computer and related specialties. In terms of emigration from Canada to the U.S.A., engineers topped the list. Almost all occupational groups experienced gains in both immigrant and emigrant flows in the first decade of the thirty year period and significant declines in the last decade. The exceptions are natural scientists whose emigration has maintained a surprisingly stable level over the three decades, and computer specialists, statisticians and mathematicians whose immigration and emigration flows have both experienced continuing substantial growth rates.

TABLE 21
Immigrants to Canada[1] and Canadians Emigrating to the United States[2] in Research-Intensive Occupations 1956-1985

	1956-1965		1966-1975		1976-1985		Total	
Occupation	Immigrants to Canada	Emigrants to the USA	Immigrants to Canada	Emigrants to the USA	Immigrants to Canada	Emigrants to the USA	Immigrants to Canada	Emigrants to the USA
Teachers	17,858	5,875	51,909	5,780	15,923	2,257	85,690	13,912
Technicians	15,284	4,490	41,296	3,058	10,143	1,921	66,723	9,469
Engineers	13,747	9,298	24,232	6,791	12,530	3,089	50,509	19,178
Natural Scientists	1,188	954	9,208	963	5,599	998	15,995	2,915
Computer Specialists, Statisticians & Mathematicians	126	nil	5,283	51	6,663	633	12,072	684
Chemists	2,582	1,081	4,392	1,011	1,116	251	8,090	2,343
Social Scientists	216	382	3,025	521	2,125	419	5,366	1,322
Professional Workers (N.E.C.)*	15,989	2,268	6,920	1,393	nil	121	22,909	3,782
TOTAL	66,990	24,348	146,265	19,568	54,099	9,689	267,354	53,605

* Not Elsewhere Classified

Sources:

1. Canada, Employment & Immigration (annual immigration statistics 1956-1984 and unpublished data).
2. United States, Department of Justice. Immigration and Naturalization Service (unpublished data).

4. Some Observations on Demand/Supply Imbalances

It is evident from the available data that Canada has experienced shortages and surpluses of highly qualified personnel at varying times in recent decades. On occasion, these imbalances have been directly linked to general economic conditions and business cycles, demographic factors and changes in government policies, the latter two affecting, for example, education and the medical care professions. It is also evident that such imbalances can be isolated, at a point in time, to one or several related occupations, e.g. shortages of engineers in Western Canada in the "boom days" of the oil and gas industry of the mid-1970s. A second example was the very high demand for teachers in the 1960s and early 1970s in response to the "baby boom" generation passing through the education system.

It is generally acknowledged that past forecasts of such imbalances have often been quite inaccurate — as have previous forecasts of university enrolments. Even in mainly non-market sectors such as education and health, the past inability to make accurate forecasts is noteworthy. In the market-dominant occupations, such as engineers and computer specialists, the forecasting task is even more difficult.

Recently, several organizations[1] have attempted to determine the future demand and supply for highly qualified personnel.

While these recent forecasts are useful, the authors themselves fully recognize the limitations of their work. For example, the assumptions used all exert a profound influence on the resulting forecast and include such factors as attrition rates, labour force and university attendance participation rates (particularly those of women), in and out migration, changes in wages and productivity, the changing nature of occupations and industry, career choices of individuals, and, the capital investment of business and government, (including investment in R&D).

Forecasting in the highly qualified personnel field encounters further difficulty because of the relatively small and highly specialized labour force: 300,000 or less than 3 per cent of the total workforce. At the level of specific occupational groups, for example, there are less than 1000 physicists with Master's or Doctorate degrees in Canada, about 300 aerospace engineers, less than 700 petroleum engineers, and, about

1. The Five-Year Planning Documents of the three Granting Councils:
   - Five-Year Plan for Financing Research in the Social Sciences and Humanities
   - Completing the Bridge to the 90s: NSERC's Second Five-Year Plan.
   - Medical Research Council Discussion Paper Proposal for a Five-Year Plan.

1000 mathematicians, statisticians and actuaries (1981 Census data). Because of the long training times required and the key nature of the occupations, even small shortfalls in supply relative to demand can cause severe bottlenecks. Also, given the nature of these occupations, often at the leading-edge of knowledge and technology, an increased supply frequently generates an increased demand as the technology and the people create new business, e.g. in biotechnology.

As shown by the data presented earlier in this paper, it is evident that the past supply of highly qualified personnel produced by our universities has not been sufficient to meet the demand for such people in Canada. Immigration, as the data also demonstrate, has been the "safety valve" for the marketplace.

During the 1960s and early 1970s, Canada's universities, along with the other components of the education system, expanded quite rapidly in response to the large numbers of student enrolments. Some observers of that decade or more of expansion have added that public policy and associated large expenditures were also predicated on the belief that education was a wise investment in economic, social and cultural terms.

In economic terms, the wise investment assumption appears to be supported by the historical fact that unemployment rates for highly qualified personnel have been generally less that one-half those for the labour force as a whole. Furthermore, these relatively low unemployment rates approach (after account is taken of frictional unemployment, e.g. unemployment between jobs), what is generally considered to be full employment. Equally important, low unemployment rates for highly qualified personnel are sustained throughout varying business cycles.

TABLE 22
1971/1981 Census Comparative Unemployment Rates by Occupation (per cent)

Occupation	Total All Education		Master's & Doctorate Degrees	
	1971	1981	1971	1981
Managers & Admin. and Related Occs.	1.52	2.64	0.68	1.51
Physical Sciences	4.37	4.51	1.62	1.58
Life Sciences	3.38	5.93	1.44	2.23
Architects & Engineers	3.52	3.66	2.27	1.76
Mathematics & Systems Analysts	2.11	2.74	3.23	1.91
Soc. Sci., Soc. Work, Law & Religion	3.95	7.28	1.69	2.73
University Teachers	3.09	5.96	2.32	3.72
Other Teaching Occs.	1.72	4.07	0.99	3.20
Medicine & Health**	2.44	4.03	2.77	0.98
All Other Occupations	8.94	11.54	5.44	9.68
All Occupations	7.90	10.01	2.61	3.11

** Includes first professional degrees (M.D.s, D.D.S.s, D.V.M.s etc) with Master's and Doctorates.

Source: Statistics Canada, 1971/1981 Census (special run).

Changes in the nature of occupations and industry are accelerating in response to new knowledge and technologies and the increasingly intense competition in the international market-place. The social and cultural challenges and opportunities associated with these and other changes are, and will, place increasing demands on Canadians in future. Thus, in spite of difficulty in accurately forecasting future demand and supply, at least some level of consensus and understanding must be achieved relating to Canada's future need for highly qualified personnel.

The most recent forecasts are those of the Economic Council of Canada which projected employment to 1995 under three scenarios:

A = designates the extrapolation scenario
B = designates the displacement scenario without re-employment
C = designates the displacement scenario with re-remployment

The Economic Council projections of the employment of "professionals" to 1995 relative to 1981 under scenario "C" show growth of over 200 per cent in occupations in mathematics, statistics and systems analysis. Next highest growth rates are projected in law (62%), social work (57%), and social sciences (40%). Growth rates in the 30-39% range are projected for teachers at the elementary and secondary school levels, nursing, and in the library and related social sciences. Growth rates between 20-29% range occur in university teaching, architects and engineers, the physical and life sciences, and in occupations related to management. Occupations projected to experience less than 20% employment growth to 1995 under the Economic Council's scenario "C" include: managers and administrators (10%), and health diagnosing and treating occupations (12%).

These growth rates for selected "professional occupations" compare to projections of about 12 per cent to 1995 for all occupations.

Note: For a detailed discussion of the Economic Council's methodology and results, reference should be made to the publication "Innovation and Jobs in Canada".

TABLE 23
Actual and Projected Employment, by Detailed Occupations, Canada 1981 and 1995

		Three Scenarios		
	1981	1995A	1995B	1995C
Detailed Occupations:		(Thousands)		
Managerial, Administrative, Related				
Managers and Administrators	367.3	403.5	373.9	405.9
Occupations Related to Management and Administration	181.6	222.0	203.9	221.4
Professionals				
Physical Sciences	25.4	27.3	27.8	30.2
Life Sciences	10.5	10.9	11.0	12.0
Architects and Engineers	109.4	122.1	124.7	135.5
Other Occupations in Architecture and Engineering	94.7	108.0	0.1	0.1
Mathematics, Statistics, Systems Analysis, and Related	36.8	39.9	105.3	114.3
Social Sciences	10.7	12.8	12.9	14.0
Social Work and Related Fields	14.5	20.9	21.0	22.8
Law and Jurisprudence	35.9	52.7	52.6	57.1
Library, Museum and Archives, Religion and Other Occupations in Social Sciences and Related Fields	6.0	7.4	7.5	8.1
University Teaching and Related Occupations	3.7	4.5	4.5	4.9
Elementary and Secondary School Teaching and Related Occupations	27.8	33.8	33.9	36.8
Other Teaching and Related Occupations	20.9	25.3	25.5	27.7
Health Diagnosing and Treating Occupations	8.3	8.3	8.4	9.1
Nursing, Therapy and Related Assisting Occupations	34.9	42.1	42.5	46.1
Other Occupations in Medicine and Health	33.1	38.2	39.0	42.3

Source: "Innovation and Jobs in Canada", p. 49, Table 4-10 extract: A research report prepared for the Economic Council of Canada, 1987

The Transfer of Knowledge, Technology and Expertise: An Emerging University Role

While the teaching and research roles are well-established functions, the third and growing role of the university is to be an active agent of progress, through the diffusion of knowledge, technology and expertise to other sectors of society. The objective of such transfers is to help achieve national and regional goals in general, and economic goals in particular. The extent to which this third role is performed depends, in large measure, on: the effectiveness of the university in producing highly qualified personnel, the strength of its research; the attitudes of both faculty and administrators towards building a strong dialogue and system of collaborative research and other arrangements with industry; and the willingness of industry and other sectors to collaborate with universities in such endeavours.

Universities can have an important impact on technology diffusion and thereby contribute to national and regional business development and competitiveness through a variety of mechanisms. One such mechanism is contract research with business firms. These activities have been growing over the past several years. Business spent over $45 million in 1984-85 on contract research in Canadian universities, compared to $17 million in 1979-1980.

Non-profit organizations, however, engage in over three times more research contracts with universities than does industry: some $160 million in 1984-85. The growth rate in contract research over the six year period has been slightly greater with non-profit organizations (41 per cent) compared to 37 per cent with industry.

TABLE 24
Contract Research in Canadian Universities
(Millions $)

	1979-1980		1984-1985	
	$	%*	$	%*
Business	17.1	2.5	45.6	3.2
Non-profit Organizations	66.9	9.8	159.8	9.5
Total Private	84.0	12.3	214.2	12.7

* % of total university R&D.
Source: Statistics Canada, Ottawa, September 1986.

Private sector contributions to sponsored research in universities, as a proportion of total sponsored research funding, plays an important role in all Canadian regions. Bequests, donations, non-government grants, investment income and miscellaneous income contributed 18 per cent to total sponsored research funding to universities in the Atlantic region, 19 per cent in each of the Western regions and Quebec, and 25 per cent in Ontario.

TABLE 25
Private Sector Funding* of Sponsored Research in Canadian Universities by Region: Year Ended in 1986 ($000)

Region	Sponsored Research Total Funding	Private Sector Funding	
	(All Sources)		
Atlantic	55,607	10,190	(18.3%)
Quebec	228,754	44,183	(19.3%)
Ontario	349,980	88,060	(25.2%)
Western	240,028	45,844	(19.1%)

* Includes: bequests, donations and non-government grants, investment income and miscellaneous income directed to the support of research.

Source: Financial Statistics of Universities and Colleges 1985-1986 prepared by Statistics Canada for the Canadian Association of University Business Officers, Report 4.1 — Sponsored Research.

Business contributions to university R&D in Canada in 1984-85 amounted to 3.2% of total university R&D, slightly less than the 3.9% of university R&D funded by business in the United States.

TABLE 26
Business Funding of University R&D: Canada and the U.S.A. 1984-85

	Canada	U.S.A.
Millions of $ (Canadian)	45.6	456
%	3.2	3.9
Total University R&D	1,424	11,591

Source: Statistics Canada; and the National Science Foundation, Washington, D.C.

The federal government's matching policy, which went into effect on April 1, 1987, is specifically designed to actively promote research collaboration between university researchers and the private sector, including industry, the private non-profit sector, foundations, charitable organizations and individuals.

The matching policy is based on a formula by which the federal government matches private sector contributions with equal funding to the three federal research Granting Councils, to a maximum of just over $380 million over four years. First indications from the Granting Councils point to a highly successful beginning of the policy.

TABLE 27
Research Granting Councils: Matching Funding Policy, 1987-91 ($ Millions)

Council	1987-88	1988-89	1989-90	1990-91	Four-Year Total
Natural Sciences and Engineering Research Council	50.8	81.0	128.0	180.8	440.6
Medical Research Council	26.2	41.8	66.4	93.6	228.0
Social Sciences and Humanities Research Council	12.0	16.6	26.2	37.0	91.8
Total	89.0	139.4	220.6	311.4	760.4

Source: Ministry of State for Science and Technology.

Note: Annual amounts include both federal and private sector contributions. Federal funding to the Granting Councils is a maximum of one-half the amounts shown. Private sector contributions can exceed the level of federal funding.

Industry-university research collaboration is well suited to regional and local development. Universities can contribute to the transfer of knowledge and technology by developing expertise in areas of natural advantage and by establishing institutes which offer research, developmental and education services. One example of successful cooperation with industry is the Pulp and Paper Research Institute of Canada (PAPRICAN) which has been linking McGill University and several Canadian pulp and paper firms since 1927.

The view that universities should be active agents in the transfer of science and technology to industry is not shared universally. The education and research functions of universities are seen by many as the priorities of the university. By contrast the proponents of the university as an active agent of diffusion of best practice knowledge and technology stress that such cooperation can yield not only additional research resources but also new intellectual challenges which can result in society-wide benefit through the application of research results.

Cooperative R&D between universities and industry can offer a significant opportunity to improve Canada's performance in the worldwide R&D stakes, to the satisfaction of both the university and the business participant.

Issues for the Future

Society is undergoing a radical transformation from an industrialized complex based on raw materials and natural advantages to an information and knowledge-based society.

The economic prosperity, and consequent standard of living, of whole nations is becoming increasingly dependant on science and technology. How well countries develop, acquire and use knowledge and technical know-how is determining their ability to compete internationally and to provide employment and a higher standard of living for their citizens.

This is the national and international context within which Canada must view its future. It is in this context that the university, too, must examine its future and the critical role that it will be called upon to play in a more knowledge-intensive society and economy.

The three functions of the university, teaching, research, and knowledge/technology transfer, can no longer be considered as independent of each other. The knowledge-intensity of society and the economy, combined with rapid changes in knowledge and technology, require the close interaction of all three functions. Furthermore, the limitations of Canada's financial and human resources suggest that it is not possible to pursue all fields of science and technology on the same scale as its much larger industrial competitors. This imposes choices by Canadians, in general, and by various sectors in society, including the universities, as to what should be the areas on which Canada should concentrate its resources.

The first major issue for the university is (recognizing its history, its current strengths and weaknesses and its vision for the future) the most appropriate balance between the teaching, research and knowledge/technology transfer roles.

In quantitative terms, the record of the recent past suggests that the universities themselves have viewed the teaching function as of paramount importance, particularly in the social sciences and humanities rather than in the natural sciences and engineering. They have reduced their own support of research as a proportion of all university research (presumably in response to teaching demands, but at a time of increased government support for university research). In addition, they have not yet reached consensus on the nature or scale of their role in the transfer of knowledge and technology to the economy.

The recent past has been characterized by financial restraint which undoubtedly exerted a major influence on the decisions made within universities. However, pressures on universities continue to grow with demands that universities respond more directly to economic and social needs in spite of limited resources.

The challenges of the future suggest that the issues centre on three basic questions:

- How should the universities identify and manage their research priorities?
- What kind of highly qualified people should universities provide to adequately respond to Canada's short and longer-term needs?
- How can the universities effectively collaborate with industry in carrying out their research function?

1. Priorities and the Management of University Research

There is growing pressure for university research to focus on areas which respond more directly to economic and social needs. At the same time, resources for research are limited, and no one university can hope to maintain leading-edge expertise in all areas of research. Is it important, therefore, to concentrate effort within strategically chosen areas of research?

If so, it suggests that universities must be selective and manage their research according to a coherent set of objectives identified by all legitimate interests. Universities must therefore carefully consider the degree to which direction can reasonably be applied to individual research activities and how appropriate overall priorities can best be determined. A number of key issues are involved:

i) The concentration of resources and research networks

The costs and complexities of leading-edge research are increasingly demanding a large "critical mass" of scientists, engineers, technicians, laboratory equipment, expensive instrumentation and support staff without which certain research cannot be attempted.

The ability of a university, or increasingly several universities together, to assemble research teams and facilities on an appropriate scale will determine the kinds of research it can perform effectively. One way of achieving the necessary critical mass of research teams, having different disciplinary backgrounds and perhaps located in different universities, is to link them through a "centres of excellence" approach using modern telecommunications systems — a field in which Canada is a world leader. Such networks could, in particular, offer smaller universities the possibility of participating in research that they could not hope to do on their own.

Related to the "critical mass" issue is the question of to what extent, and how, the private sector and government laboratories could collaborate with such university centres/networks in pursuit of excellence, sharing of ideas and as a means of marshalling and maximizing the efforts of all sectors.

ii) The importance of multidisciplinary research

Interaction between disciplines has played an important role in research break-throughs, and is likely to become increasingly important in the future. Molecular biology, for instance, grew out of research combining biology and molecular physics, and led to the development of biotechnology. Materials science is bringing the physicist and chemist closer together. In a more general sense, the complexities of modern society are demanding a more integrated "systems approach" to finding a better way of solving problems. Research on health services, for example, involves not only medical researchers, but economists and administrative specialists.

Multidisciplinary research cuts across the traditional organization of university departments. How can the universities organize to encourage and manage multidisciplinary research?

iii) The relation between basic and applied research

A distinction is usually made between basic research (the pursuit of knowledge for its own sake) on the one hand and applied research (research directed towards a specific application) on the other. A traditional concern focuses on the appropriate balance between these types of research in a university setting.

Today, however, the line between the two types of research is becoming increasingly blurred. Basic research is affected by technological developments while progress in applied technology frequently results from spin-offs — often unintended — from basic research. The rapid advances in microelectronics, material sciences and information technology have, for instance, resulted from a continual and mutually supportive interaction between basic and applied research.

The question now is not so much the balance the universities should achieve between basic or applied research, but rather how the two can be initiated and nourished in a mutually beneficial way to achieve scholarship of international repute and shorter-term benefits for society and the economy.

iv) The indirect costs of research

Research grants to universities from the federal Granting Councils are normally for the direct costs of research only. In recent years universities have expressed growing concern over the lack of sufficient funds for the indirect costs of research. Some universities say they may reject opportunities for research because they, themselves, cannot afford the additional overhead costs involved.

This situation not only restricts the amount of research universities are willing to perform, but may create a bias in the system against high-cost research, often in the natural sciences and engineering, in favour of research that is less resource intensive — mainly in the social sciences and humanities.

The question, then, becomes one of the degree to which university research planning activities are in fact affected by the different types of cost involved and what changes in current funding would be most effective.

2. The Supply of Highly Qualified Personnel

University research plays an important part in the training of highly qualified personnel (HQP). Thus, it is important to ask what kind of people Canada will need in the future, and whether the universities will be able to supply those people.

It should be noted that at both the undergraduate and graduate levels, less than one-third of degrees awarded are in the engineering/applied sciences fields; women are an under-utilized resource in these same fields, and, immigration contributes one-half as many highly qualified people to Canada as do our universities.

i) Projecting future needs

In a recent study by the Conference Board of Canada, 35% of the Canadian firms surveyed said they were experiencing a shortage of qualified personnel for research and development. In the same study 41% of the firms surveyed said they expected shortages within the next five years.

Furthermore, tenured university researchers hired to teach in the late 1960s and early 1970s in response to the post-war enrolment boom will be retiring over a ten year period beginning in the mid-1990s. It will be the task of the universities to replace them.

Predicting future supply and demand for HQP is, however, an uncertain business, and past predictions have not always been accurate. One reason predictions are difficult is that with highly qualified researchers, supply often creates the demand. In many advanced technology fields, for example, the existence of a developed research capacity creates the demand to exploit that capacity. Thus, the demand follows supply, rather than the other way around.

This suggests that universities may have a key role to play to create opportunities. When asking what kind of personnel universities should be supplying, and at what levels, should we look only at the predicted demand in certain fields? Or should we also consider the potential for creating a demand by supplying highly qualified people?

Immigration has been the "safety valve" for Canada's demand for highly qualified personnel in the past. Can immigration be relied upon to the same extent in future? If not, how should the universities prepare and respond?

ii) Women in research

While women accounted for half of the students enrolled in universities in 1985-86, only 12.3% of the undergraduates in engineering and applied sciences were women. Similarly, at the doctorate level women accounted for just 7.5% of the students in this field, and 15.6% of the students in mathematical and physical sciences. In the same fields, women accounted for 2.2% and 5.2% of the university teachers. From a national perspective, here is a vast pool of talent which needs to be developed.

How can we encourage more women to enter natural sciences and engineering studies at our universities, and to pursue research careers on graduation?

3. University/Industry Research Collaboration

There are many divergent interests involved in research. The federal government must look to the immediate and long term national interests of the country, the provinces must attend to their own regional concerns, universities must guard their long-standing traditions of independent scholarly inquiry, and, industry has a direct and growing interest in research that leads to competitive, commercially viable products, processes and services.

In the past, each of these sectors pursued its own research, often in isolation from the others. Given the growing importance of research and development, and the need to use our resources as efficiently and effectively as possible, we must find better ways to combine our several efforts in the most productive way.

Universities will have to decide to what extent they wish to respond to the role society expects them to play in the overall research effort of the nation. They will also need to continue to develop constructive partnerships with other research interests in order to fulfill that role.

i) Universities and technology transfer

Linkages between universities and industry serve two important purposes. They can give universities an opportunity to find out what problems need to be addressed from a wider perspective. And they can facilitate the transfer of knowledge and technology from the university laboratory to industry and to the market-place.

A wide range of innovative mechanisms have been developed for technology transfer. For example, some universities have developed science and technology parks or technology incubators associated with their research facilities. Others have experimented with "spin-offs", commercial businesses built around the results of university research and designed to bring those results directly to market.

Two basic questions arise concerning such transfer mechanisms. First, how can we measure their effectiveness, so that improvements can be made? Second, what place should such efforts have in the management of university research as a whole?

ii) University/industry collaboration

Active collaboration between universities and industry allows both to focus their combined expertise and resources on problems of shared concern. Encouraged by the federal and provincial governments through funding support and tax arrangements, university/industry collaboration has grown in recent years.

While universities have also expressed interest, they have also raised a number of concerns, as has industry. Universities place a high value on the independence of their research, and there is the question whether the "commercialization" of research activity may compromise that independence.

For example, potential conflicts arise over the publication of research results. Industry researchers are often required to keep their work secret, in order to afford their company a competitive advantage, while universities encourage the free dissemination of information.

It is generally agreed that university/industry collaborations should be encouraged and that the perceived barriers, different cultures, and divergent objectives can be overcome to the mutual benefit of both sectors. The key question is how this can be done more effectively, while safeguarding the openness, integrity and internal priorities of university research.

iii) The universities and regional development

Canada's universities represent a rich base of research expertise which is distributed across the country, in regions with diverse needs. The universities can play a significant role not only in disseminating the results of research to their individual regions, but in conducting research designed to serve the economic, social and cultural needs of their communities. The university can also be an effective agent for the region in accessing research from the rest of Canada and from other countries.

This raises two questions. First, what role should the research activity of a university play in regional development? Second, how can cooperative mechanisms linking the university to the community be most effectively established?

The challenges facing our universities in future are immense. The opportunities are even greater for the universities to play a more central role in the progress and prosperity of Canadian society and the economy. The objective in responding to challenges and opportunities should be to build a stronger university system of excellence and leadership that can meet the needs of Canada into the 21st century.

List of Tables and Charts