CANADA

Report of the
National Advisory Board
on Science and Technology

UNIVERSITY COMMITTEE

Presented to the
Prime Minister of Canada

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University Committee Report

February 1988

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1.0 INTRODUCTION

The University Committee of the National Advisory Board on Science and Technology (NABST) was formed on February 16, 1987. The committee was given a mandate to examine the efforts made by Canadian universities to:

a) produce the kinds and numbers of highly qualified S&T experts that are needed by an emerging knowledge-intensive economy;

b) provide high-quality pure research as a support to the teaching function and as a means of establishing the reservoir of basic knowledge that is needed to stimulate technological advancement; and

c) help industry enhance its ability to exploit the results of university research in ways that will promote Canada's regional development and competitiveness in international markets.

On June 1, 1987 the committee was asked to develop, on the basis of its study, proposals aimed at improving the quality of education and research in universities and at enhancing their contribution to economic and regional development.

In addressing these issues, the members of the committee made an assessment of the current activities of universities in the fields of science and technology (S&T). In keeping with the mandate of NABST, the scope of our report is deliberately broad. The object of a national policy on S&T concerns the economy as a whole and aims at improving its capacity to become more competitive on world markets.

Viewed in this perspective, S&T is not an esoteric endeavour that is best left to scientists and high technology firms, but a pervasive influence that permeates and transforms all sectors of the economy. That is why we give so much importance to the quality of education and research in Canadian universities and to the need to improve technology-diffusion capabilities in this country.

We recognize that, from the point of view of the universities, our report has a narrow focus in that it concentrates on mathematics, computer sciences, natural sciences and engineering. It goes without saying that the role of universities - and the scope and range of university curricula - is much broader than that. Our focus was dictated by our mandate. Thus, our report should not be construed as an attempt to minimize the other facets of university curricula or the essential contribution that institutions of higher learning make to a well-developed and harmonious society.

Among these other areas which, in our view, warrant serious examination are the links between the humanities, social sciences and technology. For example, disciplines such as industrial relations, competition law and economics clearly have a role to play in the promotion of S&T. The social sciences and humanities corollaries to S&T were not investigated. These topics deserve a distinct inquiry which was not part of our mandate. Similarly, we have not examined such issues as liberal and professional educational programs, and the effect that university governance and management practices can have on S&T.

We hope that our analysis and recommendations will provide a useful beacon to the Canadian government as it charts its course of action in matters pertaining to S&T. We also hope that our report will foster a national consensus on the urgent need to strengthen the unique capabilities of the Canadian university system in S&T. That task will be essential if Canada is to enhance its position in the world economy and to sustain a high quality of life for its citizens.

Although it is difficult to single out particular contributions in the light of the outstanding efforts of so many, we would like to express special gratitude to all the university presidents, principals and deans who commented on this report and, in particular, to those who attended the meeting on December 3, 1987 and offered invaluable suggestions in the process of completing the work of the committee.

2.0 AN EVOLVING SET OF DEMANDS ON THE CANADIAN UNIVERSITY SYSTEM

To those who are active participants in a university environment, the ideals of autonomy, independent research and the advancement of knowledge are paramount goals. Over the years, however, a broader social role of the university has also been emphasized. As a result, public expectations about the contribution that universities can make to economic and social development have led them to expand their mission.

Investment in basic research in universities and industry has been found to have a high public rate of return;[1] and analysts have demonstrated that strong links exist between education, the advancement of knowledge and economic growth. Indeed, the laureate of the 1987 Nobel Prize for Economics, Professor Robert Solow of the Massachusetts Institute of Technology, received that honour for his pioneering work on the impact of education and scientific research on economic development.[2] In the same vein, Edward Dennison showed that education and research contributed substantially to national productivity gains in industrialized countries.[3]

Thus, S&T is a major contributor to economic progress through inventions, innovations and creative adaptations that enhance the productivity and competitiveness of industries in both domestic and international markets. In addition, progress in S&T has generated a higher quality of life as new knowledge is applied in many areas of human endeavour.

For these reasons, the social returns on private and public investment in education, especially at the university level, are very high. The economic benefits that derive from labour force training and from investment in human capital served as a rationale for allocating substantial public funding to post-secondary education.

Student enrolment increased as a result, with more and more young (and, increasingly, not-so-young) people finding it in their best interest to invest time, money and energy in the acquisition of training, knowledge and degrees. In the face of the rising cost of university education and of the growing pressures for wider access to institutions of higher learning, Canadian society responded by developing a university system that is largely financed by the federal and provincial governments, while tuition fees and private contributions make up a relatively low share of total costs.

The university system that emerged provides good-quality education in all of Canada's regions.[4] Moreover, a number of universities developed a tradition of support for diffusion of technology and best-practice knowledge, especially in the fields of medicine and agriculture. Given the need to raise efficiency levels in Canadian industry by diffusing technology and best-practice methods much more widely to all productive sectors of the economy, and given the role that the application of S&T can play in the development and expansion of new industries, new expectations arose for the performance of our university system. How best to harness the research capabilities of our universities for the enhancement of

Canada's competitiveness abroad and the rejuvenation of its economy has become a central issue. Competition on a global scale makes the vitality of university education and research a key element of a national strategy. Our examination of the health of the Canadian university system and consultation with authorities in other advanced countries led us to an inescapable conclusion: we must rid ourselves of the view that university education is a consumption good. This perspective, which permeates many of our policies and approaches, is inadequate and shortsighted. The Canadian university system is a valuable and irreplaceable asset; university education must be considered as an investment in Canada's future.

Thus, Canadian universities face a dual challenge: in addition to maintaining a firm commitment to humanistic values and traditions, they must respond to new demands for greater participation in technological and economic development. Our university system constitutes an essential component of the nation's socio-technical infrastructure. It must do its part in fostering social and economic progress. In their attempts to fulfil the new responsibilities that are being thrust upon them, universities will face increasingly complex and demanding challenges. They will have to make difficult choices.

3.0 THE ROLES OF UNIVERSITIES IN SCIENCE AND TECHNOLOGY

The involvement of universities in S&T is threefold: the education and training of individuals; research activities (i.e., the discovery, explanation and classification of new knowledge); and the diffusion of best-practice knowledge and technology.

3.1 The Educational Mission

A primary and traditional role of the university is the transmission of knowledge and the training of minds.[1] The heritage of humanity was handed down to successive generations through university education in the liberal arts, philosophy and the social sciences. Professional training was provided in such areas as law, medicine and the natural sciences; over the years, new disciplines were added in the fields of health sciences, teaching, engineering, management and so on.

The educational function of the university has been characterized by increasing specialization and differentiation of the programs offered, in response to the evolution of scientific knowledge, specialization in the work place and the demands of rising student enrolments. While that function is performed mainly at the undergraduate level, education at the graduate level - where enrolments are much lower - is also an integral part of the basic mission of a university system.

3.2 The Research Mission

A second role of the university is to engage in basic research activities that lead to the systematic advancement of knowledge. This view of the university as the locus of pure research was adopted during the 19th century by the leading institutions of higher learning in the western world,[2] and it has substantially modified their educational mission. Freedom of inquiry and tenure became two important characteristics of research-oriented universities.

This vision was so widely accepted that today university professors, even at the undergraduate level, are expected to carry on some research, if only to keep abreast of new developments in their discipline. This is even more so at the graduate level, where the research and educational missions are closely integrated. Academic departments organized around disciplines, scientific publications and the training of graduate students are fundamental elements of this approach.

Though basic research activities are also performed in industrial and governmental laboratories, the relative superiority of the university setting for the pursuit of scientific knowledge is recognized. Indeed, in most advanced countries, a major proportion of basic research is carried out in universities.[3] To improve their ability to carry out substantial and advanced research efforts, universities have often superimposed advanced research programs and mission-oriented centres on department structures. New knowledge about the laws of nature and a better understanding of the physical world have led to many inventions and innovations.

By fulfilling this essential research function, universities contribute indirectly, and sometimes directly, to economic progress and to improvement in the quality of life through radical scientific discoveries. Advances in biology, physics, chemistry and information theory even led to the emergence of new industrial sectors. For example, the recent development of biotechnology as a commercial activity is the result of publicly funded basic research conducted mainly in universities over the past three decades.

3.3 The Diffusion Mission

A third, growing role of the university - one that is compatible with, and complementary to, the first two functions - is that of an active agent of progress. Through the diffusion of knowledge and technology to the other institutions of society, universities help in transforming the organization of the production of goods and services.[4] In this context, both basic and applications-oriented research activities contribute to the development and dissemination of best-practice knowledge.

In many countries, technical universities oriented toward industrial applications of science were established to perform this role. Canada, however, has few technical universities of this kind; as a result, the need to diffuse basic research and technology is placing added demands on its more traditional universities.

The role of universities as catalysts in the diffusion of state-of-the-art knowledge and technology, as well as the effectiveness with which they play that role, are issues that are at the centre of the public debate concerning research and the financing of post-secondary education.

That debate is particularly important for regions where one or more universities act as centres of expertise for the diffusion of S&T. Diffusion can take place through consulting activities, systematic exchanges and the conduct of applications-oriented research.

The adequate performance of the diffusion mission depends, to a large extent, on how well universities perform the first two roles. In other words, if the education and research functions are well developed and of high quality, they will provide a solid base from which universities can disseminate S&T knowledge to the rest of society. The extent to which they are successful in fulfilling this role also depends on the structure and dynamics of the industries with which they interface.

A word of caution may be appropriate here. Because universities are uniquely designed to carry out the education and research functions, the performance of those primary tasks must not be jeopardized by excessive commitments to diffusion activities which impose their own set of constraints if they are to be carried out successfully.

The view that universities should act as catalysts in the transfer of S&T knowledge to industry and government is not shared universally. Maintaining the education and research functions is seen by some as the absolute priority of any university system. In their view, universities already contribute to economic development by indirect means, such as training students and researchers, and by original research advancing knowledge. The transfer of S&T knowledge, it is argued, would best be left to other institutions or to mechanisms that fall outside the core functions of universities.

By contrast, the proponents of the university as an agent in the diffusion of best-practice knowledge and technology point out that universities not only should maintain good relations with industry, but also that they should make cultural changes of their own so that they become effective partners of industry and government in their joint social and economic mission. They argue, and present many examples to support their view, that the educational and research missions of universities are enhanced by maintaining closer working relationships with the 'real world'. To a large extent, this is a false issue. The numerous examples of close relationships between universities with the agricultural sector, in the medical field and with the pharmaceutical industry show that many universities have been involved in diffusion activities with considerable success. This role has been accepted for many years as legitimate. The present debate hinges on its extension to other fields.

3.4 The Need for a Diversified System

Obviously, each institution need not give equal weight to each of the three roles. It would be unrealistic to expect every university to reflect the diversity of the entire Canadian university system. Similarly, not every discipline can combine the three functions, and faculty members need not be equally involved in all three.

These issues are not unique to Canada. In the United States, for example, the Carnegie Commission on Higher Education sponsored a series of studies in the 1970s and early 1980s to examine the growing importance of basic research and related topics.[5] Western European and American universities face similar challenges in building 'multiversities'.[6]

In a diversified system, some institutions focus primarily on the educational role and foster research activities in support of high-quality professional training. Several other universities stress the importance of basic research activities beyond the requirements of the educational function and aim at contributing to a significant advancement of knowledge. A few others combine the education and research functions in the pursuit of new knowledge and diffuse best-practice technology to other organizations. They do so by supplementing their academic departments with problem-oriented, applied-research centres, and by developing multiple-career paths that combine teaching with basic research, as well as full-time, applications-oriented research activities. A few institutions attempt to combine all three roles and to develop close links with government and industry. Funding and support for both basic and applications-oriented research are secured through grants from public agencies and through private contracting arrangements.

The Canadian university system is perceived by many as lacking in diversity and comprising a group of homogeneous institutions, except at the junior-college level.[7] Diversity can be measured both internally and externally, using such variables as target population, curriculum, size, research intensity and so on. Diversity facilitates a better match of student needs with institutional characteristics. It provides a differentiated, innovative and specialized use of resources and allows the coexistence of alternative models embodying distinct value orientations.[8]

Several factors tend to restrict diversity in the Canadian university system. First, there are no private universities of any stature in Canada. This is in sharp contrast to the United States where half the colleges and universities - including many of the most prestigious ones - are private, independent institutions. The ready availability of public funding in Canada, combined with an aversion toward the concept of private institutions, led to most private and denominational colleges and universities being converted into quasipublic institutions.[9]

Second, most Canadian universities emphasized minimum standards and universal accessibility. As a result, we failed to develop a tiered system of institutions, with some that provide general education and others that seek to achieve a world-class research capacity.

A third factor is the widespread emphasis on graduate programs in Canadian universities. In this country, few universities specialize in undergraduate and liberal arts programs, but most institutions offer specialized programs at the graduate level; approximately half of them provide some form of doctoral program. Again, this is in contrast to the situation in the United States where only a few research-intensive universities account for most of the enrolment at the Ph.D. level.

Finally, strong government control over the financing and degree-granting authority tends to impede the development of mission-oriented institutions within the Canadian university system.

Nevertheless, the fact remains that most university research activities in Canada, whether faculty- or mission-oriented, is conducted in only a few of the 84 institutions that make up the university system in this country. Where research activities are concerned, there is a degree of differentiation within the Canadian university system. For example, the top 15 recipients of federal research and development (R&D) grants in 1985-86 accounted for close to 80 per cent of all research grants provided by the federal government to universities that year.

A similar picture emerges in the United States. Among the 3,300 colleges and universities in that country, research activities are concentrated in institutions that have Ph.D. programs. The remainder are essentially teaching institutions where research activities are carried out as a personal, internally funded search for knowledge. For example, California has a three-tier public system within which community colleges, state colleges and universities, and the University of California have distinct roles - as well as different admissions policies. The nine-campus University of California is one of the world's largest research universities; California State University, with 19 campuses and many off-campus centres, is a public teaching institution.

Data compiled by the National Science Foundation suggest that this three-tier pattern is found nationally among post-secondary institutions in the United States[10]:

- The first tier is composed of two- or four-year colleges that are primarily teaching institutions and perform little or no externally funded research.
- The second tier is made up of roughly 300 colleges and universities where research activities conform to the traditional picture of basic research performed mostly by faculty members and by small groups of researchers. Research in these institutions is intimately linked to graduate education.
- The third tier comprises 200 research-oriented institutions that solicit both individual research grants and larger mission-oriented grants. The size of the research projects requires the establishment of research centres or contract research institutes, and it implies the employment of engineers and scientists who are not faculty members. These research activities account for more than four-fifths of all academic research and funding in the United States.

It is not unusual for research-oriented universities to have low enrolments, with a substantial focus on graduate studies. For example, Harvard University has about 6,600 undergraduate students but more than 10,000 students at the master's and doctorate levels. The Massachusetts Institute of Technology has approximately 4,500 undergraduate students, 5,500 graduate students, and a large number of professional researchers involved in contract research activities. At the University of Chicago, the number of graduate students (7,000) is more than twice that of undergraduates (3,200).

In Canada, by contrast, the leading universities involved in research also have large undergraduate populations. The University of Toronto, for example, has 9,200 graduate students (60 per cent of them full-time) and 42,300 undergraduate students (about 70 per cent of them full-time). At McGill University, the corresponding figures are 5,700 graduate students and 29,600 undergraduates, with roughly similar proportions of full-time students at both levels. The Université de Montréal has 47,800 students - 38,000 at the undergraduate level and 9,700 at the graduate level, with full-time students making up about half the enrolment at both levels.

3.5 Conclusion and Recommendations

If Canada is to have a well-developed university system, it must be composed of many institutions that perform the three complementary roles in different ways. The relative absence of differentiation indicates that resources within the country's educational system are not allocated adequately. As a nation, Canada needs a diversified university system that can offer high-quality education throughout the country. Excellence in basic research in strong institutions and applications-oriented research on issues of national interest are also necessary to meet the needs of Canada's economic sectors and regions.

This committee believes that the focus of public policy toward universities in Canada must be to ensure that:

a) the Canadian university system performs its three functions in a manner and at a level of quality that compare favourably with the situation in other advanced countries;

b) public funds for education and research are allocated to universities in areas where they have a distinct advantage;

c) funding mechanisms and competition for R&D are operated in such a way that each institution can specialize in those functions and areas in which it is best equipped to perform and that a few can reach high degrees of research intensity.

The object of this report is to recommend means to achieve these policy objectives.

4.0 UNIVERSITY EDUCATION AND TRAINING

Both individually and through their governments at the federal and provincial levels, Canadians devote considerable resources to higher learning. This shows that they deem the education and training function of universities to be of vital importance. But universities differ from other educational institutions because they strive to give students the most advanced training at the frontier of current knowledge. That frontier is shifting constantly, and the professors who teach those students must continuously keep abreast of new developments in their fields if the university is to achieve its educational goal.

Scholarly research is an integral part of the mission of universities, even in their educational and training role. It would be difficult, if not impossible, for students - especially at the graduate level but also, to a lesser extent, at the undergraduate level - to acquire new knowledge unless they take part in research under the guidance of their professors. This is their contribution to the advancement of knowledge.

4.1 University Enrolment

The level of student enrolment is one indicator used to measure the performance of universities in their educational role. Our analysis of the available data leads to the following observations:

a) The goals of ensuring wider access to higher education and increasing university enrolment in Canada to comparable international levels are largely achieved, although there are differences among provinces. The proportion of those aged 18 to 24 enrolled in universities is high in Canada - second only to that in the United States. And the number of mature students is rising.

b) There are two main concerns with undergraduate enrolment in S&T:

   i) the proportion of undergraduate students in S&T remains stable in Canadian universities, at a time when this country must compete with nations that focus their development strategies on progress in S&T; and
   ii) female students are still significantly under-represented in natural sciences and engineering schools and programs in Canada.

c) Graduate enrolment in the natural sciences and engineering in Canadian universities is proportionately lower than in the United States or Japan, but higher than in several other advanced nations. The number of Ph.D.s graduating in those two academic fields is also proportionately lower in Canada than in the United States. Canada not only falls short in comparisons with some of its competitors, but also many disciplines are experiencing, and will continue to experience, shortages of graduates with advanced degrees.

4.1.1 Enrolment at the Undergraduate Level

During the past few decades, the federal and provincial governments invested substantial resources in attempts to increase university attendance and to ensure wider access to higher education. The results are good: full-time university enrolment rose by 45 per cent between 1970-71 and 1984-85, with more than half that growth taking place between 1980 and 1984. Total enrolment reached 748,000 (including 468,000 full-time students) in the fall of 1985, with undergraduates accounting for nearly 90 per cent of the total.[1]

Compared with other countries, Canada has a high proportion (13.5 per cent) of students in the 18-to-24 age group who are enrolled in universities or other post-secondary institutions; this country is second only to the United States (with 18.5 per cent). Relative to the total population, the proportion of Canadian students enrolled in universities or other post-secondary institutions (29.3 per 1 000 population) is also second only to that in the United States (32.7 per 1 000 population). Most other countries have much lower proportions, usually because they have different educational traditions and outlooks. The corresponding ratios for some of Canada's major trading partners are: 7.4 in the United Kingdom; 16.3 in Japan; 17.4 in France; and 20.7 in West Germany.[2]

The proportion of high school graduates who move on to full-time post-secondary education reached 52 per cent in Canada and 53.2 per cent in the United States in 1985-86. Full-time post-secondary students aged 18 to 24 made up 24.5 per cent of all young men and women in that age group in Canada and 23.3 per cent in the United States.[3]

These statistics indicate that Canada has been notably successful in raising undergraduate enrolment levels in its universities. Admittedly, participation rates in some groups are lower; however, the success achieved at the national level indicates that programs specifically designed for these groups would be required to improve their situation. We must also note that adults are increasingly enrolling in post-secondary education programs as full-time and, particularly, part-time students. All in all, it is fair to state that adequate access to universities is ensured for qualified students in this country.

4.1.2 Undergraduate Enrolment in the Natural Sciences and Engineering

Enrolment in the natural sciences and engineering accounted for 31.9 per cent of total university enrolment in 1984-85. This share has not grown much since 1970-71, when it was 28.8 per cent. The increase was particularly small in the engineering and applied sciences group, whose share grew to only 10.6 per cent in 1984-85 from 9.7 per cent in 1970-71. In contrast, enrolment in the social sciences and humanities rose from 46 per cent to 52 per cent of full-time undergraduate enrolment over the same period, continuing a trend that has been observed for three decades.

In absolute numbers, enrolment in the natural sciences and engineering increased by over 61 per cent between 1970-71 and 1984-85, compared with

67 per cent for the social sciences and humanities. The natural sciences and engineering are not gaining ground as fields of learning, despite the growing importance of S&T in our society. The distribution of undergraduate degrees by field of study in 1970 and 1985 is presented in Figure 4-1.

4.1.3 Graduate Enrolment in Sciences and Engineering

At the graduate level, enrolment in the natural sciences and engineering was more than 5,000 by 1985, but the proportion of all graduate students who entered those two fields was lower than in 1970. Relative to total graduate enrolment, the share of mathematics and physical sciences dropped by one-third between 1970 and 1985, while the share of engineering remained about the same. Enrolment at the doctorate level in natural sciences and engineering fell from 55 per cent of the total in 1970 to 47 per cent in 1984-85. As Table 4-1 and Figure 4-2 show, the proportion of graduate degrees granted in the two disciplines over that period declined.

Canadian graduate enrolment in natural sciences and engineering does not fare well in international comparisons.[4] Because of the differences between countries' educational systems and statistical reporting methods, such comparisons are indicative rather than conclusive, but they do provide useful benchmarks for measuring Canada's effort in the production of highly qualified S&T personnel.

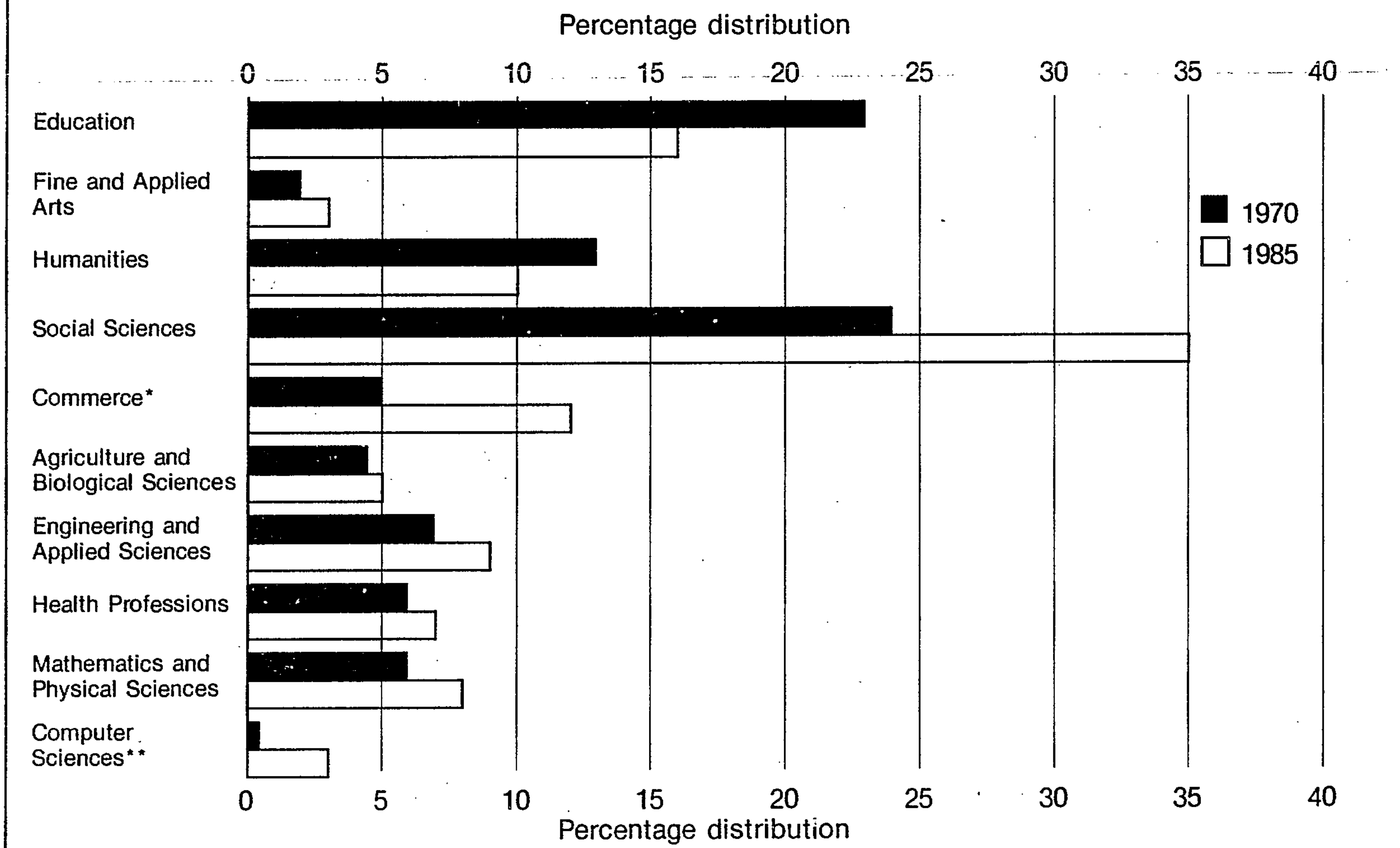
Proportionately, the United States is doing much better than Canada in both enrolment levels and degree awards in the natural sciences and engineering. In 1983, for example, there were 22,000 engineering students (about 93 per million population) at the Ph.D. level in the United States, but only 1,400 (about 56 per million population) in Canada. In Japan, 42.6 per cent of students at the doctorate level are enrolled in engineering; the figure for Canada is 18 per cent.

Table 4-2 shows that 1985 enrolment in engineering studies per million population was 25 per cent higher in the United States; in mathematics and the physical sciences, the United States was 17 per cent higher. It must be said, however, that the gap between the two countries was smaller in 1985 than in 1980.

A comparison with the United States is instructive, but it must be kept in mind that our neighbours also lag behind other industrialized countries in the production of highly skilled S&T personnel, particularly in engineering. Japan is the leader in this regard. In 1982 about 74,000 engineering degrees were awarded in Japan, compared with 64,000 in the United States,[5] even though Japan's population is only about half that of the United States.

FIGURE 4-1

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

TABLE 4-1

GRADUATE DEGREES AWARDED BY FIELD OF STUDY

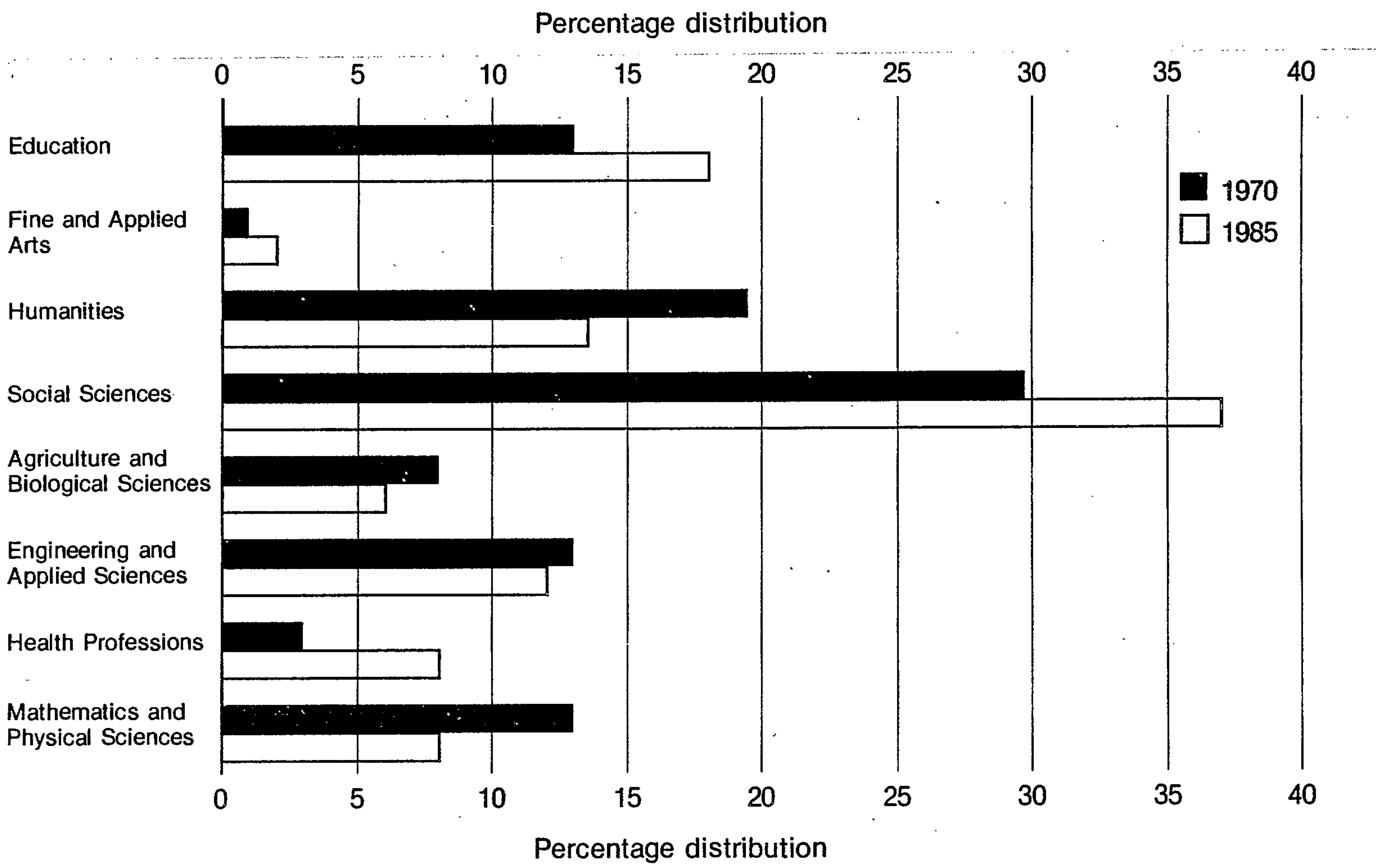
	1970	1975	1980	1985
Natural sciences and Engineering (1970 = 100) % of total	3,630 (100) 37.1	3,559 (98) 27.6	3,869 (107) 27.3	5,153 (142) 30.0
Engineering/Applied sciences %	1,185 (100) 12.1	1,190 (100) 9.2	1,300 (110) 9.2	1,888 (159) 11.0
Mathematics/Physical sciences %	1,326 (100) 13.5	1,235 (93) 9.6	1,101 (83) 7.8	1,415 (107) 8.2
Agriculture/Bio sciences %	745 (100) 7.6	709 (95) 5.5	827 (111) 5.8	949 (127) 5.5
Health professions %	374 (100) 3.8	425 (114) 3.3	641 (171) 4.5	901 (241) 5.2
Social sciences and Humanities (1970 = 100) %	6,156 (100) 62.8	9,299 (151) 72.0	10,289 (167) 72.6	11,691 (190) 68.0
Education %	1,341 (100) 13.7	2,333 (174) 18.1	3,031 (226) 21.4	3,133 (234) 18.2
Humanities[1] %	1,931 (100) 19.7	2,551 (132) 19.8	2,239 (116) 125.8	2,264 (117) 13.2
Social sciences %	2,884 (100) 29.4	4,415 (153) 34.2	5,019 (174) 35.4	6,294 (217) 36.6
TOTAL[2]	9,796 (100)	12,908 (132)	14,170 (145)	17,194 (176)

[1] Includes fine and applied arts
[2] Total includes unclassified degrees

Source: Statistics Canada

FIGURE 4-2

GRADUATE DEGREES BY FIELD OF STUDY, 1970 AND 1985



Source: Statistics Canada, Education, Culture and Tourism Division

4.1.4 Graduate Students at the Ph.D. Level

In many professional fields, a master's degree is sufficient. In many natural-science sectors, however, the need for a high level of research capability is such that a doctorate is required.

As Table 4-3 shows, the number of Ph.D. graduates in engineering is proportionately higher in the United States than in Canada. In 1985, for example, 3,165 doctorates in engineering (13.4 per million population) were awarded south of the border, compared with 277 (11.0 per million population) in Canada. If Canadian universities tried to reach levels comparable to those in the United States, they would have to produce about 20 per cent more Ph.D. graduates annually.

Estimating the demand for Ph.D. graduates is difficult. However, the Natural Sciences and Engineering Research Council (NSERC) does receive information about employment opportunities for Ph.D. graduates in the fields that come under its purview. Their sources include potential employers in industry, universities and government, as well as individuals who are seeking employment. On the basis of this information, the current situation appears to be as follows:

a) In the university sector, there is a shortage of highly qualified individuals in computer science, certain areas of electrical engineering, systems engineering, chemical engineering, industrial engineering, certain areas of mechanical engineering, statistics, applied mathematics and certain areas related to biotechnology.

b) The industrial sector is experiencing recruiting difficulties in computer science, electronics and communications, systems engineering, space technology, some areas of chemistry and chemical engineering, and certain areas related to biotechnology.

c) With a few exceptions, the government sector is phasing down. Whatever demand exists corresponds to the needs of the other two sectors.

The shortages for Canada are, in part, a consequence of the small number of citizens and permanent residents who obtain Ph.D.s in this country, as well as the strong demand in the United States for Ph.D. graduates in the fields mentioned above. In other fields, Canada appears to have an adequate supply of Ph.D. graduates. Indeed, well-qualified individuals sometimes accept jobs in other occupational fields, seek positions in the United States or take a series of short-term appointments.

The three granting agencies of the federal government - NSERC, the Medical Research Council (MRC) and the Social Sciences and Humanities Research Council (SSHRC) - already have national programs of post-graduate scholarships and

TABLE 4-2

FULL-TIME GRADUATE ENROLMENT BY SELECTED FIELD OF STUDY IN CANADA AND THE U.S.[2], 1980, 1984 AND 1985

	1980		1984		1985	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
Engineering[1]	3,527	49,000	5,766	64,000	5,496	65,000
	(1980 = 100)	(100)	(163)	(130)	(155)	(132)
per million pop.[3]	147	215	229	271	219	275
Mathematics and Physical Sciences [4]	3,534	44,000	5,225	53,500	5,267	58,000
	(1980 = 100)	(100)	(148)	(122)	(149)	(132)
per million pop.	147	193	208	227	209	245

[1] Includes applied sciences (architecture, forestry, landscape architecture)

[2] Science Resources Studies Highlights, NSF, June 1987, p. 2. U.S. figures were estimated.

[3] Based on available population figures (UNESCO Yearbook)

[4] Includes computer sciences, mathematical sciences and physical sciences

Sources: Statistics Canada, *Universities: Enrollment and Degrees*, Cat. 81-204, Annual December 1986 and unpublished data from Statistics Canada for 1985
Science Indicators, 1985: Supply and Services, Ottawa 1984. Science Resources Studies Highlights, NSF, June 1987, for 1985

TABLE 4-3

DOCTORATES BY SELECTED FIELD OF STUDY CANADA, U.S. — 1984, 1985

	Canada		U.S.	
	1984	1985	1984	1985
Engineering per million pop.	188 7.4	277 11.0	2,913 12.3	3,165 13.4
Mathematics/Physical Sciences per million pop.	373 14.8	386 15.3	4,452 18.9	4,531 19.2
TOTAL per million pop.	561 22.3	663 26.4	7,365 31.2	7,696 32.6

Sources: U.S. National Science Foundation, cited in *Statistical Abstract of the United States*, 1987, p. 571
Statistics Canada, *Universities: Enrollment and Degrees*, op. cit., and unpublished data from Statistics Canada

fellowships, but budget limitations have reduced their effectiveness in attracting the best young minds to Canadian graduate schools in recent years. The post-graduate scholarships offered by NSERC, for example, carry a stipend of $11,600 per year, whereas the median starting salary for a B.Sc. graduate in engineering was $27,250 in 1986. Not surprisingly, only 50 per cent of the engineering students who were offered new scholarships at the master's or doctorate level in 1986-87 actually accepted those offers. Obviously, steps must be taken to signal to these students that pursuing advanced research training is important for the future well-being of Canada and that they will not be penalized for choosing such a course. A substantial increase in the levels of scholarship stipends would convey such a message.

To stimulate interest in research among students at the undergraduate level, NSERC established a program of Undergraduate Student Research Awards aimed at providing them with experience in university or industrial research. The council contributes $750 per month toward the salaries of students, for periods of up to four months. About 2,500 awards were granted annually in 1985 and 1986 (2,000 in universities and 500 in industry), but budgetary constraints forced a reduction to fewer than 2,000 awards in 1987 (1,500 in universities and 420 in industry).

As Canada's economic and social development depends more and more on the contributions of S&T, it can be assumed that the demand of industry for personnel with advanced degrees will increase in such areas as microelectronics, systems engineering, industrial engineering, space technology, communications, materials science, biotechnology and information processing. This implies a greater need for, among others, electrical engineers, physicists, chemists, computer scientists, systems engineers, cell biologists and chemical engineers.

Even with the recent gains, there is a shortfall in graduate enrolment in the natural sciences and engineering that will affect Canada's ability to conduct R&D programs.[6] In a recent survey conducted by the Conference Board of Canada, 35.5 per cent of Canadian firms indicated that they were currently experiencing shortages of qualified R&D personnel; 41 per cent believed that they would face such shortages within five years.[7]

4.1.5 Female Enrolment in Science and Technology

An examination of the student population in Canadian universities reveals another imbalance; although women constitute about half the total student enrolment, they account for only 28 per cent of full-time students at the undergraduate level in mathematics and natural sciences and only 12 per cent in engineering and applied sciences. At the Ph.D. level, female enrolment represents 15 per cent of total enrolment in mathematics and 7 per cent in natural sciences. In 1984 female students received only 11 per cent of all full degrees awarded in engineering and applied sciences. By contrast, the participation of women in health-related management and in social sciences is high.

The apparent indifference of women toward S&T results from a combination of outside influences and personal choices that inhibit their entry into certain academic disciplines. The Macdonald Commission noted that the male-female imbalances in science and engineering programs are often the result of choices made at the secondary school level. Yet it would undoubtedly be possible to influence those decisions if better information and counselling were provided to female students at that level. Individual choices can also be influenced by support systems that enable women trained as scientists and engineers to participate actively in the labour force.

The present situation is sowing the seeds for continued imbalances in the monetary rewards and personal accomplishments of women in the economy in the years ahead. The efforts of organizations such as Women in Science and Engineering (WISE), which seek to provide role models and personal encouragement to female students (at the secondary level, in particular), are therefore welcome. In the long run, such attempts to influence the choices made by female students at the secondary level will have an enduring effect, since decisions to opt into, or out of, the science and mathematics streams are made at that level.

4.1.6 Matching Supply and Demand

Forecasting demand for highly qualified personnel is, at best, an uncertain exercise. The content and relative importance of occupations change with technological innovations and shifting industry dynamics. Over the past 20 years, the supply of highly qualified personnel has been such that, when net migrations are taken into account, university graduates experienced relatively low unemployment rates. Indeed, the average for university graduates has been half the national average, although there are differences between occupational categories.

The Economic Council of Canada recently estimated that employment in fields such as mathematics, statistics and systems analysis would grow by 200 per cent between 1981 and 1995 (Table 4-4).[8] Some other occupations, including architecture and engineering, are expected to grow by between 25 and 40 per cent. Management and administrative occupations are expected to grow by about 10 per cent.

Increasing the number of graduates in science and engineering would help to fill some of these anticipated employment opportunities. It would also lead to a rise in the employment of scientists and engineers in management and administrative positions. Ultimately, because engineers and scientists are becoming increasingly involved in starting new businesses, the expanded supply of new graduates would likely create its own demand.

TABLE 4-4

ACTUAL AND PROJECTED EMPLOYMENT BY DETAILED OCCUPATIONS CANADA 1981 AND 1995

	Three Scenarios			
	1981	1995A	1995B	1995C
Detailed Occupations:	(Thousands)			
Managerial, Administrative				
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 fields	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

Sources: Economic Council of Canada; *Innovation and Jobs in Canada*, p.49, Table 4-10. For a description of the scenarios see "Innovation and jobs in Canada," a research report prepared for the Economic Council of Canada, Ottawa 1987.

4.1.7 Conclusion

What conclusion can we draw from this brief survey of enrolment data? While proportionately university enrolment in Canada is among the highest in the world, not enough students are choosing science and engineering studies. This problem is particularly acute with female students. Moreover, too few engineering students are pursuing graduate studies, especially at the Ph.D. level where Canada is lagging.[9]

Yet those who decide to take graduate studies appear highly satisfied. According to a survey of 1984 college and university graduates conducted two years after their graduation, a very high proportion of those with a master's or doctorate degree perceive that their current occupation matches their field of study. In fact, the higher the educational level achieved, the greater the job satisfaction among the graduates and, generally, the more they would choose the same field again. Contrary to the widespread assumption that skills are underemployed in the Canadian economy, this survey suggests that a higher level of learning is usually associated with higher levels of employment and job satisfaction.[10]

Increases in enrolment in science and engineering should not be sought merely to improve comparisons with other nations. The rationale for increasing the proportions of students and graduates in those fields is that, by stressing the importance of S&T both in university education and in industry, Canada will be in a better position to compete internationally. Canadians must therefore make a strategic decision to build a society in which S&T will be a driving force. Canadians must invest heavily in S&T taking into account the potential economic and social effects of such investments and the challenge of international competition. For that strategic choice to make sense, however, a larger number of Canadians must also make it their personal choice.

4.2 The Quality Of Education

In designing policies to ensure wider access to university education, governments took it for granted that the quality of the education would be maintained. That assumption is somewhat heroic, however, unless specific measures are taken to monitor quality and to encourage those individuals and institutions who perform best.

4.2.1 Quality at the Secondary Level: A Prerequisite

Although not strictly within our mandate, any assessment of the current situation and future prospects of S&T in Canadian universities requires a look at the quality of education in pre-university years. Many university administrators and professors stress that the secondary school system is not preparing students adequately to meet university requirements in science and engineering. In some provinces, proposed changes to the curriculum at the secondary level will further compound the problem; they are certainly not synchronized with minimum entry standards into good quality science and engineering university programs.

The quality of secondary education in Canada, as measured by the numeracy and literacy levels of high school students, deteriorated in the 1970s.[11] There are indications that it regained some ground recently, but the situation remains far from satisfactory. International comparisons (even with their methodological limitations) suggest that, on average, Canadian students do not score as high as those in other industrialized countries.

For example, a 15-country study of the achievement of high school students in algebra and calculus shows that Canadian students are low to medium performers when compared with their counterparts in Japan, Britain, Belgium and Sweden.[12] Similarly, the preliminary results of the Second International Study of Achievement in Mathematics suggest that students in Ontario and British Columbia performed slightly better than the average but well below their counterparts in Japan, France and Belgium.

In a recent study, the International Association for the Evaluation of Educational Achievement assessed the performance of primary and secondary school students in science courses in 24 countries and areas.[13] The results reveal that although French Canadian students score above the average at the primary school level, their scores fall by at least 20 per cent below the international average from about the middle of the secondary level. The explanation suggested is that the lack of depth and intensity of science programs at the secondary level in French Canada deprives students of the opportunity to gain a comparable level of scientific instruction. Not surprisingly, their opinion of science, whether they study it or not, is not as high as that of other academic subjects.

Close to 30 per cent of all Canadian students at the secondary level drop out before obtaining their high school diploma (or an equivalent). Moreover, enrolment rates drop sharply in most provinces as teenagers reach the mandatory minimum school-leaving age. By contrast, Japan's dropout rate fell from 29 per cent to 4 per cent between 1965 and 1980 - a remarkable achievement by any standard.[14]

In view of general public concern about educational standards and quality, the Macdonald Commission recommended the establishment of a national body to develop achievement-testing procedures and monitor achievement standards in Canada.[15] The social returns on further investment aimed at improving the quality and effectiveness of the secondary school system are high; and they deserve careful consideration.[16]

We endorse the recommendation of the Macdonald Commission that a national body be established to develop achievement-testing procedures and monitor achievement standards in Canada. An assessment by standard indicators of the quality of secondary education in literacy, science and mathematics would provide valuable insights into the performance of the educational system and would go a long way toward suggesting appropriate corrective measures.

It would also provide public benchmarks against which to judge the performance of our schools, highlight the concerns for the quality of education and facilitate parent involvement in the supervision of schools. These characteristics are key determinants of the quality of educational systems.

4.2.2 The Quality of Education and Training at the University Level

Canada has an extensive network of universities and colleges spread across its different regions. As in the case of secondary education, the Macdonald Commission noted the absence of national and comparative indicators to measure the quality of university education and output.[17] The measurement of the quality of education at the university level remains elusive, although progress has been made in devising methods for that purpose.[18]

Efforts are being made to monitor the quality of university education. Some institutions call upon panels of experts to evaluate departments and schools regularly. In other cases, professional associations with accreditation powers carry out periodical reviews of educational programs. Because that information is not made readily available, however, it cannot be used by students, employers and others to assess the quality of institutions on the basis of the indicators selected. This obstacle, which deprives them of healthy feedback on the management of Canadian universities, highlights once again the need to establish mechanisms to monitor the quality of education nationally.

At the graduate level, the problem of quality acquires an added dimension. Canada has neither the diversity nor the high quality of research-oriented institutions in the United States.[19] Top-level graduate students in Canada do not always find the research programs they seek. For example, although NSERC annually awards 50 scholarships of $17,500 each to the best science and engineering graduate students in Canada, more than half the recipients go to other countries (mainly the United States) to take their degrees. There is nothing wrong with that per se, but there is no evidence that the reverse flow compensates for this exodus. Although many foreign students come to Canada to be trained, the quality coming in does not match the quality going out. Improvements are necessary in many cases to bring the quality of education and research programs up to international standards. That issue will be addressed in the next section of our report.

Measuring the quality of education poses a major methodological problem: is one to measure the quality of the output or the value added in the educational process? Whatever the answer, one should not be deterred from attempting the task. Private and public institutions can be involved in the assessment of the quality of education. Private institutions can publish tabulations of subjective ratings of departments and institutions, as well as objective indices, such as the numbers and levels of grants received, degrees awarded and publications. Since it is difficult for public institutions to publish comparative evaluations, in the United States there are public bodies that sponsor independent research institutions, such as the Educational Testing Service or the National Center for Opinion Research, to undertake evaluation studies and publish their results regularly.

We believe that to improve the quality of education there is an urgent need to identify standards of achievement and to assess progress against those standards. Reliable and diverse information provided by private or independent government-sponsored research organizations is essential for an objective and constructive debate about the quality of education at the secondary and post-secondary levels. Means of improving the availability of information on the quality of secondary and university education should be devised.

We recommend that the federal government support private groups, foundations or university-based institutes that focus on monitoring the quality of education in Canada and diffuse their results widely in the public domain.

The gathering and dissemination of objective national data would provide the necessary incentives for change and form the basis for sound policy choices. At present, strategic data of this kind are not publicly available in Canada. Although the results of such evaluations might raise sensitive issues in the early stages, we believe that as time passes a rigorous and objective debate about the goals and performance of educational institutions would improve the positive and constructive impact on the quality of education in this country.

4.3 Financing University Education

Over the past three decades, governments in Canada stressed the need for easy access to universities and assumed that the quality of education would be maintained. Considerable financial resources spent by the federal and provincial governments to ensure accessibility and increase university enrolment.

The Canadian effort is notable among western countries. In 1970, Canada ranked first within the OECD in share of GNP spent on education. That proportion was 8.2 per cent in 1982, although Canada was no longer the leading country by then. Expenditures on post-secondary education as a share of GNP stabilized around 2.1 per cent, following a period of rapid increase (from 1.0 per cent to 2.5 per cent) during the 1960s. When adjusted for inflation, per capita expenditures on education increased marginally from $250 to $290 between 1970 and 1985.

The share of government expenditures in financing post-secondary education rose substantially between 1955 and 1985. Although jurisdiction over education belongs to the provinces, in practice the federal government plays a powerful role through its funding arrangements with the provinces on post-secondary education and, since 1977, through the Established Program Financing Agreement. Unfortunately, discussions pertaining to these programs tended over the years to focus almost exclusively on their financial aspects, with little regard for the quality of education or the goals of the university system.

4.3.1 The Impact of Provincial Funding Formulas

Current provincial formulas for funding universities are based largely on student enrolment. There is only marginal consideration for the development of research and the growth of centres of excellence in support of teaching activities. Some efforts encourage the funding of educational and research programs deemed to have the potential to contribute to social development; others discourage the growth of programs considered less pertinent. However, analysis of these funding formulas reveals that a major part of university budgets is determined by admissible historical costs.

The weight of historical costs in funding formulas is such that universities are encouraged to develop popular curricula that can attract large numbers of students but do not require heavy investment in infrastructure and research. Resources are spread over a large number of programs and institutions. This funding approach does not reward excellence in graduate or undergraduate education, it simply provides an incentive to increase enrolment. It is also inherently biased against science and engineering programs because they cost more than other university programs.

Problems with the current funding formulas are not new. Several reports recommend that the formulas be modified to foster the emergence of world-class research centres and to support excellence in education and research.[20] In particular, the Commission on the Future of Ontario Universities stressed the need for a funding formula that would not be based only on enrolment, but would also take into account the present and potential research capability of the institutions. We share the commission's conclusion that the existing approach to funding universities needs to be revised.

Revisions will be necessary anyway to deal with demographic change. The proportion of students aged 18 to 24 is likely to diminish in the near future because of changing demographic patterns. Declining enrolment from this group will prompt universities to offer programs designed to attract other age groups. This might be a valuable contribution to society, but care must be taken to ensure that the courses offered meet university standards and do not degenerate into "featherbedding" with the purpose of maintaining the head count. That risk should not be underestimated, given the incentives that the existing funding formulas contain.

If current patterns persist, the decline in enrolment resulting from demographic factors will eventually lead to fewer students graduating in natural sciences and engineering. Entry requirements into fields of study such as mathematics, physics and chemistry make it much more difficult for adult students to choose those disciplines, thereby compounding the problem. To maintain an adequate flow of graduates in these areas, incentives must be offered to attract more high school students to universities and to attract a greater proportion of them to science and engineering.

4.3.2 The Role of Tuition Fees

The roles of tuition fees and public funding in financing universities also need to be reassessed. It can no longer simply be assumed that access to higher education is best promoted by direct public funding of the institutions rather than by support to students. Tuition fees are integral to financing universities. Although there may have been sound historical reasons for setting tuition fees at low levels in the past, that policy must be revised in favour of a funding approach that will place greater emphasis on the contributions of individual students. Indeed, a number of provinces already allow universities to set their own tuition fees.

Letting universities set their own tuition fees does not introduce barriers to access. If there is a consistent finding from the numerous studies of the accessibility of higher education, it is that the financial situation of would-be students is not a major obstacle to their entry into a university. Therefore, we disagree with the view that only students from certain socio-economic groups could afford higher costs. Deregulating university tuition fees and the accessibility of higher education are two different issues; they should not be confused.

Financial structures do deter low-income or undecided students, however. Consequently, a larger share of public funds earmarked for post-secondary education will have to be channelled to individual students through scholarships, bursaries and loans.

There are many benefits of allowing universities to set tuition fees by discipline. First, the students paying the tuition fees would have an incentive to conduct a more thorough assessment of the quality of education and research in specific universities, and their assessments would be taken more seriously by university administrators and professors. Second, freeing tuition fees would eventually lead to greater diversity and variety in the Canadian university system. Institutions that offer programs perceived to be of high quality would be able to charge higher fees and thus devote more resources to further improving those programs. Higher quality curricula would also attract higher-quality students. Finally, funding individuals rather than institutions would encourage students to be more deliberate in making decisions. Not only would they play their role as evaluators, but their choices of programs would be the result of more careful analysis. In short, this approach would encourage greater accountability and generate greater pressure for quality throughout the system. It would also give universities greater diversity in their sources of income.

The preference for public funding of universities instead of individual student contributions has resulted in tuition fees representing only 14 per cent of total university financing in Canada. Tuition fees for Canadian students vary from a low of $500 per year for undergraduate and $550 per year for graduate studies in Quebec, to a high of $2,200 in selected health fields in British Columbia. Foreign students must pay higher fees, ranging from $1,260 in Alberta to $7,130 in selected health fields in Ontario (Table 4-5).

TABLE 4-5

AVERAGE TUITION FEES FOR FULL-TIME STUDENTS 1985-86

	NFLD	PEI	NS	NB	QUE	ONT	MAN	SASK	ALTA	BC
CANADIAN STUDENTS										
Undergraduate studies:										
Agriculture	—	—	1 270	—	540	1 210	1 030	1 020	850	1 650
Architecture	—	—	2 160	—	540	1 270	1 110	—	—	1 650
Arts	980	1 350	1 480	1 370	530	1 200	880	1 070	860	1 380
Commerce	980	1 350	1 480	1 390	510	1 200	1 050	1 070	860	1 370
Dentistry	—	—	2 230	—	580	1 550	1 660	1 500	1 280	2 200
Education	980	1 620	1 560	1 430	510	1 200	890	1 070	860	1 390
Engineering	980	1 350	1 430	1 390	500	1 300	1 150	1 120	1 060	1 480
Home economics	—	1 350	1 460	1 310	540	1 100	970	1 020	850	1 400
Law	—	—	1 680	1 360	510	1 230	1 160	1 110	840	1 680
Medicine	980	—	1 830	—	590	1 570	1 660	1 500	1 400	2 200
Music	980	1 350	1 470	1 390	560	1 230	1 000	1 070	860	1 510
Sciences	980	1 350	1 460	1 390	550	1 240	970	1 070	860	1 390
Graduate studies	710	—	1 650	1 460	550	1 250	1 170	1 190	1 580	1 590
FOREIGN STUDENTS										
Undergraduate studies:										
Agriculture		—	2 970	—	5 800	6 790			1 280	4 130
Architecture		—	3 600	—	5 800	6 790			—	4 130
Arts		3 050	3 230	3 070	5 810	4 410			1 290	3 040
Commerce		3 050	3 230	3 090	5 810	4 580			1 290	3 200
Dentistry		—	3 930	—	5 800	7 130			1 920	5 500
Education		3 320	3 340	3 130	5 800	6 260			1 290	3 040
Engineering		3 050	3 140	3 090	6 000	6 920			1 590	3 350
Home economics		3 050	3 160	3 010	5 800	6 060			1 280	3 930
Law		—	3 380	3 060	5 800	4 930			1 260	4 260
Medicine		—	3 530	—	5 800	7 080			2 210	5 500
Music		3 050	3 170	3 090	5 800	4 680			1 290	3 490
Sciences		3 050	3 170	3 090	5 810	4 410			1 290	3 040
Graduate studies		—	3 500	2 850	6 230	6 230			2 620	1 750

Source: Statistics Canada, catalogue 81-219

By contrast, tuition fees at public (i.e., state and city) universities in the United States account for 30 per cent of their total revenues. Yet, from an accessibility point of view, the United States fares much better than Canada. Tuition fees in public universities range from a low of $500 in California to a high of $3,554 in Vermont. They are much higher in private institutions.

We recommend that universities be allowed to set their own tuition fees, up to a maximum of $2,500 per academic year.

Variations in tuition fees between disciplines and programs should reflect specific conditions such as the actual costs of the programs and the anticipated revenues of individual departments, as well as the reputation of the university and the quality of its programs.

We also recommend that the accessibility of higher education be guaranteed through public, private and university scholarships and through student loan programs. As a corollary to the implementation of our recommendation regarding tuition fees, the funding of these scholarship and loan programs should be increased and the eligibility criteria should be adjusted accordingly.

Finally, we recommend that the funding formulas used by provincial governments allow universities to retain the funds resulting from the higher tuition fees. Specifically, tuition revenues should not be subtracted for the purpose of determining provincial grants.

4.3.3 A Renewed Post-Secondary Education Agreement

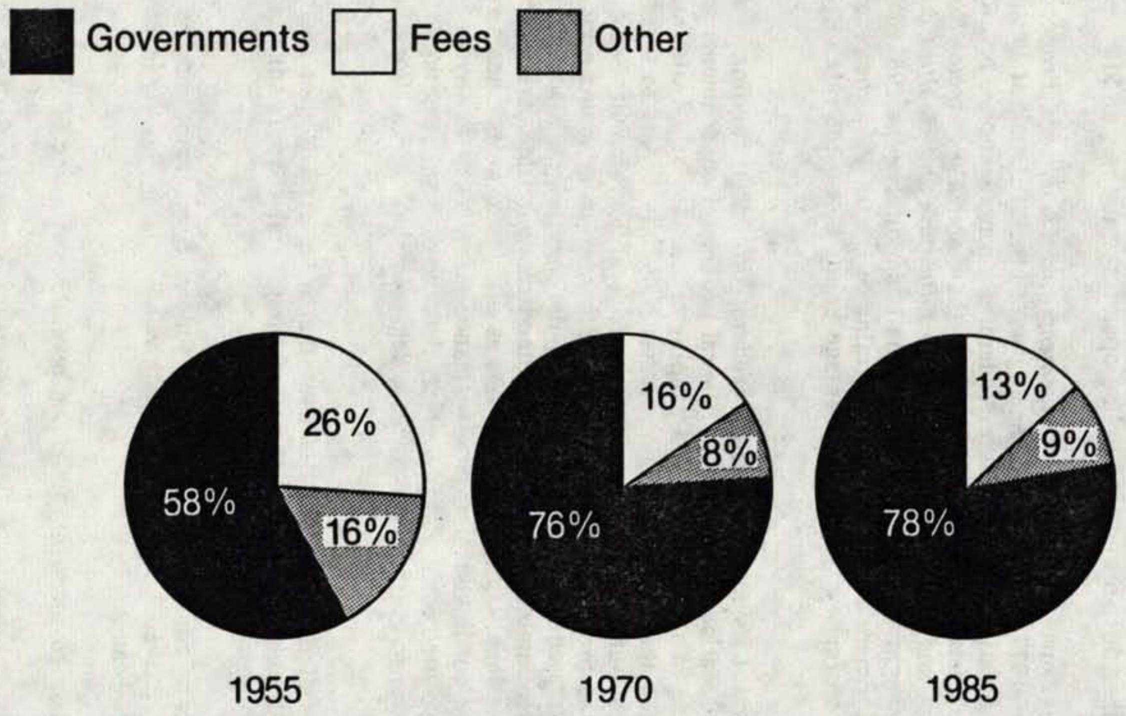
Education is a provincial responsibility, but financing post-secondary education is a joint federal-provincial matter. In 1986 approximately $10 billion was spent on post-secondary education in Canada with close to 60 per cent of that amount coming from the federal government.

The history of funding university education in Canada is complex. As shown in Figure 4-3, it is marked by increasing public involvement in recent decades. Although the *British North America Act* of 1867 assigned primary responsibility for education to the provinces, the role of the federal government is growing: the National Research Council was established in 1916 and in 1945 the government passed the *Veterans Rehabilitation Act*. This act gave universities a $150 grant for each enrolled veteran as a direct contribution, as well as capital grants for buildings and facilities.

In 1951, the federal government instituted a system of direct grants to universities, based on 50¢ per person in the provincial population. In Quebec, the provincial government instructed the universities under its jurisdiction to refuse

FIGURE 4-3

UNIVERSITY OPERATING EXPENDITURES* BY SOURCE OF FUNDS, 1955, 1970 AND 1985



* Includes sponsored research

Source: Statistics Canada, CANSIM Table Number 00590206 the grants between 1952 and 1955. This was followed by the creation of federal granting agencies; the Canada Council was established in 1957 and the Medical Research Council in 1960, although the act setting up the latter agency was passed only in 1969. In 1962 the *Federal-Provincial Fiscal Arrangements Act* was amended to allow provinces to receive (if they wished) a federal tax abatement instead of direct grants to post-secondary institutions; Quebec chose the latter alternative. The *Federal-Provincial Fiscal Arrangements Act* of 1967 replaced direct grants to the universities with a system of fiscal transfers to the provinces for all forms of post-secondary education; the financing formula was based on either 50 per cent of eligible operating expenses or $15 per capita.

The *Federal-Provincial Fiscal Arrangements and Established Programs Financing Act* (EPF) of 1977 replaced cost-sharing with block funding of health and post-secondary education. The two other federal granting agencies, NSERC and SSHRC, were established in 1978. In 1984 the *Federal-Provincial Fiscal Arrangements and Federal Post-secondary Education and Health Contributions Act, 1977* brought the increases in funding expenditures for 1983-85 under the federal government's "6 & 5" fiscal restraint policy. In 1986 the escalation of the total EPF transfer was set at 2 percentage points below the rate of growth in GNP.

Many important issues arise with the federal-provincial funding of post-secondary education. In particular, several provincial governments are unhappy about the size of the transfers and capping of growth rates, claiming that the transfers are linked to taxation points that rightfully belong to them and, therefore, are outside the purview of the federal government. Some observers retort that the provinces have not used EPF transfer payments earmarked for post-secondary education to finance well-defined programs accompanied with clear-cut accountability rules. They contend that the funds are allocated to health, educational, and other programs as provincial governments see fit and that they are not linked to any performance measures or to any national targets. It must be pointed out, in this context, that the original intention of the EPF agreement was to give the provinces a degree of latitude in allocating the funds as they saw fit.

Other critics of the existing system say that it fosters a lack of awareness in the Canadian public about the extent of the federal government's financial assistance to post-secondary education.

Other points of contention between the federal government and the provinces have emerged over the years. Several provinces claim that the level of funding is insufficient because:

a) the federal government ended the revenues guarantee in 1982;

b) the "6 & 5" policy effectively reduced the post-secondary education share of EPF from 32.1 per cent to 28.7 per cent because it was applied to post-secondary education but not to health; and

c) the total amount of the increase in transfer payments was reduced by 2 per cent, beginning in 1987-88.

The federal government's position on the use of transfer payments is that federal authorities cannot bear the blame if universities are underfunded because provincial governments divert the funds to other uses. The provinces argue that the breakdown of EPF funds - 32.1 per cent for post-secondary education and 67.9 per cent for health, fixed for the base years 1975-76 - does not reflect current realities. They claim that they have the legal right to allocate the funds differently.

The dilemma posed by the financing of post-secondary education can be approached in two ways. One approach would be to insist that the provinces follow national standards when they spend federal funds earmarked for post-secondary education. This approach would make provincial governments more accountable to federal authorities, but it would require that national standards be imposed on the provinces - a move that could be contrary to the constitutional sharing of responsibilities in education, as well as to the intentions of the Established Program Financing Agreement of 1977. It is not clear whether the provinces would abide by national standards imposed in such a manner, or that federally dictated standards would improve the quality of education.

A second, more promising approach would call for the federal and provincial governments to negotiate a new post-secondary education agreement that would incorporate national objectives and standards for the Canadian university system. This solution would recognize provincial responsibilities, while providing the federal government with a mechanism to develop a diversified university system directed toward attaining national goals.

Provincial ministers of education recognize that, notwithstanding the current difficulties, the provinces and the federal government must work together, especially where university education is concerned. Disagreement on a few points should not impede the harnessing of university research and education to improve Canada's international competitiveness. Agreements cannot be imposed from above, however, and they must respect the sharing of responsibilities enshrined in the Constitution. Only real dialogue can lead to a common vision and to coordinated action.

The potential adverse effects of failing to negotiate a new agreement on the financing of post-secondary education to foster this common vision must be considered. Post-secondary education would remain entangled in jurisdictional disputes and the focus would remain on narrow financial considerations. The Canadian public would remain unaware of the opportunities forgone and of the issues at stake. Finally, a further erosion of the potential and quality of Canadian universities in education, research, and technology diffusion would inevitably result.

We emphatically reject the idea that the federal government create a Department of Education. Too often, the premises that underlie the perspective of federal government officials seem to rest on a number of ungenerous assumptions:

a) the provinces are unable to finance post-secondary education adequately;

b) they are unable to arrive at a coordinated strategy in support of S&T; and

c) the federal government is in a better position to develop and manage a central system in that regard.

No evidence substantiates these claims. The problem will not be solved by adding other bureaucratic structures. What is needed is for the provinces and the federal government to agree on the goal of Canada's university system. There is also a need to forge a national consensus on how to build and coordinate a diversified but effective system, comprising institutions that complement one another.

Several matters could be discussed in the process of negotiating a renewed post-secondary education agreement. We have identified a few:

- the use of funding formulas that would encourage the emergence of centres of excellence in universities;
- the deregulation of tuition fees;
- scholarship and loan programs;
- the funding of the direct and indirect costs of research expenditures in universities (discussed in the next chapter); and
- incentives to attract more students to S&T.

We recommend that the federal government take the lead in seeking to achieve a federal-provincial consensus on the objectives and funding of a truly national but diversified university system, aimed at providing excellence in research and opportunities for graduate studies. This consensus should be reflected in a renewed agreement on the financing of post-secondary education, which would replace the current Established Program Financing Research.

4.4 Conclusion and Recommendations

One of the greatest contributions that universities can make to Canada's development is producing highly qualified individuals with world-class training in relevant scientific fields who can apply their knowledge. Despite doubts about the appropriateness of additional investment in education, it remains clear that the training of engineers, scientists, managers, and health professionals yields very high social returns. The rationale for investing in education is based on the recognition that the transmission of knowledge, including the new knowledge in which universities specialize, is as important a factor of production as labour or capital. Strength in scientific and engineering education and research is a prerequisite for strength not only in our high technology industries but also in our resource-based sectors.

The time has come for a constructive and comprehensive approach to the role of university education in Canada's scientific and technological development. Several of the problems identified can only be addressed by a concerted national effort. **We therefore recommend, in view of the important role that university education plays in the development of the country, that:**

a) the federal government convene the provinces to discuss the objectives of a diversified Canadian university system. Consideration should be given to incorporating the consensus achieved on these matters into a renewed agreement on post-secondary education financing. This agreement would supercede the current Established Program Financing approach;

b) new funding formulas be devised to promote diversity between universities and foster the emergence of world-class research and educational programs;

c) universities be allowed to set their own tuition fees, beginning in September 1988, up to a maximum of $2500 per academic year. Differences in tuition fees between disciplines and programs should reflect specific conditions, such as the cost of the programs, the anticipated revenues, as well as the reputation of the university and the quality of its programs;

d) individual students play an active role in the financing of universities;

e) access to university education be guaranteed through public, private and university scholarships and through student loan programs. As a corollary, the funding of these scholarship and loan programs should be increased and admission criteria should be adjusted accordingly;

f) the funding formulas used by provincial governments be amended to allow universities to retain revenues obtained through tuition fees (i.e., tuition revenues should not be subtracted when determining provincial grants to universities);

g) the availability of information on the quality of education at the secondary and university levels be improved. The federal government should support private groups, foundations and university-based institutes that monitor the quality of education in Canada and disseminate the results of their investigations; and

h) incentives be offered to encourage more students to take undergraduate science and engineering studies and to considerably increase their numbers at the graduate level.

5.0 RESEARCH IN CANADIAN UNIVERSITIES

The Canadian university system could make a significant contribution to basic research in this country, provided it is given adequate resources to harness and strengthen its capabilities in this area. Such commitment to research has been sorely lacking: our universities are suffering from well over a decade of neglect in the funding of their research activities.

We have focused on three broad aspects of this issue:

a) the situation of university R&D in the national R&D effort;

b) the problems that prevent full use of university R&D capabilities; and

c) public funding of research in Canada and the relative roles of university and government laboratories in basic research.

5.1 Contribution of Universities to the National R&D Effort

The major funders of R&D activities in Canada are the corporate sector and the federal government; the major performers are companies, universities and federal laboratories. As Table 5-1 shows, universities performed 23 per cent of R&D activities (in dollar terms) in 1986.

Total R&D expenditures in Canada as a proportion of GDP are approximately 1.3 per cent. In most countries, the trend of the R&D expenditures as a proportion of the GDP ratio has changed little over the past decade. Canada's ratio has historically been low relative to that of other countries.

Universities play a significant role in the national R&D system. As performers of R&D, they are second to the business sector and just ahead of the federal laboratories. This is attributable to the relative decline in the amount of government laboratories. University R&D activities are funded mostly by the federal government, either directly through its granting agencies or indirectly through fiscal transfers to the provinces (Table 5-2). The private sector financed approximately 13 per cent of university R&D in 1984-85, with companies contributing slightly over 3 per cent - a fact that has significant implications, which are discussed in the next chapter.

5.2 Problems in University Research Activities

Canadian universities need to raise the volume and quality of the basic research they perform to attract and hold high-quality professors and to compete internationally in their areas of strength. To achieve this objective, action is required on several fronts:

a) maintenance of a strong research component in Canadian universities;

b) availability of state-of-the-art equipment; and

TABLE 5-1

TOTAL DOMESTIC EXPENDITURE ON R&D BY FUNDERS AND PERFORMERS, 1986

	FUNDERS		PERFORMERS	
	$ millions	Per cent	$ millions	Per cent
Federal Government	2,415	35	1,433	21
Provinces	470	7	160	2
Provincial Research Organizations	2	—	91	1
Business Enterprises	2,853	41	3,528	51
Universities	658	10	1,600	23
Private Non-Profit Organizations	192	3	89	1
Foreign	311	5	—	—
TOTAL	6,901	100	6,901	100

Source: Statistics Canada

TABLE 5-2

FUNDING OF TOTAL UNIVERSITY R&D BY SECTOR AND FIELD OF STUDY, 1984-85

	Health Sciences	Engineering & Natural Sciences	Social Sciences	TOTAL
	($ million)	($ million)	($ million)	($ million)
Total Federal Government	159	303	55	517
• SSHRC	—	—	30	30
• NHW & MRC[1]	150	—	—	150
• NSERC	9	240	—	249
• Other[2]	—	63	25	88
Provincial Governments	28	91	49	168
Industry	8	29	9	46
Private Non-Profit[3]	105	23	7	135
Higher Education[4]	150	117	280	547
Foreign	5	6	—	11
TOTAL	455	569	400	1,424

Source: Statistics Canada, Science & Technology Statistics Division

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

c) access to major national research programs and facilities.

However, there are several problems that make it difficult to improve the quality of basic research in our universities. These obstacles are analysed below.

5.2.1 The Research Capability of Canadian Universities

In 1983 there were 34,630 scientists and engineers engaged in R&D in Canada; of these, 24 per cent (about 8,500) were in universities.[1] The number of research scientists and engineers in universities is largely determined by the teaching needs of these institutions. Those needs, in turn, are affected by the levels of student enrolment.

Following a period of rapid growth in faculty recruitment in the 1960s and early 1970s - an average increase of 1,500 faculty positions per year - resulting from rising student enrolment, the hiring of new academic staff with doctorates has proceeded at a much slower pace in recent years. Consequently, the teaching faculty in our universities is aging rapidly: between 1971 and 1982, the median age of all full-time university professors rose from 39 to 44. The foreseeable adverse impact of this factor on the future quality of research and education should not be underestimated.[2]

Because the faculty is now largely middle-aged, relatively few professors have retired in recent years. With the small increase in the number of university positions, this has resulted in few job opportunities for young Ph.D. graduates in Canadian universities during the 1980s. Yet, many young faculty members are needed to enhance the quality, adaptability and development of the research effort of the universities. The ability to recruit recent Ph.D. graduates plays a critical role in helping universities to adapt to new developments and enter new fields of research. This problem is further compounded by policies that unduly restrict the recruitment of scholars from abroad.

These difficulties will be followed by a transition period during which, because of an inadequate supply of Ph.D. graduates, universities will be hard-pressed to fill available positions. By the middle of the 1990s, many faculty members will be retiring, and the university system may face a shortage of highly qualified scientists and engineers in filling the available positions.

To help solve this problem, the Natural Sciences and Engineering Research Council (NSERC) created the University Research Fellowships Program. To date, this program has provided salaries and research grants for 450 fellows for five-year periods. Partial salary support for a further five years is available if the candidate obtains a tenured position at a Canadian university. Although the NSERC fellowship program has been effective in helping to attract talented young researchers to the universities, it is expected to be phased out by 1991.

The problem of building a pool of research talent in Canadian universities will remain. One solution might be to encourage a greater inflow of foreign researchers to help alleviate the shortage and to strengthen Canada's research capabilities.

A beneficial approach is to ensure that enough young Canadians enter graduate schools in science and engineering to meet the demand for highly qualified personnel that is expected to come from the universities and certain sectors of the economy in the 1990s. Unless action is taken now, the ability of many universities to perform their education and research functions at a level comparable to that in other industrialized nations will be jeopardized.

5.2.2 Focus on the Maintenance of the Research Base

The pursuit of research activities in universities across Canada is essential, not only to produce new and valuable knowledge, but also to train students in a stimulating environment. Currently, the research funds made available by the granting agencies are aimed at maintaining the science base of universities; they contribute little toward the establishment of significant new research capabilities.

The *ethos* of the academic profession in Canada, indeed in any country, is that each faculty member must be engaged in both education and research activities. In reality, the number of applications for research grants by faculty members varies between disciplines. In some, only one-fourth of the professors apply to federal granting councils; although in the medical field, for example, almost all faculty members apply for research grants.

Most of the research grants funded by NSERC, the Social Sciences and Humanities Research Council (SSHRC), and the Medical Research Council (MRC) under the peer review system are small. They tend to be distributed among many universities. For example, the average NSERC grant is about $23,000 - an amount that is adequate for establishing a small research capability, enabling the recipient's teaching to remain reasonably up-to-date. Over the years, three out of four applicants for NSERC grants have been supported by the council. At MRC, the average grant is higher (around $60,000), but inadequate funding has forced the agency to reduce the number of new grants to 15 per cent of applicants.

The peer review process ensures that the funds are allocated competitively, on the basis of individual merit. This has resulted in a reasonable distribution across the country, with some concentration in major universities. Individual grants range from a few thousand dollars to more than $150,000, depending on the productivity and quality of the research performed by the applicant. In 1985-86, one-fourth of the funding went to the top 10 per cent of applicants; the top half of the applicants received 70 per cent of the funds granted. More than half the money went to 10 institutions (Table 5-3). Eighty per cent went to 20 institutions and the remaining 20 per cent was distributed among about 35 institutions.

TABLE 5-3

TOP 15 UNIVERSITY RECIPIENTS OF FEDERAL FUNDING, 1984-85

Universities	Grants ($ millions)	Total Funding (per cent)
Toronto	65.2	14.6
McGill	40.0	8.9
British Columbia	37.0	8.3
Montreal* (ex. poly)	23.3	5.2
Alberta	22.7	5.1
McMaster	22.1	4.9
Western	18.7	4.2
Waterloo	18.2	4.1
Manitoba	16.7	3.8
Laval	16.3	3.6
Queen's	15.9	3.6
Calgary	14.6	3.3
Saskatchewan	13.6	3.0
Dalhousie	12.7	2.8
Ottawa	11.5	2.6
Total Funding to All Canadian Universities	447.0	

Source: NRC, Canada Institute for Scientific and Technical Information, *Directory of Federally Supported Research in Universities*, Volume 1, 1985/86

* Does not include École polytechnique or École des hautes études commerciales

University education requires a minimum of research by faculty members to keep up-to-date. We are satisfied with the distribution and the levels of research grants offered by the three federal granting councils insofar as they aim at the maintenance of the research base required by Canadian universities to fulfil their educational role.

5.2.3 The Underfunding of Venturesome Research

Few universities in Canada reach levels of research intensity that are comparable to those found in leading research universities in the United States. To ensure excellence in research, it is necessary not only to invest large sums of money in emerging scientific fields, but also to establish research groups whose size and funding levels compare with those in competing research universities abroad. There is ample evidence to support our conclusion. For example, a recent report on chemistry research in Canadian universities noted that the best researchers were not funded at an internationally competitive level.[3]

The funding of such research groups is inadequate in Canada. We feel that Canadian universities should be able to count on the support of the federal government for the adequate funding of competitive, world-class research. Funding for major venturesome research projects should cover the salaries of full-time research personnel and indirect costs of research. The grants currently offered by the three funding agencies are not large enough to support major concerted initiatives that would place Canadian universities at the forefront of worldwide scientific developments. We estimate that such grants should be three to four times above current levels to provide adequate funding.

Because of inadequate funding, individuals and groups at the forefront of their disciplines in Canadian universities cannot undertake venturesome and leading-edge research projects. Success is likely to be achieved late in the process, only after leading foreign research universities have established their pre-eminence in new scientific trajectories. Few large groups of scientists thrive in Canadian universities. When a notable innovation is achieved, the advantage tends to be lost shortly after to better-funded groups abroad who are in a position to exploit the opportunities it can provide.

Although the Canadian and the U.S. university systems display similar patterns, the proportion of research-intensive universities is much higher in the United States. For example, the 10 leading research universities in Canada undertake an average of CDN$16 million per year; the average for the 100 largest research-intensive universities in the United States is US$60 million.[4] A relationship exists between the size of research groups and the performance of researchers. The issue of minimum threshold levels, of a critical mass, must not be neglected. Not surprisingly, we observe that the best researchers join research universities offering these propitious conditions. For research to reach a minimum level of productivity and international quality, there must be a certain volume of research performed. Since we do not find venturesome research at these minimum threshold levels, one can only conclude that the Canadian university system is lacking in research-intensive institutions.

In addition to the resources needed to support a broad base of research capabilities across Canada, the granting councils should receive additional funding to promote venturesome research efforts at the national level. Such efforts should be under the direction of our best research scientists and engineers who can spearhead major initiatives. Not only do our researchers require increased funding, but also new methods. Greater use should be made of grants to support groups of investigators for project commitments of at least three, preferably five, years.

We believe that venturesome research in Canadian universities is severely underfunded. The granting agencies should receive adequate funding so they can promote such research efforts on a scale that will enable Canadian research groups to compete favourably with those in leading research universities elsewhere.

It would be possible to achieve these objectives by setting up a program to support research centres or networks. It would borrow features from Ontario's Centres of Excellence program, Quebec's *Actions structurantes* program and similar undertakings by the National Science Foundation in the United States.

5.2.4 Lack of a Policy on Major National Facilities

Canada lacks a policy on funding of major national facilities used by researchers in many fields of scientific investigation. Not only should adequate resources be provided to ensure that existing facilities will be well maintained and operated, but funds should also be set aside to finance new national facilities requiring major capital investments. New proposals for such facilities should be reviewed by peer groups that would include non-Canadian specialists. Only very few proposals of this type should be approved in each decade. The money for this purpose should probably be included in a revolving fund because demand will fluctuate from year to year.

No specific budget or continuing decision mechanism exists to assess the scientific merit or importance to Canada of 'big science' proposals. Instead, such projects are evaluated by ad hoc committees who often perceive them as competing with requests for normal research grants. Because there is no clear-cut and well-established evaluation process to judge the merits of occasional major proposals, it is not known if resources are allocated to their optimal uses. A few large investments may be needed to establish Canada's credibility abroad, to encourage excellence in research and to ensure that Canadians have access to the technological tools of the future.

Caution is necessary here. The allocation of funds to major national facilities could result in a substantial portion of the available resources being invested in a few risky projects that would close options for the future. Consequently, the decision-making machinery should provide for rigorous and extensive analysis of each project, bearing in mind future demands and opportunities.

5.2.5 Obsolescence of Laboratory Facilities

If Canada is to attract some of its best minds to research careers in S&T, it must provide professors who would train them with state-of-the-art equipment. The obsolescence of laboratory facilities in universities is evident, though it is unevenly spread across institutions. Between 1971 and 1983, the private and the public sector experienced an increase in the average age of machinery and equipment. This was especially true in universities where the average age almost doubled during that period (from 5.7 years to 10.7 years).[5] In some cases, as one university president noted, the equipment used in undergraduate laboratories is older than the students themselves.

NSERC has estimated that in 1981 additional investments of $50 million per year would have been required to raise the quality of our scientific and technological equipment to a satisfactory level. In 1984 a working group estimated at $48 million per year the additional investment required for the infrastructure needed to maintain and operate the equipment base. In recent years, however, actual capital expenditures for equipment have been less than half the amount required, and expenditures for operation and maintenance have been approximately $10 to $15 million per year.

5.2.6 The Indirect Costs of Research

The federal government and some provincial governments fund most direct costs of research projects. Private businesses and non-profit organizations account for 3 per cent and 8 per cent, respectively, of total university R&D funding. Indirect costs - which include the salaries, equipment and services paid for by universities - are not funded by the granting councils; they are assumed to be paid through general grants from the provinces to universities. The funds allocated for academic research are "grants in aid" and must be used to finance the direct costs of research only. They may not be used for buildings or for overhead expenses such as heating, lighting, telephone and secretarial staff. This approach is modelled after the British pattern, unlike the situation that prevails in the United States where both the direct and overhead costs of research are covered by the granting agencies.

Universities find it increasingly difficult to carry the overhead costs of research performed under grants. Some claim to have reached the point where it is difficult to accept additional research grants. In many cases, their capacity to carry on additional research depends on the projects being fully funded from outside sources.[6] Thus, the lack of an overhead provision has the effect of providing an implicit subsidy to universities that conduct little research while penalizing those with extensive research programs.

The issue of the indirect costs of research has been raised in the past.[7] Should these costs be funded by the granting agencies, their budgets would have to double. Pressures would likely arise to have these sums removed from fiscal transfers under the Established Program Financing agreement. The best approach to this issue is to make a distinction between funding for the maintenance of the research base in the universities and funding for venturesome research projects. We have given careful consideration to the arguments put forward in this matter. We have concluded that combining the funding of direct costs by the granting agencies with the financing of overhead costs through general provincial grants would be the best approach to funding for maintenance of the research base.

The general issue of overhead costs cannot be divorced from the management and budget concerns of universities. Consequently, better use will be made of public funds if that issue is dealt with comprehensively by a single authority. The presence of two agencies dealing with this problem would only create more difficulties for the universities. The granting councils are not equipped to deal with such problems, and it would be counterproductive for them to be involved in attempts to solve them. Moreover, the peer review process would most likely conflict with the management requirements of university facilities. In the United States, granting agencies cover both direct and indirect costs of research, and it would be unwise to ignore the problems that have plagued that approach to the issue.

We recommend that, as far as the funding of activities aimed at the maintenance of the research base in Canadian universities is concerned, the three granting agencies of the federal government continue to finance only the direct costs of research. The issue of the funding of indirect costs should be dealt with in the framework of a renewed agreement on post-secondary education.

The funding of major venturesome research projects raises issues of a different nature. The marginal benefits of higher levels of funding for such research are high. As pointed out earlier, current funding levels in Canada are not competitive. More important, the universities engaged in such high-level and intensive research activities in other countries have established distinct organizational structures to manage them.

We recommend that, in the case of venturesome research projects, the granting agencies' fund not only the direct costs, but also the costs of infrastructure and other ancillary costs, as well as the salaries of the full-time research personnel required to carry out these projects at a level of quality that is competitive with similar establishments abroad.

Funding the infrastructure costs will give universities an incentive to develop innovative proposals that will reach the threshold required for effective performance. A special fund should be set up for the granting councils to finance the indirect costs of major venturesome research.

The issue of overhead costs also arises in contract research.

The private sector is reasonably familiar with the need for overhead, but it is a different matter with government departments. During our consultations, several university presidents reported incidents that illustrate this sorry state of affairs. In one case, in discussions with a federal department over a research contract, it was suggested to the academics involved that they operate as private consultants out of their own homes so that no overhead would have to be paid to their university! And that is not an isolated case!

5.2.7 The Research Performance

The results of surveys of various groups by NSERC suggest that the quality of research in Canadian universities is good, but the research capability is lower than one would expect in a country of Canada's size and resources. The evidence shows that Canada's performance in competing for the best research talents - students or faculty - leaves much to be desired. The perception that outsiders have of the climate for research in any country is based partly on its success in winning major international awards that acknowledge important advances in science. The performance of Canadian universities in this respect can best be described as lacklustre.

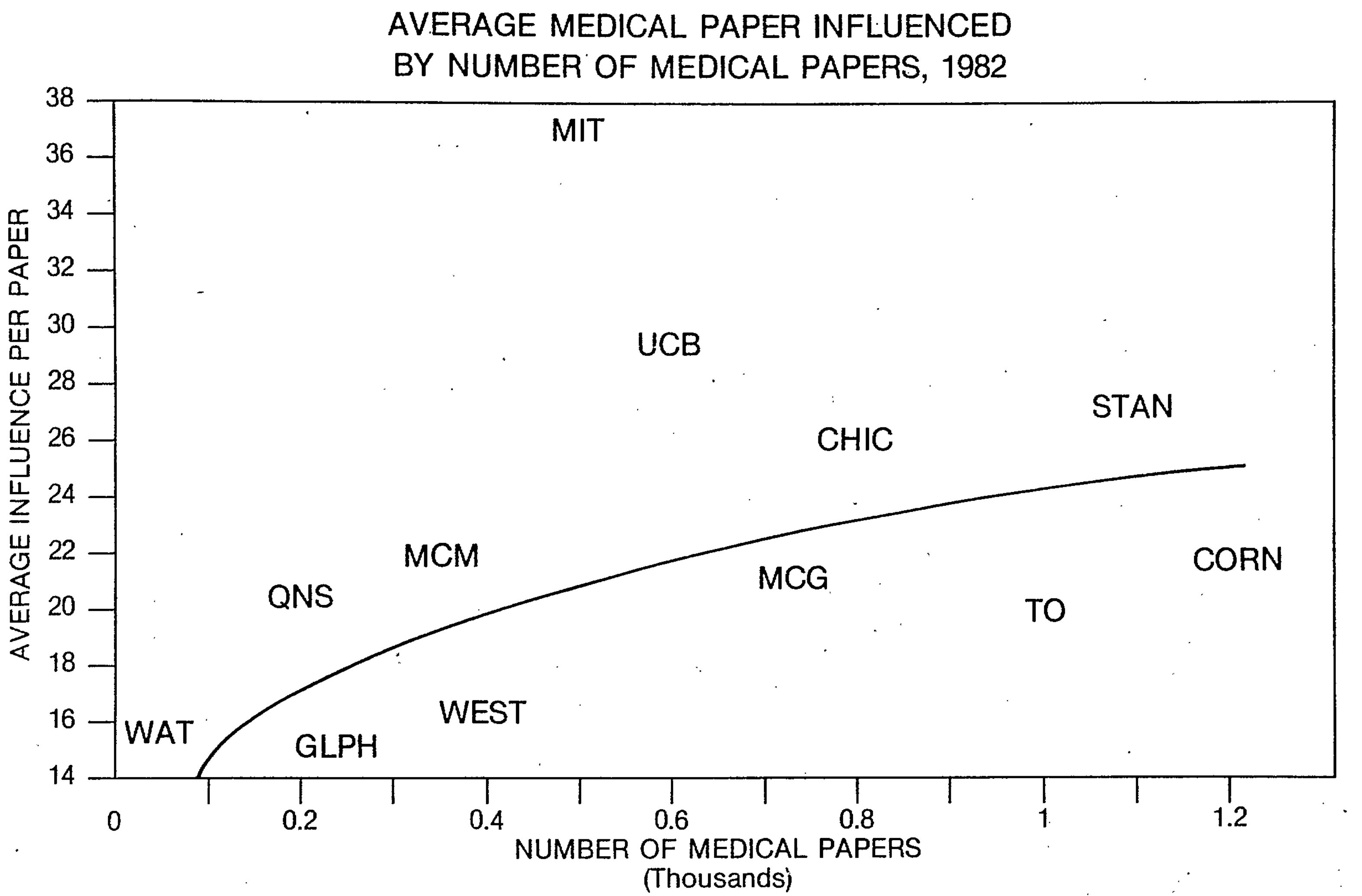
The number of research papers published worldwide can also be used as an indicator of the performance of Canadian universities in that area. Canadian scientists authored or co-authored about 4 per cent of the world's scientific papers in 1982. However, the number of published papers with Canadian authors had dropped to 11,744 that year from 11,906 in 1973. This 1.3 per cent decline contrasts with the 6.5 per cent increase in the total world output of scientific papers during that period. Japan's share rose from 5.3 to 7.3 per cent over this period - an increase of nearly 40 per cent - even though that country is often portrayed as not focusing enough attention on basic research.[8] The stagnation of research publications over the past 15 years is indicative of problems in Canada's universities.

Measuring the output of university research is a formidable task. Nonetheless, a monitoring system can be developed by using indicators such as publications, citations, scientific events and patents. One can look, for example, at the average influence of medical papers in selected Canadian and American universities (Figure 5-1). Although the number of medical papers emanating from the Massachusetts Institute of Technology is relatively small, the average influence of these papers is high. At the University of Toronto and Cornell University, professors and researchers publish many papers, but the average influence per paper is lower.

To assess how output indicators for Canadian universities could be developed, we measured the influence of papers published in 1986 by professors and researchers in the health field in five Canadian medical schools. The productivity of the schools was measured by multiplying the number of published papers by the rating of each journal in which they were published, as determined by the journal citation index of S.C.I. for 1986. Our preliminary results suggest that there is a high degree of correlation between research output and the characteristics of the faculty and the way in which research is conducted.

FIGURE 5-1

A COMPARATIVE ANALYSIS OF THE INFLUENCE OF MEDICAL PAPERS IN SELECTED UNIVERSITIES



Source: CHI, *Publication Profiles, Bibliometric Assessment of Ontario Universities*, 1984

We recommend that the granting councils annually monitor the quality of research output on a national and, more particularly, an international competitive basis, and that the results be made public.

A monitoring system of this nature might disturb some established groups, but this would be compensated by the clear focus that would be put on the quality of research output.

5.3 Financing Research in Universities

Financing direct costs of research in universities is largely a federal undertaking, although some provincial governments are also involved. Several issues are pertinent here:

a) What level and what rate of growth of funding should be allocated on a national basis for research by the federal government?

b) How should the funds be allocated between basic and targeted research?

c) To what extent should universities and government laboratories be involved in research?

5.3.1 The Level and Growth of Funding

What priority should governments in Canada give to research in general and research that is done in universities? We believe that expenditures on government-funded research must grow more rapidly than the GNP if S&T are to become strategic levers in Canada's development. Since university research usually has a long-term objective, the public sector, rather than the private sector, will inevitably be the prime source of funding.

Federal expenditures on R&D have increased almost sevenfold over the past 20 years. In 1985 direct R&D expenditures were close to $2.2 billion, with 66 per cent of the funding for research conducted within federal establishments and approximately 15 per cent directed at industrial R&D activities. Most of the remainder was for research in universities. Additional assistance to industry was provided through deductions from taxable income that firms could claim under the special research allowance and the investment tax credit for R&D. An indirect contribution to R&D is also made through transfers under the Established Program Financing agreement.

The rationale for government investment in R&D is that the output of such activities is a "public good" and that the expected social rate of return is high enough to justify them even though they might not be profitable from a private point of view. Economists have devised various methods for measuring the "social returns" on R&D investment. They have found not only that such returns are very high, but also that they are significantly higher than the "private returns" to the investing firms. According to Mansfield et al., the medians are 56 per cent per year for the social returns and 25 per cent per year for the private returns.[9] The funding of basic research is often motivated by the desire to explore an area systematically in the search of new knowledge, combined with the historical evidence that social benefits arise from basic research even though they usually are not identifiable at the outset. From society's point of view, it is proper for government to finance these high-risk activities because they result in the production of "public goods."

Most direct federal funding for university research is channelled through the three federal granting councils. Each council is an arm's-length agency governed by an act of Parliament. Its members are appointed by the Governor General in Council and are responsible for making policy and devising programs after funds have been voted by Parliament. The budgets of the granting councils for 1987-88 are:[10]

Natural Sciences and Engineering Research Council	\$338 million
Medical Research Council	\$174.5 million
Social Sciences and Humanities Research Council	\$ 69.9 million

The funding of university research - by the granting councils, in particular - declined dramatically as a percentage of GDP during the 1970s (Figure 5-2). There was some recovery in the early 1980s, followed by a sharp decline in recent years. In 1984-85, the budgets of NSERC, MRC and SSHRC had only almost reached their 1970 levels, after a decade of decline. The level of funding of SSHRC has suffered a constant relative decline, but research work contracted out to social scientists and others by royal commissions, government task forces and research institutes tends to compensate for the decline to some extent.

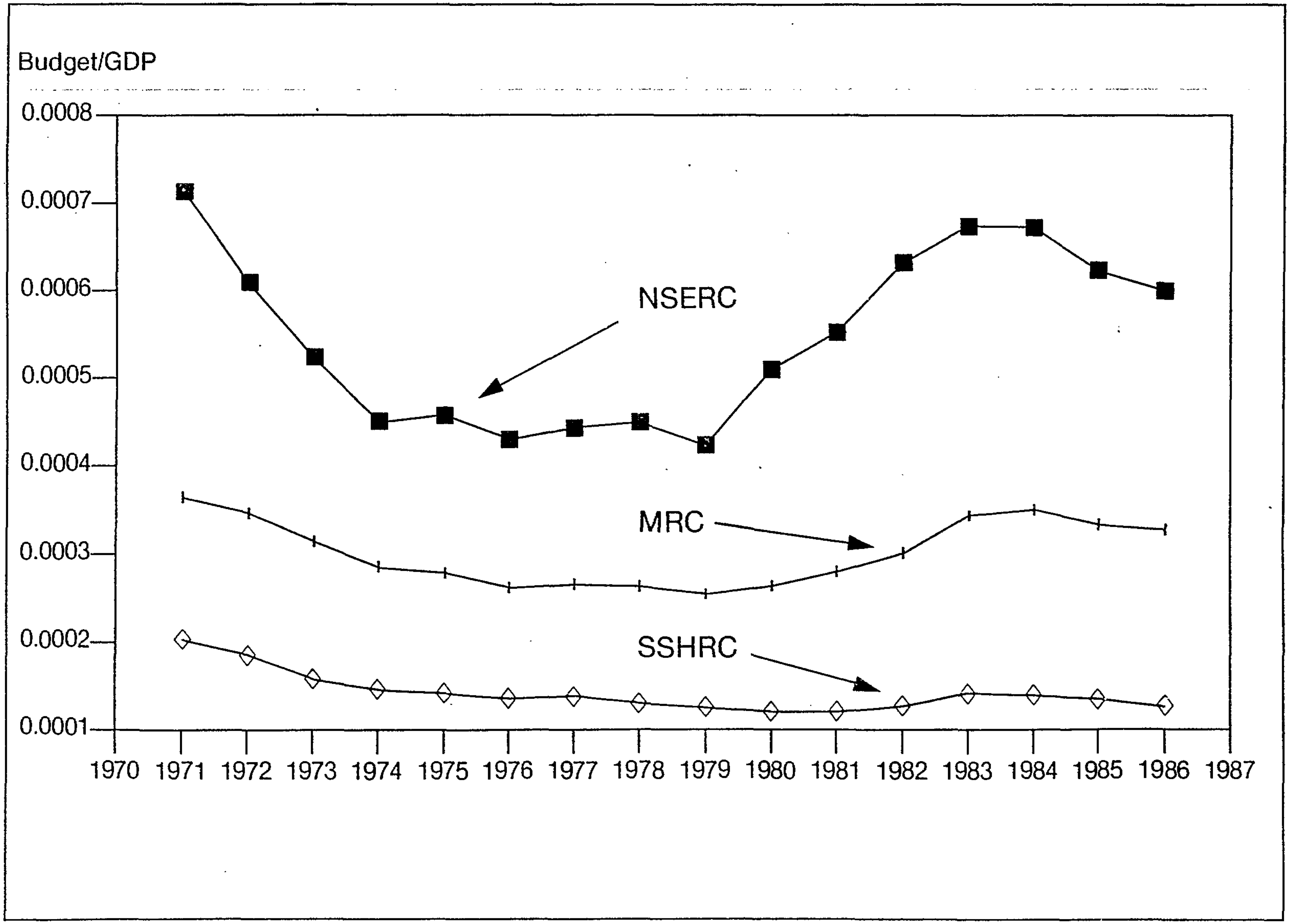
The basic budgets of the granting councils to the end of the present decade are not tied to the rate of growth of GNP. Indeed, there has never been a clear and continuing commitment to increase the funding of research at some multiple of the rate of growth in GNP. Had NSERC's budget grown at a rate 1.5 times that of GNP in the 1970s and early 1980s, it would have been \$515 million in 1986, instead of the actual \$338.1 million. The budgets of the three granting councils would now total \$900 million - as opposed to the current \$500 million.

Increased funding is required if the federal government is to help bring university research in S&T up to a level that will sustain international competition and to serve as a catalyst in knowledge-based production in this country. To erase the effects of previous neglect and to raise university R&D financing to an adequate level, we propose a one-time sharp increase in the budgets of the three granting councils - they should be doubled - to be followed by annual increases equivalent to 1.5 times the rate of GNP growth.

There are two reasons that justify doubling the budgets of the granting agencies.

FIGURE 5-2

GRANTING COUNCILS' BUDGETS AS A PROPORTION OF GDP



a) There is the need to pursue venturesome and leading-edge research more vigorously to bring Canada up to international standards. A rapid evaluation of the needs of university researchers suggests a funding level equivalent to twice the present level.

b) A similar conclusion is reached by calculating what granting councils' budgets would be had they grown at annual rates equivalent to 1.5 times the rate of GNP growth.

Adopting such a standard would indicate a strong commitment by the federal government to financing university research at a level commensurate with its importance to Canada's future.

The capacity of Canadian universities to train qualified individuals and produce and disseminate new knowledge is fundamental to the future of the country. The granting councils should be given the means to take action on several fronts:

a) Greater support should be available for individuals or groups at the forefront of their disciplines.

b) Adequate funding for equipment and facilities will stimulate a research and research-training environment; there is an urgent need to correct the severe underfunding in this area.

c) Funds should be available for targeted research in areas of national interest.

d) Funding should be provided for new major national facilities. A rigorous mechanism should be established to regularly evaluate proposals for such facilities.

We recommend that the basic budgets of the three granting councils be doubled over the next three years - that is, an additional investment of $500 million be made. Once that corrective step has been taken, the annual increase in the granting councils' budgets should be tied to GNP growth. An annual growth rate equal to 1.5 times the rate of GNP growth would enable our universities to remain at the leading edge of scientific and technological R&D.

Can our universities absorb such a sharp increase in a short period of time and use the funds effectively? We believe they can. We cannot overstress the need for, and urgency of, funding venturesome research projects at competitive levels.

Doubling the granting councils' budgets would enable them to respond, at least partly, to the demand for additional funds in the research community. In recent years, a growing number of first-rate research proposals, highly rated through the peer review process, have been approved but not supported because of a lack of funds.

A substantial group of high-quality researchers are available to enter the system; increased funds are essential to make effective use of these resources. For example, the University Research Fellows and Medical Research Council Scholars, whose funding has been discontinued because of insufficient funds. Many medical investigators have been deterred from applying for such scholarships because of funding shortages.

The sharp increase in budgets would permit purchases of equipment to provide the necessary tools for researchers at the beginning of projects.

The implementation of our recommendation would not suddenly thrust the granting councils into a surplus position. It would simply give them the resources to fund many high-quality proposals that they are now forced to reject because of their limited budgets. We are confident that our recommendation would not only enable the granting agencies to fund current proposals, but that it would also trigger many new proposals from university professors and research groups.

An increase in the granting councils' budgets should be accompanied by careful management practices. The most effective management method, in Canada and abroad, is to select the principal investigators and their research groups through the peer review process and to fund their projects at the required level. This same process should be used in allocating the additional funding recommended above.

5.3.1 Basic Versus Targeted Research

Is research the acquisition of new knowledge or the practical application of scientific discoveries? Does basic science precede and nourish technology, or is it the other way around? More specifically, is an emphasis on fundamental science a prerequisite for the development of a technologically sophisticated and successful economy? These questions highlight the need for an appropriate balance between basic research and technology development in funding policy.

The U.S. government appears to have concluded that basic science is the best route to technological superiority. In the United Kingdom and West Germany, however, targeted policies are preferred. Until recently, Japan seemed to agree, but recent policy statements suggest that the Japanese government is now giving priority to the need to boost the national capacity in basic science.

The small size of the Canadian economy has a bearing on this issue. Compared with large economies such as the United States and Japan, it seems likely that basic research activities in Canada aimed at developing new scientific fields might entail lower social rates of return than investments in education, training and the diffusion of best-practice technology. Considering the international flow of communications and ideas, it is difficult for a relatively small country like Canada to retain "first-mover" advantages or even maintain a leadership position once scientific breakthroughs have been achieved. A cost - benefit analysis of the social returns on investments in basic research and emerging scientific technologies might suggest that a deliberate 'followership' attitude in most disciplines would be appropriate.

A closer look at the scientific process suggests a less severe conclusion for Canada. Basic research is an essential part of programs for developing generic technologies because it is far easier to solve technological problems once the underlying natural phenomena are understood. Moreover, investment in basic R&D is often a prerequisite for the importation and domestic diffusion of foreign technology - a fact that has been noted by the Science Council of Canada.[11] Also, the international scientific community thrives on the exchange of information. Because membership in that community depends on one's contribution, Canada must undertake enough basic research to be in a position to "trade internationally in science and technology" from a leadership position in specific areas.

In a comparative study of the high-technology policies of five major industrial nations, Richard Nelson concluded that basic research conducted in universities and research on generic technologies conducted in collaboration with industry are the most promising avenues.[12] By reviewing the evidence, one forms the conclusion that general strength in scientific and engineering education and research is a prerequisite for vitality in knowledge-based industries. Moreover, a vital element for success is the existence of a system of scientific and engineering education that trains a significant proportion of graduates in industrial careers. That can only be achieved if many universities operate at the leading edge of research in a variety of disciplines.

We recommend that the granting councils maintain their emphasis on funding basic research. The growth of targeted research, whether in emerging technologies or in university-industry collaboration, should not occur at the expense of basic research.

Basic research is important and should continue to be stressed, but some degree of targeting is required. The allocation of funds should be aimed at developing scientific leadership in selected generic fields that are important for Canada. Targeted research needs to be encouraged by the federal government. Each strategic approach must be be developed through consultations with knowledgeable private-sector executives, university scientists and government officials.[13]

5.3.2 A Shift in the Locus of Research

Federal laboratories have played an important role in Canada's scientific development. For example, they contributed significantly to the progress of S&T during the Second World War, and two Nobel Prize winners had their work financed directly or indirectly by the National Research Council. However, the federal laboratories must now operate in a changed environment. Government laboratories in Canada perform a much larger proportion of total national R&D than those in the United States or Japan. This situation has prevailed since the end of the Second World War. Although this practice may have been appropriate in earlier decades, it has become more difficult to defend now.

Some people argue that government laboratories are required because they serve a wide array of public needs, the social rates of return on some types of research exceed their private rates of return, the risks and expenses involved are too high or industry is too fragmented to undertake the appropriate R&D activities. These arguments are often irrelevant because they pertain to the proper role of government in funding research, *not* necessarily to the locus of research activities. These arguments confuse the objectives with the instruments.

We believe that, as basic policy, the federal government should increasingly rely on universities to provide a broad base of national competence in scientific research. Our recommendation that the locus of scientific research be shifted in large part to the university system is based on the following considerations:

a) The science capability of universities has grown substantially in recent years, but they could contribute even more to basic and applications-oriented research. Other countries have led the way in achieving this kind of balance. For example, the development of a new generation of high-quality forestry scientists will only be possible if basic and applications-oriented research becomes an integral part of university research.

b) University activities in basic research are best suited to the shifting dynamics of scientific progress. Research projects can be reoriented quickly, and high-level graduate students involved. Basic and applications-oriented research conducted in universities with the collaboration of graduate students not only helps to train highly qualified personnel, but also facilitates rapid technological transfer to industry. The university system is the only research apparatus that is truly national. Because there are universities in every region of the country, they are in a better position to respond to local needs and aspirations.

c) The increased level of research activities will improve the quality of research performed in universities. In turn, quality research leads to quality teaching and attracts the best students. The process leads to a gradual but continuous improvement of the quality of our university and research system.

d) Universities are increasingly called upon to cooperate with industry in conducting applied research. They can significantly enhance their contribution if they can draw on the reservoir of knowledge created by basic and applications-oriented activities, and if the participants can use their experience in practical work to identify new problems.

e) Often, federal laboratories do not have to submit peer review or other control mechanisms that are used in projects funded by the three granting councils. We believe that Canada can achieve a higher rate of return on scientific research expenditures by more extensively using the talents in universities.

f) A problem in conducting S&T policy is the lack of market know-how and responsiveness within government agencies. We believe that universities, when linked to industry under some form of matching-funds financing, can respond and adapt to market dynamics and needs much better than government establishments.

Inevitably, the main locus of market-driven research must be industry. However, some research activities must remain under government control. For example, Canada needs an institution such as NRC to:

a) deal with standards and codes;

b) represent the country in international scientific organizations; and

c) foster industrial development not only through fiscal and monetary incentives, but also through funding of technology transfer to innovative firms. The NRC Industrial Research Assistance Program, which aims to help Canadian firms penetrate world markets with state-of-the-art technology, has received praise in this respect.

Shifting of a significant proportion of research activities from federal laboratories to universities would have major implications for science policy in this country. Why, people might ask, should Canada dismantle the network of public laboratories built over the past 50 years? This question would be a misrepresentation of our position. Others might argue that universities cannot currently use additional funds effectively. The expenditures of federal laboratories - in the area of biotechnology, for example - deprived universities and research firms of funds that could have been used to build a stronger research base in Canada. Indeed, in many new scientific fields, building a federal laboratory was the most inefficient solution because no attention was paid to existing capabilities in industry or universities. Where such capabilities do not already exist in universities, they can easily be developed once a clear policy has been outlined.

It might also be argued that the legislative responsibilities of the federal government require maintaining a critical mass of in-house capabilities - that is, the public need for research in some areas requires public laboratories. Although this might be the case in a few, highly sensitive areas - or in areas such as standards and codes - for most scientific fields the management of government laboratories can be transferred easily to the private sector or to universities, as has been done in other countries. Besides, universities can be associated with the basic research projects of federal departments on a contract basis.

Finally, some people might claim that some technical research requires facilities and concentrations of personnel that are only available from the government. The evidence from other countries, and from Canada, suggests that the management of complex laboratories could be fully transferred to universities or to the private sector without much difficulty.

Because of its visibility, suggestions that the federal government should shift its research activities from government laboratories to universities have been interpreted as an attack on NRC. This organization has certainly been the most active in the public debate. However, NRC accounts for less than 12 per cent of total *intra muros* research activities ($308 million in a total government *intra muros* budget of $2,659 million). NRC also has specific mandates that belong to a national research organization. Thus, we must not lose sight of the fact that the least efficient government laboratories and those that spend most funds are not NRC laboratories, but those directly managed by departments.

A policy to shift a large proportion of basic and applications-oriented research from public laboratories to universities cannot be implemented overnight. But there is no reason to prolong the process over a decade. With mobility incentives, the relocation of scientists occurs routinely in industry. Many scientists oriented towards basic research would feel more at home in a university environment if career openings were made available there.

We recommend that the federal government rely more on universities and less on federal laboratories for the performance of scientific research.

Our recommendation does not imply that past investments in government laboratories were wasted. Our view is that if these funds were properly allocated to universities in the future, they would yield additional benefits and result in a better allocation of scarce public resources. The role of government laboratories should be to address specific gaps in our national research system. By contracting out to universities, they would provide increased research opportunities for academic research staff and students.

5.4 Conclusion and Recommendations

Our assessment of the current research effort in the Canadian university system does not yield a very bright picture. Despite the underfunding, a broad base of university research has developed over the years. However, in many respects Canadian universities do not fare favourably compared with those in other industrialized countries. Direction and vigour in public policy have been seriously lacking and policy-makers have been oblivious to the implications of that indifference for the quality of our university system and for the competitiveness of the Canadian economy.

We recommend that:

a) **a long-term plan for publicly sponsored research in Canadian universities be developed. Attention should be paid to:**

   i) **supporting individuals and groups at the forefront of their disciplines,**
   ii) **adequate equipment funding,**
   iii) **targeted research of national interest, and**
   iv) **major national facilities.**

b) the federal government double the budgets of the three granting councils over the next three years. Subsequent budgets should grow at an annual rate equal to 1.5 times the rate of GNP growth.

c) the granting councils, within the limits of their resources, promote diversity within the university system. Resources should be concentrated on creating a few world-class centres of excellence in areas of importance to Canada's future.

d) the emphasis on basic research by granting councils be maintained. The growth of targeted research - whether in emerging technologies or university-industry collaboration - should not be at the expense of basic research.

e) annual monitoring of research output on a national basis - and particularly, on an international competitive basis - be established by the granting councils.

f) the issue of funding indirect costs of activities to maintain the research base in Canadian universities be discussed and solved as part of a renewed post-secondary education agreement.

g) the federal government fund not only the direct costs, but also infrastructure and other ancillary costs, and the salaries of full-time research personnel required to carry out venturesome research projects at a level of quality that is competitive with similar establishments abroad.

h) the federal government rely more on universities and less on federal laboratories for the performance of research.

6.0 THE DIFFUSION OF KNOWLEDGE AND TECHNOLOGY

In addition to training qualified individuals and producing new knowledge, universities play a major role in society by contributing to the diffusion of S&T. Diffusion activities make available to industry and government the best scientific and technical practice of the day. Within universities, they are conducted by faculty members active in basic or applications-oriented research. Participants in diffusion activities must be constantly aware of the evolution of knowledge in their scientific field.

High hopes are attached to the success of technology transfer from universities. Several university administrators have expressed interest in developing contract research (and other) relations with industry. For the government, the new federal matching-funds policy and provincial initiatives such as the Quebec tax incentive for university-industry R&D collaboration are of interest. The corporate-higher education forum has been established by leading Canadian executives to stimulate the development of this collaboration.[1]

Although universities can play a role in transmitting scientific and technical knowledge to other sectors of society, it would be unwise to overestimate the potential of applied research undertaken on their own. As a rule, universities are not very good at playing entrepreneurial roles. Nonetheless, their participation in joint university-industry projects can be beneficial.

These joint efforts will always represent a small fraction of R&D funding in universities, but can help them keep in touch with market expectations. The advantage of universities lies in the training of scientists and engineers and long-term basic research.

6.1 Canada's Lag in the Adoption of Technology

The rate of diffusion of new technologies in many Canadian industries - agriculture, manufacturing and services, in particular - is slower than in most other industrialized countries. In a 1983 report, the Economic Council of Canada noted that Canada was slow, relative to its major trading partners, in adopting new technologies.[2]

The diffusion of technology in Canada is lagging in three respects:

a) In some Canadian industries, new technology is often adopted later than in the corresponding industries of other nations.

b) Within Canada, there are interregional time lags in the diffusion of innovations.[3]

c) Because of inadequate training, managers and workers often resist new technologies or adopt them without being able to exploit them to the fullest.

In its most recent study on innovation, the Economic Council concluded that "Canada's persistent lag in the introduction and use of computer-based technologies is an urgent national problem of major proportion. The diffusion process of technology is too slow."[4]

What are the causes of this lag? Among the possible explanations is the fact that the introduction of innovations into certain Canadian industries is often characterized by low profitability because of the small size of the domestic market. Other factors, such as the level of R&D activities, foreign ownership and industry structure, may also explain the adoption and diffusion lag. Investment in R&D activities, which reflects how much firms are committed to the pursuit of technological opportunities, tends to be low in many Canadian industries. Finally, in most studies, managerial attitudes and a lack of appreciation for the potential of technology have been proposed as factors explaining the low rates of innovation diffusion in this country.[5]

The impact of the factors described above on the diffusion of S&T is greater than that of university R&D. Nevertheless, there are ways that universities can contribute more effectively to technology transfer and diffusion; this issue is addressed in this chapter.

6.2 A Joint University-Industry Role in Technology Diffusion

6.2.1 Private Funding of University R&D

As noted in chapter 5, an increasing share of R&D activities in Canada is financed and performed by the private sector. Not surprisingly, this growing interest has been accompanied by an increase in university-industry collaboration. As Table 6-1 shows, the corporate sector's contribution to university research through grants and contracts totaled $45.6 million in 1984-85 - 3.2 per cent of total R&D funding in Canadian universities. The corresponding figures for the United States the same year were $456 million and 3.9 per cent.

Although measuring the contributions of contract research and grants across nations and within federal systems is difficult, one can conclude that proportionately, the contribution of Canadian businesses to university R&D is slightly lower than that of their U.S. counterparts. Donations by companies (which, for statistical purposes, are counted as internal university R&D funding and thus are not included in these figures) are also higher in the United States. However, even at the Massachusetts Institute of Technology, the financing of research by industry represents only 7 per cent of total R&D funding; most funds come from agencies of the U.S. government.

TABLE 6-1

THE CONTRIBUTION OF BUSINESS FIRMS TO UNIVERSITY R&D, 1984-85

	Quebec	Ontario	Canada	U.S.
Millions of $ Canada	10.6	22.3	45.6	456
%	3.3	3.9	3.2	3.9
Total University R&D	316.6	574.4	1,424.1	11,591.0

Sources: Statistics Canada and National Science Foundation, Washington, D.C.

Several Canadian industries are moving into new areas of advanced technology and are seeking to apply science more effectively to the production of goods and services. Some innovative firms always maintain strong R&D spending, even during recessions, and continually seek to increase their interactions with universities. Consequently, the more emphasis that an industry places on technology, the more it depends on the new knowledge and talents generated by universities. Industry leaders recognize that industry can act effectively at many stages of the innovation process, but there are at least two areas where it is not effective: training scientists and engineers, and exploring new and challenging ideas that promise a potentially large payoff for the nation, but are not sufficiently well-defined to justify substantial investment by profit-oriented companies.

As Table 6-2 shows, the volume of research contracted to universities by the private sector has risen substantially over the past several years. In 1985-86 the contribution of the private sector climbed to $223.8 million, with $60.7 million originating from the corporate sector.

6.2.2 A Survey of University-Industry Collaboration

Universities can influence technology diffusion, thus contributing to national and regional competitiveness, through various mechanisms such as:

a) consulting and clinical activities;

b) contract research and joint ventures with companies;

c) participation in consortia aimed at the diffusion of S&T; and

d) involvement in consortia aimed at solving generic and common industrial problems.

Consulting activities of a clinical nature are not only an effective way to transfer technological knowledge to businesses, but they also help the learning process for faculty members. The association of universities with emerging industries fosters entrepreneurial attitudes among their students and promotes and encourages consulting within the faculty. At present, however, little information is available about the actual extent of consulting activities in Canadian universities.

Contract research within universities has been increasing, although the level is still low - about $224 million in 1985-86. Most contract research is accounted for by private, non-profit organizations and foundations. The value of business contract research has been estimated at $17 million for 1979-80,[6] and has increased since then. Contract research with industry is an important step in the development of university-industry relations.

TABLE 6-2

THE EVOLUTION OF CONTRACT RESEARCH IN CANADIAN UNIVERSITIES ($ millions)

	1979-1980		1980-1981		1981-1982		1982-1983		1983-1984		1984-1985		1985-1986	
	$	%*	$	%*	$	%*	$	%*	$	%*	$	%*	$	%*
Business	17.1	2.5	27.1	3.1	33	3.0	30.5	2.2	35.4	2.3	45.6	3.2	60.7	3.3
Non-profit organizations	66.9	9.8	82.1	9.3	105	9.6	110.0	8.0	138.2	9.0	159.8	9.5	163.1	9.5
Total private	84.0	12.3	109.2	12.4	138	12.6	140.5	10.2	173.7	11.3	214.2	12.7	223.8	12.8

* Percentage of total university R&D

Source: Statistics Canada, Ottawa, September 1987

Contract research and grants from industrial firms represent about 3.2 per cent of university R&D funding; non-profit organizations account for approximately 9.5 per cent. The contribution of the latter to funding actual research is about half that amount, however, as their funds are often earmarked for buildings, indirect costs and overhead. In 1984-85 non-profit organizations allocated most of their university R&D funds to projects in the health field; business firms spent most of theirs in S&T endeavours.

In cooperation with industry, several Canadian universities have established a number of "interface institutes" that offer research, development and education services. Some of these institutes were identified in a 1985 survey by the Corporate-Higher Education Forum.[7] These links vary greatly from one institute to another. Some are confined to a single university and several corporations - the Institute for Computer Research, for example. Others involve an entire industry and one or several universities. For example, the Pulp and Paper Research Institute of Canada (PAPRICAN), is a consortium linking McGill University (and, more recently, the University of British Columbia) and various Canadian pulp and paper firms. PAPRICAN, which has been in existence since 1927, is involved in basic and applied research, as well as graduate education. Its contribution to the forest industry was recently assessed as follows:

> For the forest industry in Canada, it is an excellent example of synergy permitting individual companies to do research and development locally with almost immediate application to their needs, and ensuring broader and longer range research to be done more centrally with a carefully crafted basic and applied distinction. It has also served as an excellent vehicle for sharing research amongst industry members, for supporting basic research at universities and the training of graduate students, and for ensuring a two-way street in technology transfer between industry and the universities.[8]

Joint-ventures between universities and industrial firms are even more numerous. Most of the 37 joint ventures identified in a 1984 survey by the Corporate-Higher Education Forum were oriented towards research and technology transfer.

6.3 Some Problems in Developing University-Industry Collaboration

The effectiveness of these joint efforts varies considerably. For each type of effort, there are some resounding successes, many average performances and some clear-cut failures. Success depends partly on the circumstances under which each scheme is developed.

When universities attempt to assist the diffusion process, they use several service or entrepreneurial initiatives. Difficulties may then arise not only for universities themselves, but also for their business partners.

6.3.1 Value Conflicts

In the past, the level of interaction between universities and industry in Canada has been low. The possible causes of this situation have been often discussed: Does the absence of linkages explain this lack of ties between industry and the universities, or is it caused by a cultural mismatch between them? There are two conflicts:

a) General conflicts of values and goals that arise when, as a result of industrial involvement, some of the major functions of the university (e.g., the advancement of fundamental science or the objectivity of scientific enquiry) are felt to be jeopardized. The academic community is sensitive to such conflicts because of its adherence to the traditional *ethos* of the university.

b) Institutional or organizational conflicts involve the internal standards of the academic system. When these standards are ignored or challenged, the purpose of universities is undermined.

A review of the conditions of success of university-industry collaborative research reveals that:[9]

a) Success of the institutes depends largely on the presence of a dynamic leader.

b) The institutes enjoy strong and direct support from the university and industry; the government acts as a catalyst and does not interfere with their management.

c) The institutes do best when they focus on a combination of generic and applied research. The most successful of them are involved in areas of S&T that cut across industry lines.

d) The success of these collaborations depends heavily on the presence in the universities of enough scientists and engineers who are strongly motivated to take on industrially relevant problems and to work on them according to industry's notions of costs and time constraints. These motives and this behaviour are often seen, however, as being in conflict with the academic mission of universities.

Our brief survey of university-industry efforts indicated that substantial results have been achieved over the past five years. However, several stumbling blocks could prevent their further development. The Corporate-Higher Education Forum noted that the value differences and the conflicts are more apparent than real.[10] The bottom line is that the university researchers and industrial corporations involved benefit from these joint efforts, and Canadian society benefits as well.

6.3.2 Difficulties in Managing Technology

To speed up the technology adoption and diffusion process and achieve closer cooperation between universities and industry, the ability of Canadian managers to master technology will have to improve. Too few Canadian corporations have learned to master technology as a competitive weapon. In this regard, our educational system, particularly at the university level, is seriously lacking.[11]

Technicians, engineers and scientists acknowledge that they cannot be fully effective without a broader education. Graduates in business, the humanities and social sciences must also recognize that they cannot effectively contribute to Canada's economy unless they have an adequate knowledge of S&T. Because of the importance of S&T in modern society, university students must have a solid exposure to it and must be aware of the role S&T plays in human affairs. However, our liberal-arts departments typically show little interest in S&T.

The importance of S&T is also undervalued in Canadian schools of management. Marketing and financial risks are given greater consideration than the strategic management of technological risks and opportunities, or the transformation of human organizations that must occur when technology is included in management strategies. In recent years, several universities across Canada have offered courses in innovation, entrepreneurship and new venture activities, generally within their MBA programs. That these courses have achieved great success among students bodes well for the future. Beyond that, however, few universities offer programs in technology management, although some interest has been shown by deans of management schools. Programs concentrating on managing scientific research and technology-intensive business should be more widespread.

The lack of technology management courses in Canadian universities is reflected in the business world. In a recent survey by the European Management Forum Canadian managers were ranked low on a scale of developed countries in management of technology.

6.3.3 Inadequate Exploitation of Intellectual Property

If Canada is to derive economic benefits from university R&D activities, there must be greater emphasis on the protection and exploitation of intellectual property. The rapid exploitation of patents should be of prime concern. Some Canadian universities seek to play a more direct role in arranging for the commercial exploitation of intellectual property. However, marketing patentable inventions and other technology requires expertise not generally available in an academic environment. Although an original patent is important, by the time a product or a process is commercially exploited, the original investment usually represents a small share of its value. Large additional investments are needed in further development, marketing and working capital, to launch the new product or process. Consequently, universities should seek the assistance of the private sector in providing the financing and the entrepreneurial skills necessary to develop and market the results of university research.

The federal government's policy for patents and other forms of intellectual property is based on the premise that the ownership of innovations developed through publicly funded university research belongs to the Crown. This policy tends to undermine the incentive for universities to pursue the research once the contract has expired. It should be changed so that the university conducting the research or the researchers involved own the patents and other forms of intellectual property, reserving for the federal government a royalty-free right to use the patent for its own purposes.

It is often assumed that most high technology companies are started by university professors or around universities. However, a recent survey of start-ups in high technology clusters in the United States, Canada and Britain suggests that very few of them are linked directly to university professors or directly started by them.[12] Most high technology firms are started, in fact, by engineers or science graduates who discovered opportunities while working for 'incubator' organizations such as high-growth companies, corporate development laboratories or contract research institutes. The major contribution of universities in this respect is that they trained engineers and scientists who later became entrepreneurs. We must be careful to distinguish the situation that prevails today in well-developed high technology clusters from the conditions that existed at their origin.

In the early years of these high technology clusters, university professors were actively associated with the birth of science-based companies. There are, even now, high technology companies that are linked to university-based researchers. Such start-up companies usually focus on technical areas that are in the early stages of active development and are changing rapidly because of discoveries in basic and applied research. Current examples are found in biotechnology and biomedical instrumentation. Similar developments occurred in microelectronics in the 1950s and in computer-assisted design and manufacturing in the 1960s. Basic and clinical research offer opportunities that are visible to university professors and researchers at the leading edge of their disciplines.

The universities and the federal government should adopt measures that can foster entrepreneurial involvement by faculty members or facilitate the exploitation of patents resulting from university R&D. Within universities, such measures would be characterized by the avoidance of structured rules governing faculty links with industry.

In adopting a liberal attitude toward creating a climate of entrepreneurship, universities can consider several steps:

a) encouraging the development of links between the faculty and corporate and government clients to make the transfer of state-of-the-art techniques easier. Consulting activities can take place on an individual basis or through firms in which professors hold an equity position.

b) vesting the ownership of intellectual property with the university professor or researcher who conducts the work, unless the research contract specifies otherwise. The premise is that, with proper encouragement, inventors will have a greater incentive to exploit this know-how commercially. In return, should the venture be profitable, the university would expect contributions or donations from the professors who received research funding.

c) recognizing that it is legitimate for university professors to hold equity and management positions in consulting, contract research or manufacturing companies, with the aim of transferring technology resulting from university research.

d) offering the use of university laboratories and other facilities for applied or clinical research, or for consultation activities, performed by professors for corporate or government clients within mutually accepted limits and upon payment of a fee.

The adoption of a liberal stance toward the commercial use of university research has had positive results for Cambridge University in Britain, where a high technology cluster has been active for 40 years.[13] This has also been observed at many American universities, in particular at the Massachusetts Institute of Technology, during the 1940s and 1950s. Peer pressure and faculty responsibility have kept these schemes within acceptable bounds and have led to a heightened sense of responsibility toward excellence in research and economic development. In fact, the liberal policies adopted by universities for matters such as consulting activities, equity or patent ownership, and the use of university facilities for contract research, have probably had a greater effect than the actual amount of R&D performed on new business creation by faculty members.

In contrast, many Canadian universities take an institutional approach, insisting on university ownership of patent rights (as many institutions do in the United States) and attempting to structure faculty involvement in start-up businesses. Formal mechanisms, such as industry liaison offices and patenting and licensing offices, have been established in several cases. A major problem with exploiting patents or technologies resulting from university research is that development funds are needed to transform the ideas or patents into engineering concepts that are advanced enough to attract investors. Many universities have attempted to resolve this problem by controlling and fostering the development of patents by:

a) licensing the technology to corporations able to fund the required development work;
b) gathering funds from government and commercial sources to finance the design and engineering work; and
c) developing joint agreements with commercial or venture-capital firms to the exploit the patents and engineering concepts.

However, Canada would best be served by the rapid exploitation of patent rights. It can be argued that vesting patent ownership with university researchers would contribute more - and more quickly - to economic development than tightly controlled development. This liberal approach could be reviewed in the light of actual experience and achievement. As noted previously, it is an approach that has had positive results in the United Kingdom and the United States.

Recent changes to the *Canadian Patent Act* have substituted the "first to invent" rule with the "first to file" rule. It is now more important than ever that universities convince professors and researchers to prepare patent applications and to seek other forms of intellectual property protection as soon as possible prior to publication. If this protection is not sought, in Canada and abroad, the potential economic benefits of the technology - and of our investment in research activities - will be lost.

We believe that a liberal policy toward the commercial exploitation of university-based R&D - including vesting patent rights with university researchers - is more appropriate for Canada than more formally structured approaches.

We recommend that government policy for patents be changed to vest the ownership of patents and other forms of intellectual property in the university where the research is conducted or with the researchers involved, reserving for the federal government a royalty-free right to use the resulting intellectual property.

Canadian Patents and Development Limited (CPDL) is a government agency that acts as a marketing agent for patented technology owned by universities. CPDL has not been effective; currently, its revenues barely exceed its expenses. As a result, Canadian universities have begun to establish their own services to license technology. If the research activities of federal laboratories are reduced - as recommended in this report - there will be no need for CPDL.

We believe that CPDL has outlived its usefulness and recommend that it be dismantled.

In many fields, intellectual property legislation needs to be reviewed. In biotechnology, for example, patents are difficult to secure because the laws regulating intellectual property do not adequately cover life forms and processes. Because of the importance of agriculture to Canada, the *Patent Act* should be amended to cover these innovations and breeders' rights legislation providing protection to breeders for new species and varieties should be enacted.

We recommend that the intellectual property legislation be amended to allow the patenting of life forms and processes.

6.3.4 Differences in Industry Structures and Regional Situations

Some industries are dominated by a few large firms; others are more fragmented. The institutional links between industry and universities will need to reflect these differences. Uniform solutions would not be suitable.

The same applies to the contribution of universities to the development of the regions where they are located. Once again, efforts must ensure that collaborative research funding focuses on those regional issues and local economic needs that universities can deal with, given their human resources.

Canadian universities are widely distributed throughout the country. They form a valuable infrastructure that could play a more active role in raising the rate of technology diffusion across the country. This important aspect of the system should be given more prominence in government industrial policies.

6.3.5 Inconsistent Choices

Despite the federal government's intention to stimulate university-industry interactions, inconsistencies in the implementation of certain policies have had undesirable effects, conveying messages that contradict official policy. This is not surprising when one considers that separate agencies are charged with applying laws and programs that have inconsistency embedded in their design and goals.

The recent purchase of a 'supercomputer' - a high-speed computer used for complex mathematics and simulations of physical processes - by the University of Calgary provides a clear example of this. Supercomputers are not made in Canada but in the United States and Japan only. They are purchased mainly by government research agencies, oil and gas exploration companies, large manufacturing firms and universities. At present, universities are the fastest-growing market.

The *Excise Tax Act* allows scientific apparatus used by educational institutions to be exempted from federal sales tax, provided it is not for sale or rent. The University of Calgary's supercomputer will be used mainly for research purposes:

a) 60 per cent by Alberta universities;

b) between 15 and 20 per cent by other universities across Canada;

c) 15 per cent by the government of Alberta; and

d) between 5 and 10 per cent by Control Data Corporation and other firms.

Revenue Canada has decided that because computer time is being sold to outside clients for research purposes, the University of Calgary is not using its supercomputer for educational purposes only. Consequently, it has slapped a $1 million tax bill on the university to cover the federal sales tax, the customs duty and interest charges.

Other universities are contemplating the purchase of a supercomputer. However, they are likely to be deterred by the current tax and customs legislation, which so obviously conflicts with the policy of encouraging university-industry interactions. These inconsistencies should be removed. Since customs duties on such equipment will be among the first to disappear because of the recent Canada-U.S. free-trade agreement, why not remove it immediately?

6.4 University Support of Technology Diffusion

Through its research funding to universities, the federal government is in a good position to encourage university cooperation in joint projects with industry. Five areas can be targeted for such action:

a) the encouragement of generic (or pre-competitive) research in university-industry consortia;

b) the management of technology;

c) the support of regional university-industry collaboration;

d) support for technical institutes; and

e) the matching-funds policy.

6.4.1 Grants for Pre-Competitive Research

The federal government has long acknowledged that it must provide selective encouragement to research of national importance. To that end, in 1977-78 NRC began its Strategic Grants Program, which has since been taken over by NSERC. The program has had much success in encouraging individual and group research aimed at increasing knowledge in selected areas. Although no assessment of its impact has been completed, there is an impressive amount of anecdotal evidence suggesting that it has resulted in a successful transfer of technology.

Two major problems were encountered. Although the Strategic Grants Program has been successful in attracting high-quality research proposals, its funding rate has dropped to 25 per cent of applicants because of its limited resources. This low percentage deters researchers from competing for the funds available. The second problem pertains to determining the fields in which targeted research is to be encouraged. Since 1977, the research community has determined what areas are of socio-economic importance and deserving of public financial assistance. NSERC is currently trying to devise a mechanism that would broaden the participation of industry R&D executives in the selection of areas of strategic importance.

The efforts to focus university basic and applied research on generic industry needs, rather than on company-specific targets, have produced impressive results. In the United States, the National Science Foundation Engineering Research Centers Program has also succeeded in involving faculty members in generic problem-solving consortia.[14] These successful attempts encourage us to support the retention and strengthening of the Strategic Grants Program and to encourage NSERC, MRC and SSHRC in their efforts to implement a more effective means to define the areas that deserve public support.

It is also important to encourage the transfer of knowledge from university researchers to groups of companies. In response to this need, NSERC has initiated a university-industry program that, in just three years, has resulted in the creation of approximately 50 university research chairs, with base funding provided by industry. Such efforts indicate a welcome change in attitudes. Targeted research activities are leading to the emergence, in many universities, of strong research groups linked to the corporate sector. Much has been accomplished, but much more must be done to meet Canada's needs.

We recommend that NSERC, MRC and SSHRC give increased importance to funding targeted research leading to university-industry consortia that focus on emerging scientific applications or generic industry problems. This new emphasis should not be at the expense of basic research.

We believe that after this recommendation is implemented, the resulting competition between universities for chairs or institutes will lead to the introduction of greater diversity within the Canadian university system.

6.4.2 Universities and Regional Technology Transfer

Universities could play a more active role in the diffusion of technology to business firms and other organizations. Already, they maintain links with many institutions that contribute to the economic and cultural life of their region. Because of their prominence in society, they are in a position to establish "interface institutes" capable of diffusing best-practice technology to business firms in the area. A major problem is that, in certain regions, industry is often fragmented and unable to form consortia with local universities.

The federal government has developed an array of programs designed to support the diffusion of technology - that is, the Industrial and Regional Development Program (IRDP), the Defence Industry Productivity Program (DIPP) and the *Small Business Loans Act* (SBLA). Several technology centres, operated by the federal government or the provinces, deal with such topics as computer-assisted design and manufacturing, robotics, software computing technologies and energy.

We recommend that special attention be paid to requests from universities for funding joint university-industry proposals **for building consortia with industry** as **a means of transferring technology** to **regional firms.**

The federal government should ensure that these interface institutes have enough resources to remain viable in the long run.

6.4.3 Support for Technical Institutes

Canada's technical institutes play a growing role in the country's economy. They focus on new ways of applying technology to the changing world of production. The research performed at the institutes focuses on productivity, efficiency and the effectiveness of business and industry. An increasing number of firms are turning to the technical institutes for help in training their workers and their customers in the application of new technology.

Governments fund the capital requirements of the technical schools; they also finance most operating expenses (75 to 95 per cent). However, that contribution is gradually decreasing as income from business contracts and partnerships increases. Enrolment at Canada's technical institutions is rising, and the increased pressure associated with the rapid growth in technology requires a quick response to changing needs in the composition of the work force.

Although we do not offer any recommendations about technical education, we recognize that our technical institutions play a growing role in the diffusion and utilization of technology in our economy. Governments are encouraged to facilitate the links that have developed between business and the technical schools over the past few years.

6.4.4 The Management of Technology

The success of economic exploitation of new scientific and technical knowledge will depend critically on the ability of Canadians to manage technology effectively. In fact, the management of technology is developing into a new branch of management sciences - one in which there is still much to be learned.

Traditionally, management science has dealt with the organizational and control factors that affect the management of financial risk. However, more skills are needed for effective management in an environment dominated by innovation. They include:

a) recognizing opportunity;

b) assessing and controlling technical risk; and

c) organizational factors affecting rapid innovative response.

Universities should take immediate steps to improve training opportunities in technology management for science, engineering and business students. Research is needed now, on a scale compatible with the scale of research in S&T, to improve the effectiveness of Canadians in the management of technology.

However, very little research of this type is currently under way. "Management science" is classified as a social science and competes with other disciplines under that heading for research funding from SSHRC. Because of the nature of the research, grants provided by SSHRC are much lower than those offered by NSERC and MRC - too low to support the scope and quality of research required in the management of technology. Although some of the more quantitative aspects of modern management science have been considered "operations research" and thus eligible for support by NSERC, the split jurisdiction between the two councils creates additional problems for the researcher seeking support.

We recommend that the money for research in the management of technology be significantly increased. We recognize that this could create a problem within SSHRC by raising the grants for one discipline far above the others. Should that problem become unmanageable, the responsibility for research in management

sciences could be transferred to NSERC. This would increase communications between the fields of natural sciences and management sciences.

6.4.5 The Matching-Funds Policy

In February 1986, the federal government announced its "matching-funds policy" along with a five-year financial plan for the three federal research-funding councils. The stated objectives of that policy were:

a) in partnership with the private sector, to increase the level of university-based research, research training, and directly related activities;

b) to increase the level of university-industry collaboration with respect to the mutually desired direction of university research, and to transfer the results of that research for application by the private sector; and

c) to encourage joint research activities that capitalize on the strengths and interests of the private sector and universities for the economic and social benefit of all Canadians.

The three councils' base budgets are stabilized at 1985-86 levels (in current dollars) until 1990-91. Additional funding was made available in 1986-87 to adjust the base budgets. Beginning in 1987-88, the federal government will provide additional funds so that the councils can match private sector contributions for university research up to a maximum of 6 per cent of the eligible matching budget of the previous year. Companies and foundations are expected to increase their contribution from about $34 million in 1987-88 to $155 million in 1990-91. This would raise their share of university R&D funding substantially.

Two issues need to be addressed concerning matching-funds policy:

a) Does it resolve the funding problems of university R&D?

b) Will the policy lead to increased university-industry interactions?

6.4.6 An Inadequate Solution to Funding Problems

The matching-funds policy will fail to provide any real increase over inflation before 1989-90. It does not solve the problem of funding university R&D; it simply compounds it. The matching-funds policy is a clever way to camouflage a decision to constrain the growth of government funding to the granting councils.

By 1990-91, the annual increase in government funding of the three councils will vary between 4 and 5 per cent. If private sector contributions are taken into account, the increase in university R&D funding will be between 8 and 9 per cent. Several considerations follow from this observation:

a) The policy implies a substantial increase in private sector financing over the next few years. The private sector may provide additional funds, but that contribution may be directed at applied, rather than basic, research. Therefore, the matching-funds policy ties the growth of funds to contributions from the private sector (companies, non-profit organizations and individuals), which represent a small proportion of university R&D funding. **To avoid this, we believe that funding for basic research should be kept conceptually distinct from funding for applications-oriented research.**

b) The matching-funds policy limits the growth of the granting councils' budgets to predetermined increases in private sector contributions. Should the latter be greater than anticipated, the granting councils could have difficulty finding the necessary matching funds. They could only do so by limiting the growth of their core programs. Within the limits of existing programs and budgets, NSERC will match private contributions dollar for dollar, on average, for specific research projects or chairs. The NSERC policy of returning a bonus to the university (which, starting April 1988, will be 30 per cent of the government's matching funds) for activity outside the council's direct matching programs, may prove to be a strong incentive for increased collaboration.

The major flaw in the matching-funds policy is that it attempts to achieve too much and fails to address the fundamental issue. The objectives of increasing collaboration and joint research between the private sector and universities can be met. It is unrealistic to expect this policy to solve the problem with respect to the quantity and quality of research across all disciplines in Canadian universities, since the granting councils must focus their activities on industrial needs in order to attract the private funding that generates matching government dollars. Thus matching funds cannot serve as a useful basis for setting government policy for financing S&T in universities, especially basic research. It cannot, and will not, provide the support to the community that was originally envisaged.

We recommend that the matching-funds policy of the federal government be reviewed to take into consideration the need for increased funding of basic and generic research in universities. For the policy to be successful, the university R&D base must be in good financial health.

6.4.7 Stimulating University-Industry Relations

We agree that matching funds should be used to extend university-industry collaboration. Joint funding of research projects and research chairs has been used extensively by NSERC since the early 1980s. It is an excellent way to ensure that a portion of the basic research conducted in universities is connected to market possibilities. Joint funding is a sensible way to encourage the private sector to increase its support of basic research and to foster collaboration between universities and industry. Similar policies have been adopted by some provincial governments. They have provided a strong incentive for fund-raising and for building a firm foundation for ongoing activity.

By encouraging the development of consortia, institutes and joint ventures, joint funding helps universities be in closer contact with market dynamics. Ties are created and better circulation of know-how results from joint projects. Joint funding should also respond to the concerns that the granting councils have generally demonstrated little interest in technology diffusion.

It has been argued that the new policy thrust will reduce the funds currently allocated to certain areas and increase support to sectors of greater interest to Canadian industry. This is the objective of the new policy. It will tend to be of greater benefit to certain sectors, such as engineering, applied sciences and certain universities - and that is desirable.

Universities are not good at setting priorities for applications-oriented research. Because of the limited funds available, the resources committed to university research for applied work should not be allocated in an unfocused manner. One of the benefits of a matching-funding policy is that it will reorient a small but significant portion of academic research in a direction that is more closely attuned to Canada's needs and comparative advantages, and avoid the pitfalls usually associated with centralized decision-making.

6.5 Conclusion and Recommendations

The demands made on the Canadian university system by industry and government are high and likely to increase. Much is expected from universities with respect to the diffusion of knowledge. To achieve what is expected, the federal government must adopt consistent policy actions.

For example, the strategy of relying more on universities for collaborative research with industry must be associated with measures to increase the number of qualified researchers in universities. The obsolescence of present research equipment also needs to be addressed. The interrelationship between the three roles of universities must be considered explicitly and dealt with in a balanced manner.

If university-industry collaboration is successful, it will not solve the broader issue of university R&D funding. The federal and provincial governments must therefore maintain their roles as leaders in the funding of university R&D.

We recommend that:

a) **greater emphasis be given to funding generic pre-competitive research collaboration by university-industry in research consortia;**

b) **granting councils and other government agencies pay particular attention to universities involved in regional university-industry collaboration;**

c) **emphasis be placed on the necessity to prepare patent applications and to seek other forms of intellectual property protection as soon as possible prior to publication in Canada and abroad;**

d) **government policy toward patents be changed to vest the ownership of patents and other forms of intellectual property in the university where the** research is conducted or with the researchers involved, reserving for the federal government a royalty-free right to use the intellectual property. Universities should adopt a liberal policy toward the exploitation of university-based R&D, including the vesting of patent rights with university researchers;

e) CPDL be dismantled;

f) intellectual property legislation be amended to allow patenting of life forms and processes;

g) the federal matching-funds policy be reviewed in light of our recommendation to double the budgets of the granting councils over the next three years and to increase budgets at a rate equivalent to 1.5 times the annual rate of growth of the GNP;

h) matching funds made available to NSERC, MRC and SSHRC be used to accelerate the establishment of joint-research agreements between universities and the private sector. The matching funds should be directly proportional to the contributions of the private sector and tied to specific initiatives (i.e., the "project should be matched"). The peer review process should continue as a means of assessing and ranking such initiatives; and

i) teaching and research efforts in the management of technology be significantly increased.

7.0 ENHANCING THE APPEAL OF STUDIES IN S&T

Many Canadians agree that education and research are essential to improving the nation's competitiveness and maintaining its standard of living. However, there is strong evidence that the awareness of Canadians about S&T needs to be heightened. Governments can assume a leadership role, but major efforts can only be sustained if a consensus about the opportunity and advisability of pursuing this policy exists.

To build a social consensus, one cannot rely on any one action or on government advertising programs. Rather, the process must involve consistent actions and the clever use of symbols that typify the desirable direction in the minds of Canadians.

We recommend that the Prime Minister institute a national merit scholarship program for undergraduate students entering science and engineering programs and that additional funding be made available to the three granting councils to make existing postgraduate scholarship programs more attractive to students in these faculties.

At the undergraduate level, we envisage that the new national merit scholarships will be awarded following a national competition, a national examination, and that there should be 2,500 awards given each year, each award being renewable for the duration of the degree program. The scholarships should be transferable as long as the students enrol and pursue studies in mathematics, natural sciences, engineering or computer science. The level of the scholarships should be substantial - we recommend $4,000.

At the post-graduate level, we recommend that substantial increases be made in the post-graduate scholarships offered by the three granting councils. For example, in the case of the awards given by NSERC, we recommend that the stipends be raised from their current level of $11,600 to $15,000 per year for candidates at the master's level, and to $20,000 per year for Ph.D. candidates.

The changes in these stipends will emphasize the government's commitment to ensuring an adequate supply of highly qualified scientists and engineers who will be needed by industry and universities in the future. They will also be a clear message to the best of our undergraduate students in science and engineering that they can play an important role in Canada's economic development by pursuing their studies to the master's and Ph.D. levels.

Establishing the Prime Minister's national merit scholarship program would serve many purposes:

a) It would symbolize Canada's commitment to realigning the national resources, both human and financial, toward S&T activities.

b) It would not only increase awareness of high school and university students about the importance of S&T, but it would also provide powerful incentives to pursue studies in those fields. This is important because the decision of high school students to opt for the science-mathematics stream determines whether they can enter S&T fields at the university level. The choice for one's whole life is made at that early age.

c) Since the results of the national competition would be publicized, they would provide a benchmark for comparing the quality of the output of schools across Canada. The national merit scholarship program would introduce a healthy level of competition between schools and universities across Canada.

Obviously, the national merit scholarship program and the strengthening of the national post-graduate scholarships will not solve all difficulties in the area of S&T. But, they would constitute powerful symbols of the new determination of Canadians to master S&T to enhance the country's competitiveness in the world economy and improve the quality of life. And, in the end, a national consensus is built with such symbols.

NOTES

Chapter 2

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2. Robert Solow, "Technical Progress, Capital Formation and Economic Growth," *American Economic Review* 52, no. 2 (May 1962).

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Chapter 3

1. Cardinal Newman's *The Idea of the University*, a much-reprinted work, is recognized as a seminal work on the modern conception of the educational role of universities, especially on the training of the mind.

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3. Herbert I. Fusfeld, *The Technical Enterprise* (Cambridge, Mass.: Ballinger, 1986).

4. The notion of universities as agents of progress began in the social sciences, but it has also spread to the natural sciences over the past half-century. See Alfred North Whitehead, *The Aims of Education* (London: Williams & Norgate, 1929); and Clark Kerr, *The Uses of University* (Cambridge, Mass.: Harvard University Press, 1963).

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6. W. Henry Lambright, *Governing Science and Technology* (New York: Oxford University Press, 1976); "Towards the Multiversity," *Economist* (11 July 1987); and Organization for Economic Co-operation and Development, *Universities under Scrutiny* (Paris: OECD, 1987).

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Chapter 4

1. Statistics Canada, *Education Statistics Bulletin*, Cat. no. 81-002 (May 1986).

2. UNESCO, *Statistical Yearbook* (Paris, 1986). These figures are based on 1983 data. The definitions and classifications of statistical information used by UNESCO differ from those used by Statistics Canada. As a consequence, there may be differences between the two sets of figures. However, the figures provided by UNESCO are useful in that they permit international comparison on a standard basis.

3. Based on information provided to the University Committee by the Association of Universities and Colleges of Canada.

4. UNESCO, *Statistical Yearbook.* Figures based on 1983 data for Canada and Japan, and on 1982 data for the United States.

5. National Science Board, *Science Indicators* (Washington, D.C., 1985).

6. Fifty-two per cent of full-time Ph.D. candidates in engineering and applied sciences are foreign students who, in all likelihood, cannot stay in Canada after they graduate. Foreign students represent around 30 per cent of Ph.D. enrolment in other disciplines. See Statistics Canada, *Science and Technology Indicators, 1986.*

7. Conference Board of Canada, *Research and Development in the Canadian Corporate Sector* (Ottawa, 1987).

8. Economic Council of Canada, *Innovation and Jobs in Canada* (Ottawa: Supply and Services Canada, 1987).

9. The summer research fellowships offered by MRC and NSERC have a strong influence on the recipients' later decisions to undertake graduate studies and a career in research. See *Medical Research Council Newsletter* (July 1987).

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Chapter 5

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