Science Council of Canada
Conseil des sciences du Canada

Report 39

Winning in a World Economy

University-Industry Interaction and Economic Renewal in Canada

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April 1988

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April 1988

The Honourable Frank Oberle, PC, MP
Minister of State for Science and Technology
House of Commons
Ottawa, Ontario

Dear Mr Oberle,

In accordance with Section 13 of the Science Council of Canada Act, I take pleasure in forwarding to you the Council's Report No. 39, *Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada.*

Yours sincerely,

Geraldine A. Kenney-Wallace
Chairman
Science Council of Canada

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Prologue

The twin themes of striving for excellence in science and technology and seeking international competitiveness, long discussed by mavericks in the corridors of university research laboratories, over boardroom tables and in trade associations, have finally bubbled up into the wider public policy arena in editorials, business periodicals, and scholarly debate. However, the rhetoric sometimes outstrips action, and we must not be misled into thinking that the issues of technological excellence or competitiveness are about to be comfortably resolved for Canada. There is still an urgent economic and social imperative underlying the international clarion calls for linking science and technology to economic renewal. But the arguments are especially persuasive when put into specific context for Canada, and that is the goal of this prologue.

Canadians are still struggling economically, intellectually, culturally, and spiritually for a new paradigm as the 21st century beckons. If we are a polity of "peace, order and good government" in search of a nation, then within that polity the science and technology community has been many actors in search of a single script. At the present time, over four years after this Science Council project was first conceived, such a script is beginning to emerge and the roles of the actors are being questioned, reaffirmed, or redefined. For too long there has been a confusion of roles, an absence of lead players with national goals, and competing economic and social objectives. This has meant, among other things, that we have not been able to use our scientific and technological strengths and comparative natural advantages to build an indigenous and vigorous R&D base within the industrial sector. As a consequence, our R&D performance in the private sector is only a pale shadow of that in other industrialized countries.

Let us not debate the reasons any longer. Let us focus instead on the urgent need to find a mechanism to redress the situation. Strategic partnering between university and industry is one such mechanism. What we need are not quick-fix solutions but a coherent and constructive long-term strategic plan, which will unfold over the years regardless of changes in political mandates and institutional leadership. This national plan must have as its goal the development of the sustained intellectual and economic competitiveness so crucial for prosperity in a global economy. Simply stated, we must focus on wealth creation, because without it we cannot afford the social values that distinguish Canada as a caring society.

The underlying theme of this Science Council report is that to compete internationally we must cooperate nationally. We need to integrate people, ideas, opportunities, markets, and capital in new and effective ways. The most urgently needed linkages are those between the research community within the universities and the private sector. A new sense of strategic partnership must become a reality. If our goal for

the 21st century is to have built in Canada a vigorous R&D base within the industrial sector, by revitalization and diversification of our existing and mature industries, and by creating spin-off firms and more advanced high-technology industries, then we have no option than to put our science and technology to work.

For the university, this is a call to intellectual arms. The most valuable resources for economic renewal are people with the knowledge of frontier science, technology, and technology management, who operate on broad horizons, and who can cross the usual discipline boundaries. To do the unexpected requires a champion with a vision. To be competitive is to be intellectually and economically strategically positioned to accomplish that vision. To put visions into reality requires a clear and factual understanding of where we were, where we are now, and where we wish to be. Only then can the mechanisms be conceived and made fully operational, and the individual or collective commitment to action through those mechanisms be linked to the consequences of success and failure. The onus is on our scholars to transfer ideas and results from the laboratory and the library to the national and international marketplace, and on the private sector to build upon this knowledge bank.

In 1988, science and technology, research and development blend naturally with news on the business pages of newspapers around the world, and policies and programs have begun to appear, their roots linked to the imperative for economic renewal. Universities are moving to assess their missions and mandates for the future, conscious of the new directions and enormous challenges ahead to identify and build upon their desirable differences and intellectual strengths. Whether in centres or networks of excellence, cooperative education programs or interdisciplinary research projects, the research-innovation interface is rapidly expanding. Still, much remains to be done as the facts clearly show.

During the past four years the Science Council has held workshops on numerous aspects of university-industry linkages as they relate to international competitiveness. This final synthesis is our contribution to a national science and technology script that is finally beginning to emerge in Canada. If you believe the report's message to be self-evident, you are probably one who has helped us to write it, through participation in our workshops or contributions to the discussion papers on university-industry linkages. If you find the message to be a revelation, then we urge you to take personal action to help make the research-innovation interface between university and industry a viable, vigorous reality, and to make it one that builds mutual respect for complementary objectives in such partnerships.

Science is international and not linked to geographical or ideological borders. The creative tension between discovery and invention, and

theory and practice, has shaped societies since the time of Plato, and at the turn of the century this was the subject of great debate in Canada. It is time to move beyond abstract debate over whether the changes in relations between university and industry are a distraction or part of the university's destiny. We believe that destiny includes closer university-industry interaction and, if wisely handled, the consequences will not distract from the essence of scholarship and learning. But we must move to action. It is imperative that the university's knowledge be put to work for winning in a world economy.

Geraldine A. Kenney-Wallace
Chairman
Science Council of Canada

Introduction

Today, knowledge and people are crucial resources in the growth of a nation. Natural resources can no longer be the singular fuel for the economies of the industrialized world. We must realize that global competition for trade is tougher than ever before and that the long-term economic outlook is not good for Canada - a nation whose main exports are bulk commodities and whose main imports are finished goods. But we do not have to concede the battle to remain a competitive industrialized country. It is possible for us, by building on our intellectual strengths and comparative advantages, to restructure our industry and compete successfully on world markets.

Universities can help countries to compete in the new world economy. They can do this not only through their traditional activities of creating and disseminating knowledge but also through forming imaginative and effective linkages with industry. In recent years all industrialized countries have moved to put more emphasis on cooperation between universities and industry. They have done this for the following reasons:

- The conviction is spreading that vital national economies depend on all sectors of society acting together.
- Advanced technology is now viewed as necessary to avert economic and subsequent social crisis brought on by growing global competition.
- The commercial value of certain fields of science is growing. (For example, in many countries the central role of microelectronics in current technological change coupled with the potential of biotechnology and the strong, direct dependence of these fields on universities have ensured a prominent position for universities in discussions on meeting economic challenges.)
- In order to be competitive a nation must cut down the time between discovery and application by finding more efficient mechanisms to deliver discoveries to the marketplace.

Canada's need for linkages is especially great. Our country has relied upon natural resources and has a weaker industrial R&D capability than most of its competitors. A larger proportion of its research is done in universities than is the case in other countries, reflecting the low level of industrial R&D. Almost 25 per cent ($1.7 billion in 1987) of total Canadian R&D is performed by universities.[1] Hence it is especially important to move the results of that R&D into Canadian industry. This is why the Science Council decided to focus this study on the role of universities in economic development.

In Canada, links between universities and industries go back to the 19th century, but never have they been taken as seriously by both universities and industries as they are now. They are proliferating

rapidly. In addition to a dramatic rise in the incidence of more traditional forms of collaboration, such as consulting and research contracts, many new ways of linking universities and industries are being experimented with: university offices for technology transfer, university science parks, and university advanced technology training centres are some examples. And these are supported by many new government programs that promote interaction. Despite this activity, the overall level of university-industry interaction is, in the Science Council's view, still lower than it should be. For example, even if research sponsored by industry were to double overnight, it would still not amount to more than 8 per cent of university R&D.

Calls for greater university involvement in the economy have come at a time when Canadian universities face many problems, many of which have been aggravated by the financial restraint that has confronted universities for more than a decade. These problems include preserving accessibility and autonomy, the full-cost financing of research, maintenance of high academic standards, upgrading of facilities and equipment, support of graduate students, an ageing professoriate and too few opportunities to hire young faculty, and the preservation of public confidence. Critics of university-industry interaction have argued that these problems are more important and should be dealt with first. Some believe that universities should wait for improved funding before taking on the additional challenge of economic renewal. But the Science Council believes that university interaction with industry should not wait for the solution of these problems. Even if they were resolved, if there were sufficient funds for current university activities, the economic challenge facing Canada and its implications for the country's universities would remain. The issue is too important for Canada's future to be relegated to a secondary position. Determining how universities can more effectively contribute to the economic renewal of Canada must be one of the key touchstones in deliberations about responses to all the challenges facing Canadian universities. The consequences both for Canadian universities and for the nation of not giving a high priority to this issue will be grave.

Because of the social and economic significance of university collaboration with industry, the Science Council decided to undertake a major project that approached the subject from a broad science and technology policy perspective. *Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada* is the final report of that project.

The project began in 1984 with the striking of a committee to look into university science and technology and Canadian economic renewal. The committee quickly discovered that despite all the talk

about university-industry collaboration, little documentation existed about its forms, extent, problems, successes, or implications. A research program was therefore established to review the state of some important forms of linkage in Canada. Because of the special importance of university-based research in this country compared to other industrialized nations, the program focused on the university end of linkages, and the changes required there. It examined both research and educational linkages, because both are important to industry. Eight discussion papers and workshop proceedings were prepared for the committee and published by the Science Council during 1986-87:

- *University Offices for Technology Transfer: Toward the Service University;*
- *University Spin-Off Firms: Helping the Ivory Tower go to Market;*
- *University-Industry Research Centres: An Interface between University and Industry;*
- *Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities;*
- *Postsecondary Cooperative Education in Canada;*
- *The Teaching Company Scheme: A Study of its Application in Canada;*
- *R&D Links between Firms and Universities: Six Case Studies;* and,
- *Learning from Each Other: University-Industry Collaboration in the Continuing Education of Scientists and Engineers.*

All these discussion papers concentrate on linkages involving science and engineering, partly because of the mandate of the Council and partly because linkages are more developed in these areas than in the humanities and social sciences. However, the Council believes that the importance of university-industry linkages in the humanities and social sciences is growing and that these linkages will be more in demand as Canada's economy becomes more dependant on research-intensive industries. A review of linkages involving the humanities and social sciences was published in 1988 as a discussion paper entitled:

- *University-Industry Interaction in the Social Sciences and Humanities: A Threshold of Opportunity.*

Universities are only one part of Canada's higher education system. Community colleges are important though often overlooked, especially in discussions of higher education relations with business. An overview of the contributions of the colleges as a counterpoint to the project's examination of universities was published in 1987 as:

- *Employer Interaction with Public Colleges and Institutes in Canada.*

The important contribution the colleges can make to the economy is also being highlighted by the "Making Canada Productive" project of the Association of Canadian Community Colleges.

The efficiency, effectiveness, and implications of linkages are difficult to judge. But it is clear that there can be no one blueprint: each university must develop its own set of linkages based on its perceived mission, its resources, traditions, goals, and external environment. Furthermore, such interaction is only one facet of the university's mission.

University interaction with industry is a balancing act. Universities should no more be harnessed to industry than they should be isolated ivory towers. It is on the ground between these two extremes that various forms of linkage are flourishing and new ones are appearing. This final report of the Science Council's study of university science and technology and Canadian economic renewal aims to further understanding of how mutually rewarding linkages may be fostered in universities. The Council hopes the report will contribute to the development of more effective university-industry interaction and suggest to faculty, senior university administrators, and their industrial counterparts desirable directions for new linkages.

1

The Challenge of Change: Keeping Canada Competitive in World Markets

Canada now confronts a world economy that is moving to a new plateau of knowledge-intensiveness. The world economy is becoming saturated with resources and low technology goods but its capacity to absorb services and high technology goods is still growing. A variety of indicators show that the Canadian economy like other industrialized economies is moving from tangible output to increasingly intangible output.

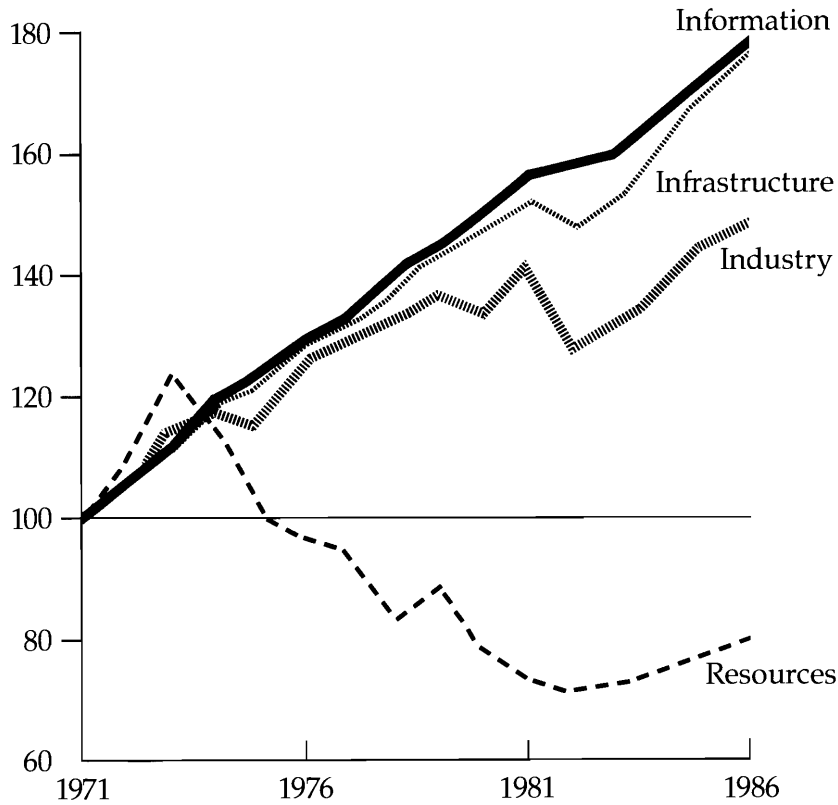
Figure 1 shows that the information and infrastructure sectors of the economy each increased by 78 per cent during 1971-86. That is three times the growth rate of goods production.[2] "The production of goods is a less and less important part of what Canadians do for a living. It has been a declining share of the economy for much longer than most people think."[3]

Figure 2 indicates that in recent years economic growth has come from service industries and high technology manufacturing. In contrast, resources (comprising over 40 per cent of Canada's economy) have generated limited growth. And, as Figure 3 notes, not only economic growth, but growth in employment has come from tertiary industry. These three figures paint a picture of an economy in which human intelligence is an increasingly important component of production costs.

In such an economy technological innovation in both service industries and goods-producing industries is more than ever the key to improving economic performance. It is the engine of economic growth. To maintain competitiveness Canada must use new technologies to revitalize mature industries and generate new high-technology industries.

But although Canada's economy is changing, there are indications that it is not doing so rapidly enough. Although high tech goods are becoming an increasingly important segment of international trade and Canada is both importing and exporting more such goods, our balance of trade deficit in this area is growing (Table 1).[4] Our industrial technology appears to be relatively underdeveloped compared to that of other advanced countries - indeed, the graphs in Figure 4 need different vertical scales to display changes in national trade balances.[5] Furthermore, the ability of Canadian businesses to adopt and adapt

Figure 1: Real Growth Rates of Share of Gross Domestic Product

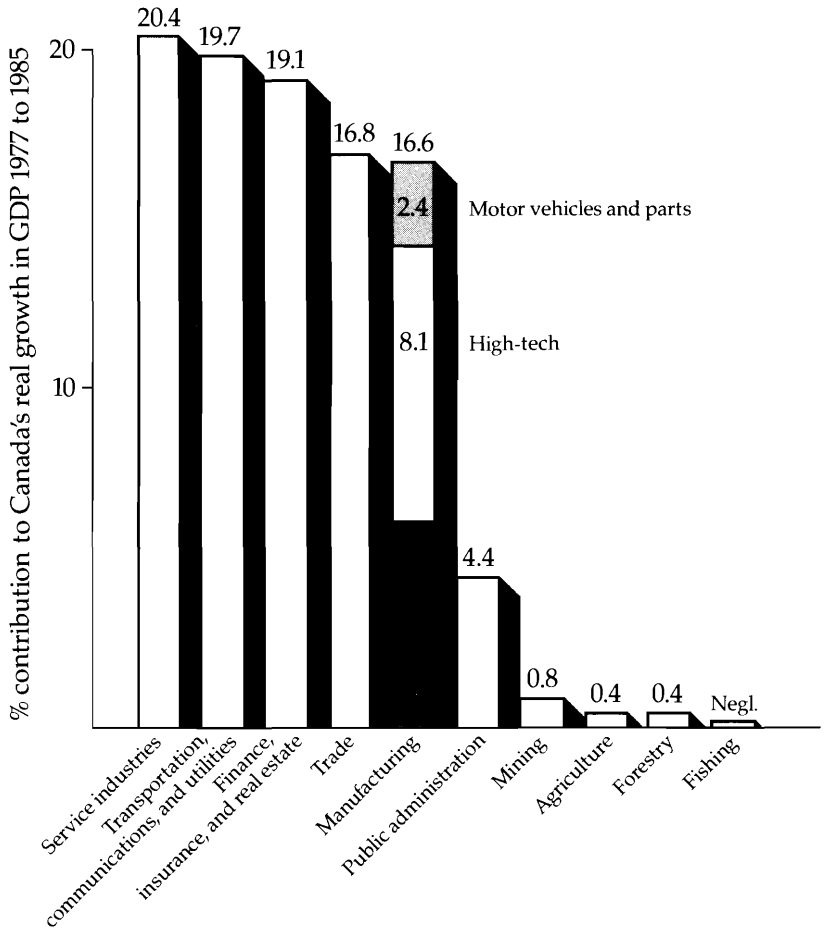


Source: "How to think about the economy, Part 3, "*John Kettle's FutureLetter* (30 April 1987). Note: "Information" consists of those sectors whose final output is some kind of information; "Infrastructure" is the service activities whose main job is to support the rest of the economy; "Industry" is manufacturing and construction; and "Resources" comprises both renewable and nonrenewable resources.

new ideas and processes quickly and effectively leaves much to be desired (Figure 5).[6] Canada gets poor ratings for innovation.

The increasing economic importance of advanced knowledge and technology challenges our country's R&D system. That system needs to be healthy and to provide the necessary technological innovation. It needs to be amended so that the transfer of knowledge and technology is optimized, so that links between its parts are developed and strengthened, and so that research results are exploited more quickly. Where necessary, governments and universities should help industry

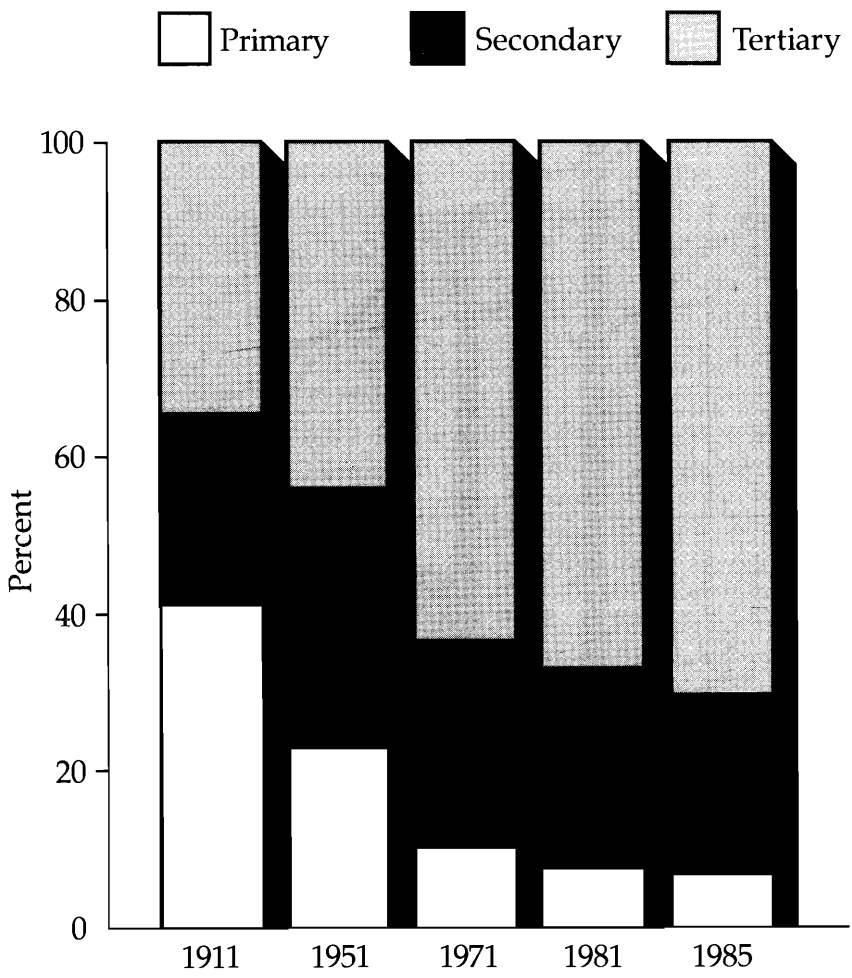
Figure 2: Source of Canadian Economic Growth, 1977-1985



Source: Canadian Advanced Technology Association, *The Report of the National Technology Policy Roundtable* (Ottawa, n.d.), 14.

to acquire the technology and knowledge it requires. The system has to find better ways of acquiring foreign knowledge and technology: acquisition calls for a "smart importer" philosophy based on science and technology know-how.

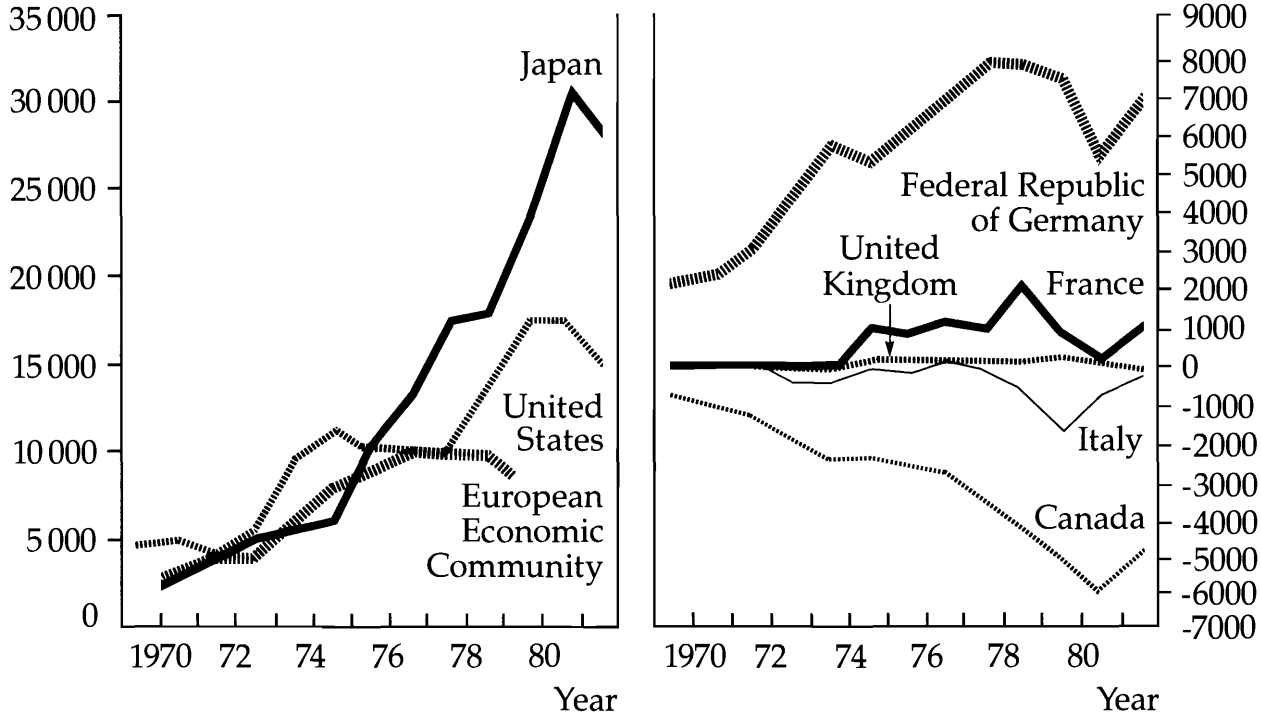
Figure 3: Employment Patterns, by Industry Sector, Canada, Selected Years, 1911-1985



Source: Economic Council of Canada, *Innovation and Jobs in Canada* (Ottawa, 1987), 5.

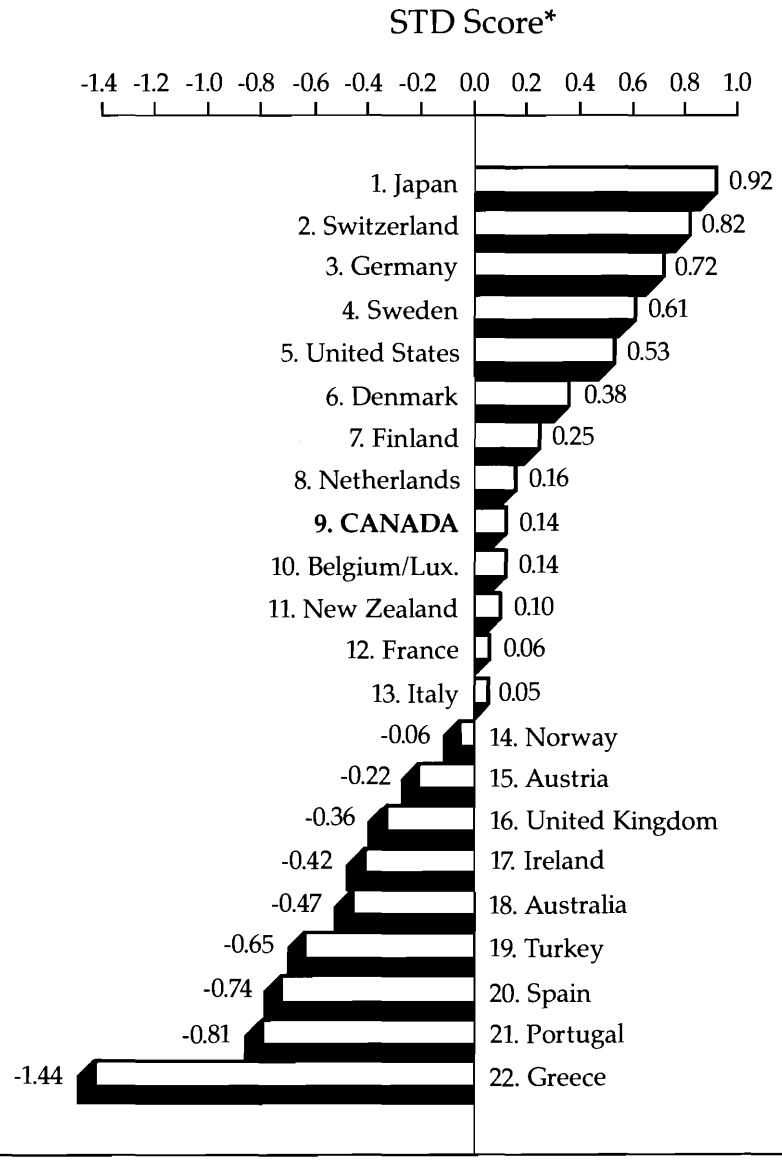
Knowledge-intensive economies require a strong educational base, one in close touch with the needs of the economy. Canadian industry, like its counterparts internationally, is reassessing its commitment to R&D and realizing the need to make full use of the R&D system in Canada. Consequently, universities, as an important part of that system, are being called upon to play a greater role by improving their collaboration with industry through both research and education.

Figure 4: Trade Balance of Highly R&D Intensive Industries by Country ($000 000s)



Source: Ministry of State for Science and Technology, *Science, Technology and Economic Development: A Working Paper* (Ottawa, 1985), 38.

Figure 5: Forward Orientation. This indicator measures the commercial sector's ability in long-range planning and flexibility in adapting to change. It covers criteria related to the development of technology and its role in fostering competitiveness.



Source: Joseph R. D'Cruz and James D. Fleck, "The 1986 EMF Scorecard on Canada: Mixed but Encouraging," *Business Quarterly* 51:2 (Summer 1986), 85.
*The STD Score measures the competitiveness of a country compared with all the other 21 OECD countries in the study.

Table 1: Balance of Trade in "High-tech," Natural Resource, and Other Manufactured Goods, 1978-1986 ($000 000)

Year	"High-tech"	Natural resource	Other
1978	-2 990	14 263	-6 960
1979	-3 785	18 236	-10 026
1980	-4 611	22 423	-9 034
1981	-5 447	22 530	-9 791
1982	-4 232	26 088	-4 034
1983	-5 097	27 749	-5 004
1984	-6 382	31 400	-4 292
1985	-6 368	31 256	-7 413
1986	-7 011	27 714	-10 520

Source: Statistics Canada, Science, Technology and Capital Stock Division, "International Trade in 'High-Tech' Products 1978-1986," (Ottawa, 1987), 18.

Canadian universities are going to have to play a more direct role in maintaining the international competitiveness of the Canadian economy. They are, of course, only one part of the solution to our economic problems. Other educational sectors, all levels of government, and especially industry have roles to play. Universities, however, are a necessary factor in renewal. To meet the challenge, some basic changes will be needed in the university and in its relationship with industry.

If Canada is to prosper and the university is to flourish, the status quo is not an option. Economic renewal and intellectual renewal are inextricably linked.

2

The Canadian University in a Knowledge-Intensive Economy: An Active Role

Challenges Facing Today's University

Calls for greater university involvement in the economy come at a time when Canadian universities face many problems. These stresses on the university have been compounded by financial restraint. Table 2 shows that in Canada, as in many other countries, enrolments have grown faster than public expenditures on higher education.

Table 2: Growth of Enrolments and Real Public Expenditure on Higher Education between 1970 and 1983

Country	Expenditure[a]	Enrolment
Austria	49.4%	157.8%
Canada	**3.9**	**62.2**
Denmark	-7.0	45.7
Finland	104.4	100.7
France	-25.0	47.2
Germany	29.9	179.0
Italy	24.2	49.8
Japan	27.6	31.5
Luxembourg	46.8	159.9
Netherlands	21.6	64.6
New Zealand	-7.7	35.0
Norway	43.0	64.9
Sweden	-29.9	53.2
United Kingdom	-4.8	42.8
United States	13.6	46.2

Source: Organization for Economic Cooperation and Development. *Costs, Expenditures and Financing: An Analysis of Trends*, ED(86)10, 1986, 163.
[a] Adjusted using OECD educational expenditure deflators.

Canadian universities must cope with dwindling resources as governments attempt to control public spending, and at the same time cope with demands for greater accountability as groups outside the university try to inject their own agendas. The result is a paradox. Universities appear to be in decline at the same time as the public is attaching a growing importance to them and challenging them to change.

Despite the clear evidence of financial need, solving the problems facing Canadian universities requires more than financing. Statistics show that Canadians are already spending a higher percentage of gross domestic product on higher education than most other countries (Table 3). If more money is to be directed to universities, first universities and those who fund them should address a deeper problem of the institution, "a more generalized malaise of purpose."[7]

Table 3: Public Expenditure on Higher Education as a Percentage of Gross Domestic Product (GDP)

Country	Percentage of GDP
Australia	1.58
Austria	0.77
Canada	**2.00**
Finland	0.89
France	0.69[a]
Germany	0.59
Italy	0.53
Japan	0.41[a]
Netherlands	1.76[a]
New Zealand	0.11
Norway	0.79
Sweden	0.62
United Kingdom	1.09[a]
United States	2.49[b]

Source: Based on *UNESCO Statistical Yearbook 1986*, Paris, Table 4.3.
[a] Data from 1982
[b] Data from 1981

Our universities, in the opinion of many Canadians, are not wholly suited to the current and emerging needs of the country. They now face "the challenge of adapting rapidly enough to survive the conditions that they themselves, through the advancement of knowledge, have created."[8] A gap is perceived between external expectations about the university and internal practices. Many critics of the university believe it is isolated from the needs of society, not only the technological and economic needs with which we are chiefly concerned in this study, but also social, political, and other needs. The education students receive, for example, is said to focus narrowly on a single discipline, leading to a cloning of professional academics, instead of incorporating the knowledge that students need for life in an increasingly complex world. Similarly, it is claimed that the evaluation of faculty performance is skewed toward disciplinary research, resulting in university research that is too inbred. Many Canadians believe

that their universities are not playing as significant a role in society as they could.

It is this sort of criticism that has contributed to the malaise of purpose within the university, raising a number of tensions: knowledge for its own sake versus knowledge as a means to improve society, autonomy versus accountability, the ability to preserve existing strengths versus calls for new areas of activity, and individual academic freedom versus institutional planning and management. In resolving these tensions, determining how the university can contribute more effectively to Canadian economic renewal must be a key consideration.

The Science Council's project on university-industry interaction and Canadian economic renewal has described in a series of publications some of the new linkages between universities and industry. On the basis of this documentation and bearing in mind the university's strengths in liberal education and fundamental research and the need of society for these functions, the Science Council sees an expanded and challenging role for universities in our knowledge-intensive economy.

An Expanded Role for the University in a Knowledge-Intensive Economy

Transferring Knowledge and Technology

Knowledge and technology transfer becomes an increasingly important university activity as we move toward a more knowledge-intensive economy. This report takes "knowledge and technology transfer" to mean interaction between the university (faculty, students, and/or administration) and industry or the community, aimed at the effective assimilation of intellectual property held or developed in the university. The word "knowledge" is included in the term "knowledge and technology transfer" to indicate that the report does not take technology to mean simply artifacts, for example, tools or instruments, nor merely the products of science and engineering. Technology is understood also to be a body of knowledge of "techniques, methods, and designs that work, and that work in certain ways and with certain consequences, even when one cannot explain why."[9]

The culture of the university in a knowledge-intensive economy has to be one in which the interests and concerns of the marketplace are prominent. Universities need to engage in knowledge and technology transfer that is oriented to wealth creation and responsive to social needs both to a greater extent than before and in new, more direct ways. The essence of transfer activity is that it is useful to those

outside the academic milieu.

Canadian universities are already involved, in a limited way, in knowledge and technology transfer although that term may not be used. The extent and effectiveness of this transfer activity is indicated by the presence of such forms of university-industry linkage as the interchange of personnel with industry or government, research or consulting contracts, patents and licences, university spin-off firms, cooperative education, continuing education courses for firms, technical entrepreneurship courses, and university-industry research chairs and centres. Through these linkages universities can measure how successfully they are transferring knowledge and technology to industry. Some of these linkages are described in a series of Science Council background papers that are summarized in the appendix of this report.

Knowledge and technology transfer is more than simply a label for a collection of university activities. It expresses the direction for Canadian university development in the coming years. Universities that do not follow this path risk losing opportunities and people.

The Transfer Function as a University Priority

Priority among university activities is now usually given to fundamental research and to teaching full-time students. However, calls for closer university-industry relations have served as a reminder that these activities do not completely fulfill the university's mission. Some Canadian universities have already recognized the need to emphasize the importance to the university of a more complete mission. With respect to research, for example, the University of Guelph in its recent mission statement acknowledges the full spectrum of research from fundamental through developmental, in reasonable balance, as appropriate and desirable activities for its researchers.[10] All Canadian universities have a responsibility to do more than conduct fundamental research and teach full-time students.

Universities will have to develop clear, broad, and flexible mission statements. Each statement should include the customary components of the university's mandate: teaching, research, and service (which subsumes knowledge and technology transfer). However, each should also reflect the special strengths that individual universities have achieved and the priorities that they have set for themselves. As a result, desirable differences among universities will be reinforced as each institution strives to fulfill its potential. In the United States and Europe different emphases in the missions of universities have led to a rich array of teaching and research institutions.

The transfer of knowledge and technology to industry, which is

but a reorientation of teaching and research, has to be widely recognized as a legitimate university activity and given a high institutional priority. The willingness of Canadian universities to make it a priority will, in turn, be the most important factor in determining the success of linkages.

Implications for the University

A greater emphasis on transfer activities will have major implications for the university. A recent book by two distinguished scholars of higher education, Ernest A. Lynton and Sandra E. Elman, shares many of the Science Council's views on what the new university will be like. It outlines the changes as follows:

> The "new" university is an institution less clearly delineated than the traditional one; it is more closely interrelated with its surroundings, and it is in fact a part of the context in which it operates. It is extended in terms of its student body, which can no longer be uniquely defined in terms of age and full- or part-time status, or even in terms of whether they are matriculated degree candidates or not. The new university is extended as well in terms of its instructional objectives. It focuses on developing and maintaining a kind of competence that requires more than narrow technical expertise, more than abstract theory. Instruction in the new university encompasses practical experiences as an integral part of the curriculum and focuses as much on generalizing from the particular as it does on the more traditional mode of deducing specific applications from broad principles. Its faculty will include practitioners who have learned to incorporate their experience into a theoretical framework, and conversely it will ensure that its academically trained professors will have opportunities for first-hand practical applications of their theoretical knowledge. And, most importantly perhaps, the extended university as a whole will define its scholarly and professional responsibility so as to give equivalent weight, value, and prestige to the entire range of professional work, from basic, nondirected research through applied work to technical assistance and public information.[11]

The "new" university will play a greater role in local concerns and development. The "new" professors will need to rethink their profession. They will be engaged in a greater mix of activities than is now usual and will not only need to be experts in a discipline but also to be aware of its relations with other disciplines and applications. The "new" programs will be more multidisciplinary and more oriented

toward the concerns of the world outside the university. And, in addition to the traditional type of student there will also be, in large numbers, "new" students who will be older, possess more work experience, and be in attendance part-time often taking non-credit courses to upgrade or update their skills.

Although many universities perform some form of interaction with industry, there is not yet a university such as we propose. In the "new" university that is needed for Canada's emerging knowledge-intensive society, the present ways of teaching and performing research would not be displaced so much as reoriented. The essence of this university would be rigorous, critical, and thoughtful enquiry in a dynamic, integral relationship with society.

Seeking a Balance in the University's Activities

In recognizing the transfer of knowledge and technology to industry as an integral and valued university activity, the university must ensure a balance and mutual reinforcement among its functions. Teaching and research should not be totally oriented toward meeting social needs or the present-day needs of the economy. A balance is necessary between those needs on the one side and, on the other, the value of a liberal education and of advancement of knowledge for its own sake. Neither can any university be expected to address all of the problems or opportunities presented to it. The institution and its faculty have to set priorities. Furthermore, the requirement to transfer knowledge and technology for wealth-creation does not merely apply to the university's science and engineering departments. Society in a knowledge-intensive economy has a great need for the knowledge available in the humanities and social sciences. All parts of the university must explore how they can fulfill the institution's mission.

Some risks are involved in giving greater importance to the transfer function of the university. But the greatest danger to the Canadian university is that it will not search for ways to fulfill its mission that are suited to the needs of the knowledge-intensive economy and society. Universities must continue to evolve and play a more active role in Canadian society and the economy. If they do not change, their role will diminish as alternative ways are found of obtaining the teaching and research that are required by those outside the university milieu. Collaboration with industry, far from being a distraction, is a necessary part of the university's destiny.

3

The University's Role in the Economy Is Already Changing

A Quantitative Overview

Dramatic increases in sponsored research, faculty, and enrolments, and growing university-industry interaction are evidence that Canadian universities are beginning to respond to the needs of an emerging knowledge-intensive economy.

Sponsored Research

University R&D in this country is concentrated in relatively few institutions: 15 per cent of institutions carry out 75 per cent of the R&D. Sponsored research[12] at Canadian universities increased by 166 per cent between 1975-76 and 1982-83 (Figure 6) to reach $665 million (current dollars) in the latter academic year.[13] Sponsored research experienced one of the highest rates of increase of any of the sources of university income.[14] As a percentage of total university expenditure, sponsored research has gone from 9.5 per cent in 1975-76 to 12.0 per cent in 1982-83.[15] Universities in Ontario and Quebec perform the bulk of sponsored research with 41.8 per cent and 24.7 per cent respectively.[16]

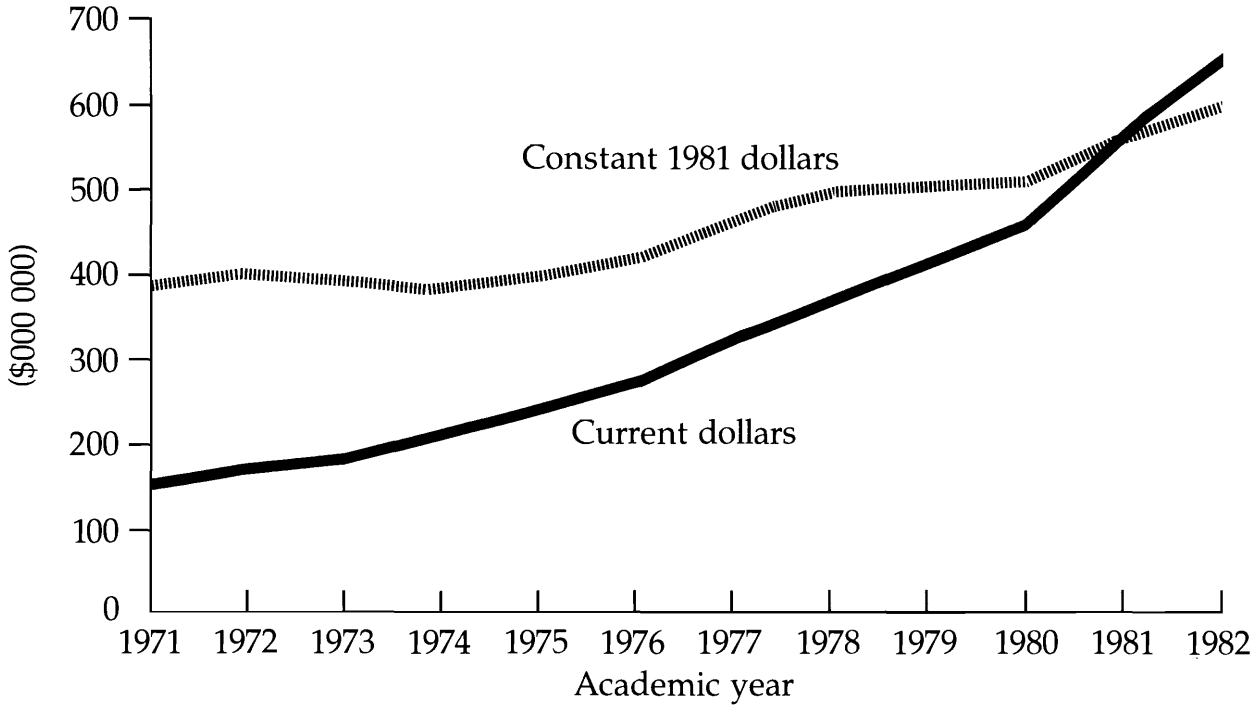
Canadian universities perform a significant amount of Canada's R&D (Figure 7). This share is relatively large compared to the share in other countries, reflecting Canada's poor industrial R&D performance. For example, in 1983, Canada spent 24.7 per cent of its gross expenditures on R&D in the higher education sector, whereas the corresponding figure for the United States was 13.4 per cent, West Germany 15.6 per cent, France 15.8 per cent, and Japan 23.0 per cent.[17] Given this significant capability in university R&D, the transfer of its knowledge and technology to the private sector is crucial.

Faculty

The number of faculty at Canadian universities[18] rose by more than 42 per cent between 1970-71 and 1984-85 to reach 34 925 full-time faculty.[19] They form a strong reservoir of expertise upon which Canada can draw.

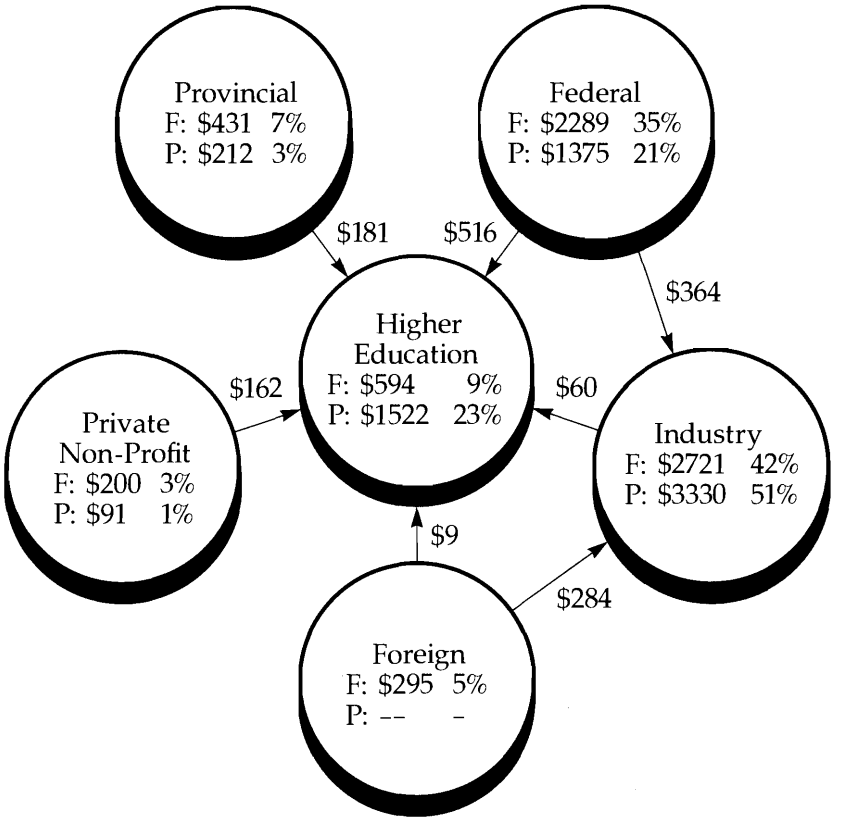
We do not know much about the actual allocation of working time by Canadian faculty. Presumably it is much the same as in the United States. Analysis of a recent survey of American doctorate granting institutions indicates that research and development accounts for 31 per cent of the total time that science and engineering faculty spend

Figure 6: University Sponsored Research Expenditures



Source: Statistics Canada, *Financial Statistics of Education, 1982-83* (81-208) (Ottawa: 1987), 71.

Figure 7: Higher Education within the Canadian R&D System, 1985. R&D (in the Natural Sciences, Engineering, Humanities, and the Social Sciences) Financed (F) and Performed (P) in Each Sector ($000 000)



Source: Statistics Canada, *Estimates of Canadian Research and Development Expenditures by Region, 1979 to 1985* (Ottawa: 1987), 9.
Note: Total research and development expenditures were $6530 million in 1985 of which $516 million went to the humanities and social sciences.

on professional activities.[20] Another survey, which included members of the social science, natural science, and engineering faculties, estimated that 24 per cent of their time is spent on research.[21] The balance of their time is spent on teaching (39 per cent), public service (19 per cent), and on professional enrichment and remunerative outside work (18 per cent).[22]

Enrolment

Reflecting in part the knowledge requirements of the economy, the demand for higher education continues to increase. Full-time enrolment mushroomed in the 1960s. Although enrolment slowed somewhat in the 1970s (declining briefly between 1977 and 1979), levels continued to rise in the first half of the 1980s (Figure 8). In 1985-86 full-time enrolment reached a high of 467 287, representing an increase of 26 per cent between 1975 and 1985.[23]

Full-time enrolment within the 18-24 year age group has risen from 6.7 per cent in 1960 to more than 14 per cent in 1985.[24] However, as a percentage of total university full-time enrolment, this age group has been declining. It formed 77 per cent of the full-time university population in 1985.[25]

Of special significance is the strong growth in part-time and non-credit enrolment. Between 1975 and 1985 part-time enrolment increased by 53 per cent, double the rate for full-time enrolment.[26] This growth was most strongly felt in the fine arts, health professions, and the mathematical/physical sciences.[27] In 1985, 77 per cent of part-time enrolment was formed by students who were 25 years old and older.[28]

Non-credit courses have become increasingly popular as part of continuing education programs. In the 1982-83 academic year, 19 per cent of all students at universities were enrolled in part-time, non-credit courses.[29]

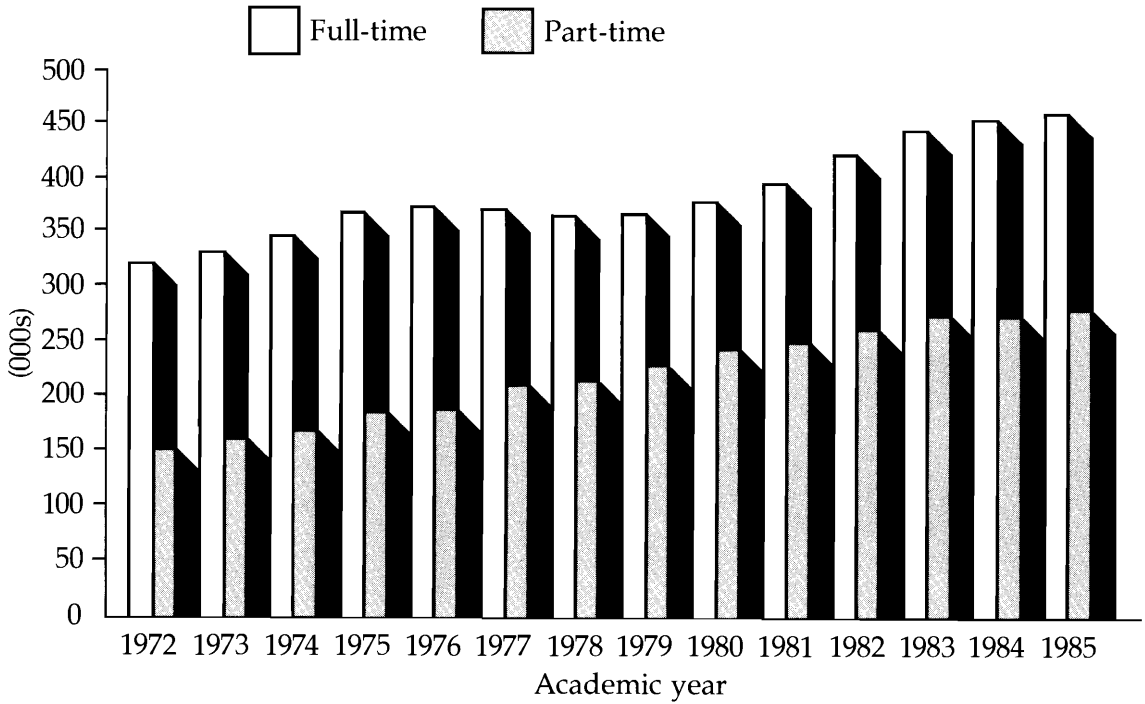
A growing percentage of graduates are finding employment in the private sector. Data from Ontario indicate that 51.3 per cent of graduates in 1982 were employed in the private sector; this had risen to 54.1 per cent in 1985.[30] The balance of the graduates found jobs in the public sector, including public administration, crown corporations, as well as government-sponsored educational, health, and other services.

University-Industry Interaction

There are few statistics on the relationship between universities and industry in Canada. Some data, however, are available, mostly for collaboration involving research. Figures from Statistics Canada, for example, show that private support to universities was $305 million in 1982-83,[31] with about half of this estimated as coming from corporations.[32] Universities spent a total of $5130 million that year.

Business support for R&D was $60 million in 1985 or 3.9 per cent of the total R&D funding available at Canadian institutions of higher education (Figure 7). This estimate of funding by Statistics Canada can be compared to numbers derived by the Corporate-Higher Education Forum, which indicate that industry contributed $49.1

Figure 8: University Enrolment, Part- and Full-time



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

million toward Canadian university R&D in 1984.[33] The forum found that approximately two-thirds of this amount came from subsidiaries of foreign companies. The $49.1 million can be divided into $19.1 million of "directed" support (project-related contractual research) and $30.0 million of "non-directed" support (for example, funded chairs, grants, scholarships, equipment). Directed support comes primarily from Canadian-controlled companies, whereas non-directed is given primarily by foreign-controlled companies.[34]

There are distinct asymmetries between the methods used to record industrial support for universities in Canada and those in other countries. This, coupled with the difference in general philosophy toward the funding of universities, makes intercountry comparisons difficult. If these caveats are kept in mind, however, data from other countries may be used as a rough gauge of the situation in Canada. Corporate funding of university R&D in the United States has risen dramatically from 3 per cent of total university R&D funding in the mid-1970s[35] to 5.7 per cent in 1985 - over (U.S.) $538 million.[36] Surveys conducted in the United Kingdom show that industry contributed £32.7 million or 10.7 per cent of the value of research grants and contracts in 1983-84.[37]

Outside consulting by faculty is widespread at Canadian universities. A survey by Frank A. Darknell of science and engineering faculty at the universities of Montreal, Waterloo, and Alberta, indicates that 60 per cent did some form of outside consulting in 1983-85.[38] A parallel, more extensive study conducted in the United States has similar results with 64 per cent of science and engineering faculty reporting recent consulting experience.[39]

Of those Canadian science and engineering faculty members who indicated that they had participated in consulting activity, 81.5 per cent had performed this work for Canadian industry and 58 per cent for the federal government (Table 4). The level of participation by faculty ranged from 90 per cent of engineering professors down to 54.7 per cent of mathematics professors (Table 5).

Another indication of the current extent of faculty contact with industry is found in a survey by the Natural Sciences and Engineering Research Council (NSERC). It surveyed 208 holders of operating grants in 1982-83 and found that 28 per cent of the researchers had transferred research results to an industrial firm in the past five years.[40] In addition 54 per cent of the respondents indicated that they expected to transfer the results of some of their present research to the private sector in the next five years. Grant holders rely heavily on NSERC's operating grants with over 72 per cent citing them as their major source of funding.[41] The findings of Darknell and NSERC suggest that the figures from Statistics Canada and the Corporate-Higher Education

Forum for industrial sponsorship of university R&D are underestimated. These figures are not capturing all the activity, perhaps because some of the work sponsored by industry is not reported to the university for reasons of overhead. The matching grants program of the granting councils should lead to the development of a more accurate picture of university-industry interaction in R&D.

Table 4: Distribution, by Client, of Science and Engineering Faculty Who Were Consultants in 1983-1985

Client	Percentage
Canadian private firm	81.5
American private firm	32.1
British private firm	5.3
French private firm	4.1
Other foreign private firm	12.3
Canadian federal government	58.0
Canadian provincial government	50.6
Canadian local government	15.6
American federal government	11.9
American state government	2.5
British government	1.2
French government	1.2
Other foreign government	6.6
International agency	12.3

Source: Frank A. Darknell, "Pilot Study of Consulting by Science and Engineering Faculty at the University of Montreal, the University of Waterloo, and the University of Alberta (1986)," (unpublished).
Note: Many of the consultants indicated that they were employed by more than one agency; therefore the numbers do not add up to 100 per cent.

Table 5: Percent of Faculty in each Science and Engineering Field Who Report Consulting Activity

Field	Percentage
Engineering	90.2
Physical and environmental science	67.4
Computer science	76.5
Mathematics/statistics	54.7
Biological sciences	66.0

Source: Frank A. Darknell, "Pilot Study of Consulting by Science and Engineering Faculty at the University of Montreal, the University of Waterloo, and the University of Alberta (1986)," (unpublished).

Forms of Knowledge and Technology Transfer to Industry

Transfer to Industry Is Already Happening

University-industry interaction is in a state of ferment in Canada. The Science Council was encouraged to discover that much experimentation is going on. Statistics on this activity, however, do not capture the complex of factors involved in collaboration, nor do they reveal the extent and diversity of interaction. In addition, private firms that are not R&D-oriented are often unaware of the extent of interaction. For these reasons, the Science Council published a series of background papers to provide a deeper examination.

In the past, the interface between the university and the marketplace did not receive much attention. The university produced qualified scientists and engineers, and made the discoveries of students and faculty available through publication. Graduates and discoveries were usually left to find their own way to their respective careers and applications. There was little or no concern in the university for its relationship with the outside community. The initiatives that are now springing up are focused on bridging that gulf between university and industry, and facilitating the transfer of graduates and knowledge.

Many of the forms of current linkage are not new. Consulting, contract research, and cooperative education, for example, have existed for quite some time. What is new is a greater interest in these linkages, reflected by a higher level of activity. Of equal significance has been the development of novel forms of linkage such as joint ventures, science parks, and incubators. Like the older forms they are reflections of the renewed interest in collaboration. They also indicate that the university is searching for better ways to engage itself effectively in the complex process of technological innovation.

A large number of initiatives aimed at developing closer links with industry have been taken in Canadian universities within the last decade. In fact, every university collaborates with industry, although none yet does enough to qualify as a "new" university. It seems likely that the level and effectiveness of this collaboration will continue to increase in the near future. The question universities now face is what kinds of linkage are needed and to this question there can be no one answer. Each university has to formulate its own response, taking into account its organization, faculty, strengths, and traditions, the characteristics of the firms it will deal with, as well as other specific features of its community. Nevertheless, in developing their strategies, universities can learn from each other's successes.

Benefits of Interaction

The Science Council found that many benefits were flowing from successful examples of the types of university-industry interaction it investigated. In general, those benefits greatly outweigh the costs of interaction. The discussion papers and workshop proceedings issued by the Council describe the benefits of specific types of linkage. The general benefits of linkages are presented here.

- They help transfer the knowledge and technology of the university to industry for the benefit of national and local economies. This is their primary benefit.
- They make use of local talent and keep it in the community, and contribute to a climate encouraging economic diversification and technological innovation.
- They provide universities with greater exposure to society and to the economy thus contributing a new dimension to their intellectual vitality (for example, contract work helped develop aerospace science at the University of Toronto to the point where it has an international reputation). The university can gain strengthened political influence, greater public visibility, and an enhanced image in the community. Linkages can also help attract good students, additional research funding, and create or reinforce centres of excellence.
- They contribute to increased student awareness of the concerns of their society and economy. Through linkages, teaching is enriched with outside perspectives and experience, and students gain new skills, both professional and personal development, and new opportunities for careers.
- They increase faculty knowledge of the business world. Some faculty will obtain funding, equipment, or expertise from industry to pursue research that they could not otherwise have done.
- They enable firms to engage in and complete research projects they could not otherwise undertake. Firms also benefit by obtaining windows on advanced knowledge and a first-hand knowledge of the skills and work habits of potential employees.
- They attract money from industry that can help to develop new activities and enhance the quality of existing work.

Types of Linkages

Because of the large number and variety of relationships between universities and industries in Canada, the Science Council's project explored a number of forms of linkage that are being or could be pursued in this country. These forms are examples of how the Canadian university can exercise its function of transferring knowledge and technology to industry in a knowledge-intensive economy.

This section presents an overview of the linkages examined by the Council, sorted into four categories. Further information is provided in the appendix.

University Services to Support Linkages: Offices for technology transfer are organizational units of a university whose function is to accommodate and encourage partnership with industry. By providing such offices, universities are signifying a change in their attitude to business and are recognizing the importance of the process of knowledge and technology transfer to industry.

Linkages Based on R&D: Although R&D linkages are becoming more popular, very little is known about them. Understanding just how they work is complicated by the fact that the process of moving from basic science to marketable products and services is itself complex and little understood. Therefore, the Science Council analysed how they work in six case studies of R&D links between firms and universities in Canada. The project's aim was to identify more clearly those factors that contributed to, and those that inhibited, success, as well as to learn more about the dynamics of the links. The researchers found that the success or failure of such links rests not on any single cause but on a whole set of social and economic factors.

R&D linkages can take a variety of forms. The Council's study examined three of these. One form is the university-industry research centre. Such centres can be found throughout Canada, for example, the newly established centres of excellence in Ontario. They appear to be a highly effective way of promoting both the growth of scientific knowledge and the competitiveness of industry. They are likely to become a favoured way of engaging in joint university-industry research in the future.

Another form is academic entrepreneurship. University spin-off firms have sprung up in all parts of the country. Such spin-offs, in particular those that are high tech firms, may have great significance for local and national economic prosperity. Compared with universities in other countries, the university in Canada is a relatively more important source of high tech spin-off firms.

A form of linkage that Canada might adopt with profit is the British Teaching Company Scheme. A proposed Canadian version, the Corporate-University Partnership Program, generated an enthusiastic response from Canadian executives. Most said the program would be valuable if it provided for both engineering/technology and business/management types of projects.

Linkages Based on Teaching: Canadian business executives and their associations have long recognized the importance of educated and versatile brains for competitiveness. Therefore, it is not surprising, at a time when there is much discussion of closer university-industry ties, that business has a renewed interest in educational linkages.

The introduction of courses on the management of technological innovation and on technical entrepreneurship is an example of how university curricula are being broadened in order to promote the transfer of scientific, engineering, and management knowledge. This development illustrates how knowledge-intensive economies are challenging universities to increase the range of intellectual skills cultivated by their curricula, by encouraging the crossing of disciplinary boundaries. The number of such courses has grown dramatically in the past five years.

Cooperative education is a form of educational linkage that allows students to alternate between terms of formal instruction and work experience. This type of education, as a way of lessening or bridging the gap between academic learning and the uses of that learning, is an example of how university relations with business challenge the mode of instruction at universities. In Canada, cooperative education is held in almost universal positive regard and is experiencing very rapid growth in numbers of programs and students.

Providing continuing education in the form of updating and retraining for adults already in the labour market is another way that Canadian universities are responding to our evolving economy. Universities are being challenged by the growth in knowledge and by technological change to do much more by way of providing this sort of continuing education. The group that the Science Council's project looked at in most detail, scientists and engineers, have many innovative courses available to them. In this way, universities are extending their educational mission beyond their usual clientele by addressing the continuing education needs of firms.

The Humanities, Social Sciences, and Colleges Need Stronger Linkages: Due to the focus of the Science Council's study all of the previous forms of linkage with industry involved universities and were examined from the viewpoint of science and technology. However, in the process of trying to determine how university science and technology might better contribute to economic renewal, it seemed essential to put that focus in a broader context. As a result, the study looked at two other important topics: university-industry linkages involving the humanities and social sciences, and interactions between industry and the other part of the Canadian higher education system, community colleges and institutes.

The humanities and social sciences are usually perceived as performing essentially cultural and critical functions. This view reflects a general underestimation of the economic contribution of that knowledge. In a knowledge-intensive economy there is an increasing need for many branches of knowledge and not just those that are scientific or technical. A number of fields in the humanities and social sciences - economics, business administration, and communications, for example - are growing in commercial value. Our review showed that while collaboration involving the humanities and social sciences is more extensive than often assumed, there is even less documentation about these relations than exists for those involving science and engineering. And, on the whole, the linkages are more fragile, fragmented, and lacking in support than those involving the latter fields.

Knowledge-intensive economies not only place a high value on all types of useful knowledge, they also seek such knowledge wherever it may be found. The same general economic forces that are contributing to a greater interest and activity in university-industry linkages are also drawing the other part of higher education, community colleges, and institutes into closer touch with industry. These institutions already undertake as much collaborative work with industry as universities do, if not more. Now they are expanding their missions and shifting their priorities even more in the direction of meeting the needs of employers. Not only can much be learned from their experience in linking with employers, but the Council's review of college relations with industry suggests that linkages between higher education and business would be more effective if colleges and universities coordinated their activities and cooperated as required.

4

Overcoming Deterrents to More Effective University-Industry Ties

Most university-industry links have been responses to specific opportunities by individual faculty members. Consequently, they have sprouted in a piecemeal and uncoordinated way. Despite their haphazard history, the number of links has greatly increased in the last few years, and many different types have been tried.

During this time a new, positive attitude has emerged about the role universities can play in the economy. Rather than regarding links as leading to a situation where the university is co-opted by industry, they are now being viewed as ways of strengthening the university. Yet the future of linkages is by no means assured. Most have not taken full root in the university and the level of interaction is still far from what is needed and from what universities are capable of. Effective linkages will depend on the removal of many deterrents. This will not be easy and it will take time. But it is essential that a free, flexible, and supportive environment be fostered, both within and outside the university, so that faculty can contribute fully toward renewing the economy through technological innovation.

Each of the various forms of linkage examined by the Science Council revealed deterrents to their establishment and growth. Some impediments were specific to a type of linkage; many were common to all. This chapter reviews the major common deterrents to university interaction with industry, grouped into three sections. The first section looks at how our image of the university and that institution's practices should change to meet current social and economic needs; the second, at fears about the implications of university-industry linkages for academic values, and fears about the impact of closer ties on ethics in the university; and the third, at the need for both the participation of industry and adequate funding.

The Image and Practices of the University

The University as an Ivory Tower

The primary deterrent to better university-industry linkages is the widely held image of the university as set apart from society, and, especially, from the economy. Consequently, calls for closer, more direct relations between the university and society or the economy

are rejected or portrayed as creating a dilemma for the institution. But this view of the university as an ivory tower does not reflect the true nature of the institution. In fact, the university and its functions have evolved, and the way in which the university has fulfilled its mission has changed over time, as we can see by looking to the past.

No Learned Leisure

> The Principal of a Canadian University can hope for no learned leisure such as is enjoyed by the head of some ancient endowed college limiting itself to a classical training. Greek and Latin and Mathematics are not subjects that require ever new methods of attack. But Electrical Engineering will not 'stay put'; Mechanical Engineering has become a new subject with the internal combustion engine; Medicine has to deal with the advances of biochemistry and X-ray work; Physics cannot be taught without abundance of apparatus for demonstration and research; Chemical Engineering cannot be conducted in a corner with old appliances when both peace and war are everyday making its importance more plain.
>
> Robert Bruce Taylor
> Principal of Queen's University,
> 1917-1930[42]

History shows that universities have so far been able to change in order to continue to meet the needs of society. The university in Canada underwent a major transformation at the beginning of the 20th century. From small colleges devoted to liberal culture, some institutions were evolving into "modern" universities. That meant, at that time, developing a practical, vocational, public, and secular character, as well as placing an emphasis on specialization, graduate studies, and research. These universities experienced a spectacular growth in numbers of students and staff, in buildings and in endowments. They became the model for university development in Canada.

Science was one of the major forces behind the modern university. As natural philosophy, it had been a well-established part of the university curriculum. Now, with the quickening growth of scientific and technological knowledge, more and more scientific specialties were emerging and there was pressure to accommodate them all within the university. Moreover, following the model of first German and then American universities, there were also efforts to participate in the advancement of scientific knowledge by establishing research as a function of the Canadian university. As the quote from Principal Taylor suggests, a new sense of urgency was thereby also being added to the perennial problem of financing higher education.

The rise in the importance of science and of research on the campus was part of a broader change in science in Canada that saw a growing awareness of the need for organized research and development activities. A strong movement promoting a greater effort in scientific and industrial research in Canada flourished at the turn of the century.[43] It produced changes in both government and industry. For example, the National Research Council was established in 1916 (indeed, its original name was the Honorary Advisory Council for Scientific and Industrial Research), the Research Council of Alberta in 1921, and the Ontario Research Foundation in 1928. And in industry, R&D began before World War I and expanded rapidly between the two world wars. By developing their potential to teach and do research in science, including its applications, universities became important parts of the growing R&D system in Canada.

Both the development of scientific R&D and the emergence of the modern university reflected a changing Canadian society and economy. The shape of the latter had been greatly altered by increased industrialization, the vigorous expansion of secondary industry and the rise of large-scale manufacturing. Changes in Canadian universities were a sign of the institution's efforts to develop new ways of fulfilling its mission in a country with new needs. For some contemporaries, the changed responsibilities and duties were at odds with their experience and conception of the university and were accordingly denounced. From the perspective of the late 20th century that opposition may appear both futile and reactionary. For us, the transformation of the university looks like an inevitable evolution, determined by the importance of the university to Canada and by the ability of that institution to evolve with the times.

A New Image Is Needed for the University in a Knowledge-Intensive Economy

The image of the university as separate from society is now no longer appropriate. It is not conducive to meeting the economic and social needs of an emerging knowledge-intensive society. Furthermore, this view does not take into consideration many faculty activities, nor the numerous linkages already being pursued at Canadian universities. It also tends to limit discussions of the university's role to simply doing more, or less, of what was done before. That image of the university does not promote the new kinds of activities needed.

The current priorities of the university should not be confused with its essence. As noted in the previous section, research became recognized as a university function in Canada at about the turn of this century. The service function, interestingly enough, also emerged at the same time. By 1920 it was regarded by Canadian universities as one of their primary functions.[44] Together, teaching, research, and

service are generally taken as the basic tasks of the university in Canada. They are usually elaborated on in setting university objectives or in justifying specific university activities. For example, in 1984 the Bovey Commission identified as the fundamental objectives of the Ontario university system: to develop a more educated populace; to educate and train people for the professions; to provide study at the highest intellectual level; to conduct basic and applied research, including development and evaluation; and, to provide service to the community.[45] And fulfilling certain labour market needs, providing a vehicle for social mobility, training for leadership roles, and acting as a source of expertise for the university's region are all examples of more specific interpretations of the three basic functions.

The unifying process behind teaching, research, and service is learning. With knowledge as their essence, universities benefit not only society but perhaps first and foremost the individual student by contributing to his or her cognitive and affective qualities as well as the student's practical competence in life.[46]

A new image of the university is needed, one in which the institution is in greater, more direct touch with society and the economy. That image has to foster fulfilment of the university's mission in ways that meet the needs of a knowledge-intensive society. Were the university regarded in this way, the transfer of knowledge and technology would be recognized as suitable work for scholars. Adopting this image does not mean that universities should be harnessed to industry, nor that they should be primarily engaged in meeting short-term needs. It does mean, however, that universities will have to be committed to playing a more direct role in the economy by the transfer and application of their expertise.

The transformation of the university that is occurring does not represent a radical break with the traditional mission of the university. Precursors exist in the traditions of the land-grant university and agricultural extension. For example, Walter Murray, a former president of the University of Saskatchewan, wrote in his 1908-09 annual report:

> The University's watchword must be service to the state in all things that make for happiness and virtue as well as things that make for wealth. No form of service is too mean or too exalted. It is fitting for the University to place within reach of the solitary student, the distant townsman, the farmer in his hours of leisure, or the mothers and daughters in the home, the opportunities for adding to their stores of knowledge and enjoyment.... Whether the work be conducted within the boundaries of the campus or throughout the length and breadth of the province, there should ever be present the consciousness that this is the University of the people,

established by the people, and devoted by the people to the advancement of learning and the promotion of happiness and virtue.[47]

The transfer of knowledge and technology is a part of the service function of the university. This function, as noted previously, is an accepted part of the mission of all Canadian universities. Unfortunately, however, forms of service are not well articulated and usually do not possess much status within the university.[48] This situation must change. In particular, the transfer of knowledge and technology by the university should be seen as an important part of its mission. Transfer is but a reorientation of teaching and research, or the conveyance of the products of teaching and research. Just as research is held to be necessary for university teaching, so too should transfer activities be necessary for university research and teaching. Both of the latter can benefit from being better informed by outside problems and issues. The three functions of teaching, research, and service need to exist in a synergistic balance. Each university must find the balance that is appropriate to its own circumstances.

University Practices as Disincentives

University practices and policies often reflect the conception of the university as separate from society. Evaluations of faculty performance may not take transfer activities into account. The organization of the university along rigid disciplinary lines makes tackling social and economic problems difficult, as these problems usually require a multidisciplinary approach. It can also contribute to an outmoded curriculum and a fragmented research effort.[49] The answer is not to do away with disciplines but to ensure that students and professors are able to move among disciplines.

Some university policies need to be modified to accommodate linkages. Policies dealing with intellectual property rights and patents vary from university to university across Canada, giving rise to difficulties with inter-university projects. These policies need to be clear, concise, and consistent with respect to the universities' various clients. Also, some practices have simply not developed at some universities because they have not yet engaged in transfer activities. To promote involvement in industrial research, for example, a university needs to maintain the management capability and support services such research requires.

Fears Concerning Academic Values and Ethics

Interpreting Academic Values in a Knowledge-Intensive Economy

The fear that the integrity of the university will be destroyed by closer links between universities and industries is a powerful deterrent to transfer activities. It is fed by critics who portray academic and business values as polar opposites and denounce all university-industry links as leading to the subversion of academic values. The two sets of values are not diametrically opposed. Like the image of the university, the university's values need to be interpreted in the light of current circumstances. Intrinsic academic values need to be protected. But they can be furthered, not necessarily subverted, through university-industry interaction. Linkages can be a means for the university to disseminate its values.

At least four academic values are often said to be at risk.

Academic Freedom: Like university autonomy, academic freedom is not an absolute. It has to be considered in the context of responsibility.[50] Some argue that science should not be planned by those outside the scientific community, that it progresses best when governed least. Yet the funding for science comes from society, and limits on the freedom to do research already exist in the forms of limited funds, sponsors' priorities, and peer review. Determining what research should be done is not the same as determining its conclusions. Academic freedom should not and need not be unduly limited by collaboration with industry. Linkages can provide an environment for a better appreciation on the part of industry of the need for intellectual freedom and for increased academic freedom for faculty whose research interests coincide with those of industry.

Two other facets of the academic freedom issue need to be raised. The first is the concern that an imbalance could develop between the university and its clients in determining the institution's activities, or among its clients in favour of those who could afford the university's services.[51] The second is the fear that ties with industry would result in the university losing its credibility as an objective critic. The latter seems unlikely because the level of interaction (as indicated by the level of business funding for university research) is rather low. If it did become a problem it would be due to much more than the existence of ties. Universities will have to take steps to guard against imbalances and the loss of credibility.

Free Flow of Information: The free exchange of ideas and information is an essential academic value. A brief delay of publication to allow sponsoring companies to maintain a competitive advantage seems like a reasonable accommodation of this value, especially as delays of up to a year are already involved in the process of refereeing and

publication in journals. Moreover, special care needs to be taken so that publication delay does not put students at a disadvantage. The onus is on the universities and the granting councils to show flexibility here. On the positive side, linkages can provide a vehicle for an increased sharing of information.

Pursuit of Knowledge for its Own Sake: Universities must pursue pure or basic research, in the sense of advancing or understanding a branch of knowledge for its own sake. The issue is what proportion of a university's research effort this should be. Some claim that universities should perform only basic research because applied work depends on it. This view, however, is exaggerated. Technology is not simply the application of science; and basic research usually does not lead in linear fashion to technological innovation.[52] The full spectrum of R&D activities ought to be accepted as legitimate in a university. In deciding on the balance, a number of factors have to be taken into account: for example, the amount of basic research performed by government and industry as part of their mandate, the size of Canada's contribution to international science,[53] the needs of Canadian society and of the economy, and the fact that engaging in research linkages does not necessarily mean being limited to short-term or developmental work - much pure science, as biotechnology has shown, has commercial value today. Each Canadian university must determine what balance in its research effort is appropriate.

Teaching and Research as Priorities: Here the apprehension is that engaging in the transfer of knowledge and technology to industry will distract the university from its essential activities. This fear is based on a limited view of the university's clientele. The transfer function itself consists of teaching and research, but for a different clientele than the university has been accustomed to dealing with. Learning must continue to be the core of the university. Now it has to be expressed in different ways than before.

Minimizing Ethical Problems

The chief ethical concerns raised by university-industry interaction - conflict of interest, unfair competition, and exploitation of students - are not new, but are more prominent now due to the increased number of linkages. Interaction should not be prohibited simply because these problems exist. They can be minimized by a combination of appropriate university guidelines, common sense, and faculty care.[54] Precautions, such as the disclosure of major activities and resulting income, can be taken to avoid conflict of interest. The related problem of the fulfilment of a faculty member's responsibility to the university can be dealt with through, for example, unpaid leave. Unfair competition, due to use of university resources such as lab

space, equipment or staff, can be avoided by charging the full cost of the work or by a policy of working with a private sector partner. There are times when it may be in the university's interest to do such work even if at a loss. With regard to students, a broad range of practice in the use of postdoctoral, graduate, and undergraduate students can be found in Canada. Care needs to be exercised so that students are not exploited. But the fact that students are sometimes taken advantage of by faculty does not mean that students should be banned from linkages. They should be involved in university-industry interaction; faculty must be held responsible for ensuring the educational value of the experience.

Lack of Participation by Industry and Need for Government Funding

The deterrents to linkages noted so far in this chapter are all located within universities. They have been singled out because of the focus of the Science Council's project, not because universities are the only source of obstacles to effective linkages with industry. However, two deterrents found outside the university must be mentioned: the lack of industry participation and the need for government funding.

Lack of Industry Participation

The level of industry collaboration with universities is still too low. For example, in 1985 business contributed only 3.9 per cent of the total R&D funding available at Canadian institutions of higher education. Little benefit will come from universities strengthening their transfer function if industry does not increase its collaboration. The full participation of industry is necessary if linkages are to be effective and if the needed changes at universities are to take root. Relationships in which industry simply buys "off the shelf" from the university or universities do only what they want with industry's money will not support the kind of change needed at the university.

Although it is in industry's interest to participate in linkages, universities have a part to play in encouraging industry involvement. Universities can market themselves to industry, to make industry aware of their teaching and research capabilities and of their willingness to interact. At the same time universities should resist the temptation to oversell their potential contribution. Universities also need to find ways of interesting firms of all sizes in engaging in links. In addition universities should encourage more communication with industry, so that faculty gain a clearer idea of industry's needs and industry can become more aware of what universities do, thereby increasing the likelihood of collaboration in teaching and research.

Need for Government Funding

Canadian universities became more open to interaction with industry in part because of their search for alternative sources of funds. But experience with links and comparisons of the financial needs of universities with the disposable funds available to industry showed that industry could not replace government to any great degree as a funding source for universities (leaving aside the question of whether industry should displace government, which most would regard as a dangerous situation for the university). Money from industry does not amount to very much when compared, for example, to university research budgets.

The lack of adequate funds is a major deterrent to effective university-industry interaction. With their current commitments, universities have little flexibility to reorient themselves to engage in transfer activities. Private funding may not be available to set up linkages, nor to finance fully certain kinds of interaction such as cooperative education. There are also firms that could use the help of universities but which cannot afford the costs of linkages. Government funding, already providing the major share of university financing, will be indispensable in creating the flexibility needed by universities.

Although more funding is necessary if Canadian universities are to give more weight to the transfer function, the answer is not simply to give universities untargeted funds. Some government financing should be targeted for university-industry interaction to encourage universities and their faculty to participate in this activity.

Governments, both federal and provincial, have already moved to provide financial incentives for collaboration. For example, the federal government has recently increased the dollars committed to its matching funding policy for the granting councils,[55] and the Ontario government provides supplementary funds for work with industry through its University Research Incentive Fund. More money needs to be committed to incentives that lead to increased collaborative research. Special funds need to be allocated to educational linkages, not just research interaction. Aid for linkages is likely to be more effective if both the federal and provincial governments coordinate their efforts.[56]

Funding for linkages should not come at the expense of basic research and liberal education. These are primary functions of a university, and it is essential that they be adequately funded.[57] Quality and excellence are fundamental not only to research and teaching but also to the success of linkages. However, the function of transferring knowledge and technology to industry as defined in this report has been relatively neglected by universities. Because of its

importance for Canada's economic future, a larger proportion of new funding for universities will have to be devoted to the transfer function until it achieves a comparable position with the university sector's other major functions.

5

A University Strategy for Responding to the Challenge of Economic Renewal

Canadian universities must place greater emphasis on the transfer of knowledge and technology to industry. University-industry linkages should be fostered because of the good they can do for our economy and society. The consequences of not developing effective linkages will likely be a lower standard of living in Canada and an increasingly marginal role for its universities.

The relationship of each university to the economy is unique and complex. Yet the Science Council believes that there is a broad strategy universities can pursue. The following recommendations represent the Council's view of the basic elements of that strategy; more detailed recommendations and suggestions may be found in the project's 10 background papers. The stakeholders in each of Canada's universities will have to decide how their institution can best develop the strategy. Out of these responses will come a more competitive, knowledge-intensive Canadian economy.

Acknowledging Transfer in the University's Mission

Few universities have developed an explicit commitment to the transfer of knowledge and technology to industry. University presidents and administrations need to exercise leadership in making sure the university environment promotes a concern among faculty and students about the needs of society and of the economy. The first important step in this direction is to ensure that the transfer function is seen as part of the university's mission.

1. Given that almost 25 per cent (an estimated $1.7 billion in 1987) of total Canadian R&D is performed by universities, they must ensure that the transfer of knowledge and technology to industry be developed as an integral and valued extension of their teaching and research mission.

For change to occur, faculties, departments, and other university units, as well as individual faculty members, will need to examine how they can best incorporate the transfer function into their activities.

Involving the Humanities and Social Sciences

University-industry linkages involving the humanities and social sciences are often thought of as nonexistent. But many such ties do exist, especially in the social sciences. At a time when problems are multidisciplinary and knowledge is increasingly valuable, universities should not overlook the humanities and social sciences in the mechanisms they develop to foster closer ties with industry.

2. Universities should make special efforts to build upon the already widespread practice of individual consulting by faculty in the humanities and social sciences, and to develop other types of links between that expertise and the needs of the private sector and society.

Financing University-Industry Linkages

The private sector should contribute to the costs of linkages, but private funds may not always be available to set up linkages or to finance them fully. There are also groups and firms unable to afford the costs involved. Government financing is needed, but it should be available only for effective, clearly needed forms of linkage.

All parts of a university's mission - teaching, research, and service - need to be adequately funded. Without a healthy research base, for example, research linkages will not be strong. Formulas for university core funding should take into account the university costs of transfer activities. Until that time, governments should encourage these activities through special financing. This financing might come from funds realized by government privatization.

3. Federal and provincial governments, in particular ministries of industry and higher education, should provide further special funds for supporting existing university-industry research and educational linkages, for experimenting with new ones, and for assessing their effectiveness.

Universities also have a responsibility to see that their transfer activities receive an adequate share of university resources. As with government financing, care needs to be taken that these activities are meeting some market or social demand.

4. Resource allocation both within and among universities should recognize and reward the transfer of knowledge and technology as one of the university sector's essential functions. Furthermore,

goals for transfer activities should be established and the results evaluated on a regular basis.

Supporting Knowledge and Technology Transfer to Industry through University Policies and Services

The policies and services of a university need to reflect and support all of the institution's functions. At the very least, they should not act as disincentives for faculty to engage in any one function. The university can and should ensure that its policies foster transfer of knowledge and technology to industry by faculty. Faculty must know that they can obtain tangible support from the university.

5. University policies, especially those touching on hiring, tenure, and promotion, should recognize and reward the transfer of knowledge and technology as an acceptable and desirable function of the professor.

Most universities already provide a variety of services to support faculty. For example, research administration services are widespread and usually act as an incentive and help to faculty research. Because of the heavy management requirements transfer activities entail, professional assistance to faculty engaged in such work is especially needed.

6. Universities should provide services to promote the transfer of knowledge and technology, such as those commonly offered by technology transfer offices, innovation foundations, distance education offices, and continuing education services. These services must be adequately financed and staffed with the needed professional expertise.

These university services should not act as bureaucratic obstacles to transfer activities. The kind of support services a university finds appropriate to facilitate interaction will depend on how it has chosen to carry out its transfer function. Transfer services should encourage direct relations between faculty and those in business; they should not act as a surrogate for either side.

Improving University-Industry Dialogue

The promotion of ongoing dialogue between the university and the private or public sectors is a significant factor in the establishment of

more and better forms of interaction. Universities need to encourage ties between their faculty and outside groups in both teaching and research.

7. Universities should formally and periodically assess the need for and performance of formal mechanisms (such as advisory boards, personnel exchange programs, and joint participation in research, education and training projects) that increase consultation and the interchange of personnel with the private and public sectors.

Most Canadian universities are already improving their communications with the general public through, for example, public relations offices and magazines. This is a very important activity. Business and industry in particular need to know more about what universities can offer them.

8. Universities should ensure they successfully communicate and market their expertise to the private and public sectors. In particular, each university should maintain an accessible, up-to-date inventory of its research and teaching expertise and of its business opportunities.

Although universities and industries are taking linkages much more seriously and are beginning to make a long-term commitment to these relationships, little knowledge exists about the dynamics of such ties. Much more needs to be known about the factors contributing to successful linkages.

9. Sponsors of university-industry linkages should ensure that the linkages are evaluated for effectiveness.

Developing Educational and Research Linkages

Although industry participation is a prerequisite for successful linkages, the university usually takes the lead in starting them up. Canadian universities, through their faculty, are already very active in developing and experimenting with private sector links. The following recommendations deal with important forms of linkage. They do not cover all the ways universities can profitably link with industry or the private sector, but they mention forms of educational and research linkages that, in the Science Council's view, Canadian universities ought to pursue.

Educational linkages can be important for the success of business and industry as well as for fulfilling the university's mission. Our

examination of postsecondary cooperative education in Canada shows it to be a remarkably productive collaboration. Among other benefits, it provides an excellent way of injecting practical experience into the university curriculum.

10. Canadian universities should continually assess their potential to expand and strengthen cooperative education, and actively search for new ways to fund such programs. Financial support from government and industry for cooperative education must be increased.

A modern university education should equip students to live and work in a knowledge-based economy. Courses about science and technology and their impact need to be part of a liberal, general university education. It is important that certain of these courses be recognized as part of a specialized, professional education as well.

11. Courses in technical entrepreneurship and the management of technological innovation should be offered by universities to their science, engineering, and management undergraduates.

Continuing education, in particular professional updating, upgrading, and retraining activities, needs to be a central objective of universities in a knowledge-intensive society. Universities should act to strengthen this function. In particular, they should be more active in establishing continuing education programs for business and industry. Both universities and industry need to be committed to the goal of life-long learning.

12. Universities and industry need to work together more closely to identify and develop mechanisms for responding to the continuing education needs of employees.

Our review of employer interaction with public colleges and institutes suggests that relationships between higher education and business or industry would be more effective if the two sectors of higher education were to develop stronger forms of collaboration, combining technological and general education.

13. Universities and community colleges and institutes should coordinate their efforts in providing both degree/certificate courses and short-term courses for business and industry.

Research linkages between universities and industries in Canada are better developed than educational linkages. Still, there is much

room for improvement and expansion. Universities need to find better ways of responding to the research needs of industry and of society.

14. Universities should establish organizational units that transcend university disciplinary structures and address particular needs of the private sector, such as centres of excellence or university-industry research centres. For the next few years the units should be a priority for government funding.

New institutions should not be created where networking or clustering would be adequate. These have advantages in promoting the crossfertilization of disciplines, in involving a number of different institutions, and in being easier to close.

In exploring new types of R&D linkage, much can be learned from the experiences of other countries. Our review of the British Teaching Company Scheme revealed its success and how it might be applied in Canada. A Canadian version, the "Corporate-University Partnership Program," would aim at project-specific partnerships on the development end of the R&D spectrum and on management needs.

15. The Department of Industry, Science and Technology should fund and assume overall national responsibility for a Corporate-University Partnership Program pilot project.

Appendix

Digest of Background Papers

This appendix provides a synopsis of the 10 discussion papers and workshop proceedings prepared for the Council's project on how universities can contribute more effectively to Canadian economic renewal.

Services to Support Linkages

In the last few decades Canadian universities have made significant changes in the way they support, plan, or otherwise manage their research efforts. Some of the organizational innovations that have been made to facilitate research include the establishment of research boards or standing committees, high-level administrative positions responsible for research, and offices of research administration.

The desire to improve industry's access to the university has always been a factor motivating these innovations. But in recent years, concern about this has mushroomed. Many individuals and groups, including at least one research team at Queen's University and the Canadian Manufacturers' Association, believe that university-business cooperation would improve if universities had an administrative structure to encourage and deal with industrial contacts.[58] At the same time, several Canadian universities have made organizational changes - creating science parks, incubators, and industrial liaison offices - to foster the transfer of technology and knowledge.

The Science Council's research focused on one such innovation, the university office for technology transfer, which has sprung up rapidly in universities across Canada in recent years. University offices for technology transfer are organizational units of a university. They provide a variety of technology transfer services and monitor the activities and interests of the university as well as those of industry and government. The offices may be involved in increasing faculty awareness of the value of interaction with the private sector, in identifying commercially significant research, in advising or assisting faculty to commercialize research, in screening inventions, and in providing expertise in marketing. From time to time the offices are also involved in the development of innovations or the establishment of spin-off companies. Other activities include liaison and acting as brokers between the university and external groups, and connecting into the network of expertise provided by federal agencies, provincial research organizations and programs, and private groups.

Besides having a wide range of functions the offices also have a wide range of structures. For example, they may be separate from the university, at the central administration level, at the faculty level, or at the departmental level. This variety is the outcome of the individual university's characteristics, traditions, environment, and priorities.

The discussion paper, *University Offices for Technology Transfer: Toward the Service University,* profiles the great variety of initiatives that have been taken in this area in Canada. The spread of these offices reflects a significant change in the university's attitude toward business. Universities are recognizing the importance of technology transfer and the need to provide an organizational structure to accommodate and encourage further partnership with industry.

The impact of the offices lies not only in the increased commercialization of university ideas and inventions, in benefits to the economy, or in financial returns to the university and its faculty. There is another set of effects, less tangible yet equally important, namely the degree to which the offices shape attitudes toward universities and alter the university's organization and activities. Offices for technology transfer are a sign of the university's commitment to transfer and as such they help to win the confidence of industry.

Many offices have been set up across Canada, but few have been fully accepted within their university. Although their future success and development depends on their acceptance, many other issues will also have to be resolved. For example:

- How involved should universities be in the business end of the innovation process?
- How large (in staff and resources) must an office be in order to be effective?
- Can an office's functions be extended to include the transfer of knowledge through training programs and to encompass the innovations produced by the humanities and social sciences?
- Where should offices be located?
- How should they be supported?
- What role would they play in a national technology delivery system?
- To what extent should the university devote its resources to the support and development of the offices?

R&D Linkages

Research and development linkages between firms and universities in Canada are not new. What is new is their large number and the fact that both parties are taking them much more seriously than before.

Despite the current interest in R&D linkages, little is known about them. Understanding just how they work is made more difficult by the fact that the process of moving from basic science to marketable products and services is itself complex and little understood. As part of its research the Science Council looked at four facets of R&D linkages. One of the subsequent reports investigated the dynamics of R&D links. Two others focused on existing forms of linkage, namely university-industry research centres and university spin-off firms. The fourth assessed a new form of linkage that might be developed in Canada.

Learning More About R&D Links

To find out more about the dynamics of R&D links the Science Council opted for a comparative study of six links. Key issues for research included: What motivations and expectations lie behind these links? What activities are engaged in and what problems are faced? What are their benefits? What impact do they have on the firm and on the university? The resulting discussion paper, *R&D Links between Firms and Universities: Six Case Studies,* helps answer these questions. It illustrates the diversity of the links and shows that their success or failure rests on a complex set of social and economic factors. Links included university-private sector collaboration in:

- genetic engineering and tissue culture for forestry (Simon Fraser University and Clay's Nurseries of Langley, B.C.);
- the development of software to control continuous flow production processes (the University of Calgary and Willowglen Systems);
- using computer simulation to help design a factory (the University of Waterloo and John Deere and Company);
- computer-aided design for a hydroelectric construction project (École Polytechnique, seven Quebec engineering firms, la Société d'énergie de la Baie James, and Hydro-Québec);
- testing new ways to improve apple storage (Acadia and St. Mary's Universities, the Scotian Gold Cooperative, and the Norfolk Fruit Growers' Association);
- funding a chair in metallurgy (the Stelco chair at McMaster University).

Each link owed its existence to the presence of at least one person who could act as a champion or catalyst.

The paper points out that much of the success of a link depends on it having a strong focus, realistic objectives, and adequate and flexible funding. In addition, both parties in the link must see the prospect of tangible gains; key players must remain long enough for the project to become established; and all personnel must be strongly

committed to making the link work. University attitudes and reward systems can also be important to the success of a link. For example, the university needs to regard industrial R&D as a legitimate activity and see that academic rewards are available to faculty for this work. The university can also help by setting up coordinating units that understand industrial R&D to handle negotiations between the university and the firm. Other factors that contribute to successful links include good communication between the partners and mutual respect for the academic and industrial cultures.

The discussion paper notes several benefits generated by R&D links. Universities benefit from the sponsorship of research and the access to or donation of equipment; firms benefit from their enhanced competitiveness. The paper also points out several equally important but less tangible benefits: the transfer of technology and knowledge associated with a link, the creation or reinforcement of a centre of specialization, and the contribution of a link to the regional economy.

Fostering University-Industry Research Centres

University research centres are not new, but in recent years they have grown in number to such an extent that they have become one of the most significant developments at universities and in the Canadian R&D system. They are likely to become even more popular in the future as universities respond to calls for flexibility, adaptability, greater specialization, and excellence.

Not all university research centres have ties with industry, but many do. Approximately 90 such centres across Canada devote over 20 per cent of their time and resources to carrying out research for industry. They appear to be highly effective in promoting both the growth of scientific knowledge - often of a multidisciplinary nature - and the competitiveness of industry. Some observers feel that the participation of industry in these centres contributes to the pursuit of excellence since industry is likely to press for the concentration of resources needed for excellence;[59] industry thereby provides a useful counterweight to the tendency of governments to spread resources around.

In May 1985 the Science Council organized a workshop to review university-industry research centres. As the summary proceedings, *University-Industry Research Centres: An Interface between University and Industry,* note, participants were convinced that these centres are an important form of R&D linkage with substantial benefits both for university and industry. For example, because centres are interface organizations, they can offer a stimulating environment to their researchers and, at the same time, provide industrial clients with R&D that can improve their economic performance. Participants at the

workshop described the intense synergetic interaction that frequently occurs when individuals from different sectors work on common projects or share research facilities.

Universities and firms also benefit in other ways. The centres stimulate industrial support and involvement in university research, increase a university's research capabilities, help train graduate students, and help a university to attract research grants and contracts. Industry gains a window into emerging areas of fundamental science, meets students who may become future employees, and gains from the precompetitive and contract research performed. Moreover, the centres help to diffuse technology and to develop R&D policy for industrial sectors.

All university-industry research centres are interface organizations yet there are striking differences between them. They differ with respect to their place in the university's organization, the academic status of their staff, the number of disciplines they encompass, and whether they deal with one or more companies, or with an industrial sector.

Workshop participants identified a number of factors that contribute to successful centres. For instance:

- centres tend to be created and sustained by enthusiastic, charismatic, entrepreneurial individuals;
- personnel need to share a general spirit of cooperation and commitment;
- R&D activities should serve the needs and interests of both university and industry;
- centres should be organized according to sound business practices and possess marketing capabilities that enable them to identify markets and sell their services or products;
- funding should come from a variety of sources.

Perhaps the most crucial success-related factor is the ability to develop and maintain good contact with industry. Workshop participants felt that industry should be encouraged to participate in the centres formally and in a variety of ways. They also recommended personnel exchanges and frequent communication between the university and its industrial partners.

University-industry research centres are hybrids of the academic and industrial cultures. As such, they possess their own modes of operating and have their own problems and imperatives. They also have strengths not found in the usual organization of research in the university. They therefore represent a new type of research organization that, like a hybrid, is often exceptionally vigorous.

Encouraging Academic Entrepreneurship

One form of academic entrepreneurship is the establishment of a new business, the university spin-off firm. Spin-offs, in particular high tech spin-offs, may have great significance for regional and national economic prosperity. For example, in the Cambridge, England high tech complex, only 17 per cent of the firms were originally set up by entrepreneurs coming straight from the university, but subsequent spin-offs from these companies mean that the university was indirectly the origin of virtually all of the indigenous firms.[60]

The university spin-off firm contributes to regional development in at least three ways: by stimulating other components of the economy, by using and keeping local talent in the community, and by helping to create a climate encouraging economic diversification and technological innovation. Moreover, spin-offs have other benefits. The academic entrepreneur stands to gain satisfaction, new challenges, and money. The university may also gain financially, perhaps through equity in the firm. There are also many other, less tangible benefits: funding for chairs, scholarships, career opportunities for students, increased contacts between faculty, students and the business world, research contracts, and a heightened degree of intellectual vigour are some of the possible rewards.

In November 1985 the Science Council organized a workshop to review university spin-off firms in Canada. The summary proceedings, published as *University Spin-off Firms: Helping the Ivory Tower Go To Market*, show that participants were extremely positive toward these firms and that they felt much could be done to encourage their development. Universities, for example, could ensure that general university policy explicitly supports spin-offs. Second, universities could ensure that their more specific policies and practices are conducive to commercial development by researchers. These policies and practices include those governing conflict of interest, intellectual property rights, use of university resources, use of students, and the university's reward system. Finally, the university could provide a variety of special services - such as science parks, incubators, and technology transfer offices - to help faculty to commercialize ideas.

Participants also felt that much could be done to improve the environment within which spin-offs operate. For instance, the general environment for small business could be more supportive. Here, participants saw a need both for more venture capital and for seed capital for high tech ventures. They also saw a need for government programs to help set up university spin-offs. Finally, they felt that Canadians should foster a culture that encourages science, engineering, and entrepreneurship.

Spin-offs themselves could do more to promote their success.

Participants noted that the academic entrepreneurs involved in spin-offs do not usually possess much business know-how. These entrepreneurs must recognize the need for expert advice on marketing, management, and the development of business plans and ensure that they have access to such expertise.

A question that concerned many workshop participants was whether spin-offs, once established, benefit from an ongoing relationship with the university. One study of academic entrepreneurship found that manufacturing spin-offs, if led by part-time academic entrepreneurs, seemed less aggressive and less growth-oriented than "independent" firms.[61] This finding suggests that universities should not be overly concerned with keeping academic entrepreneurs on campus. At the same time, however, spin-offs have much to gain from continuing contacts with the academic world: they are able to exchange ideas and discuss problems with other academics, they gain access to equipment and highly-qualified workers, and they have the use of the university's research capabilities. Indeed, as the Cambridge complex, Silicon Valley, and other technically oriented complexes demonstrate, high tech firms are often attracted to areas where strong universities exist (although that is not the only reason for the location of the firms), and once there they have numerous links with the university. To take the Cambridge example once again, over half of the firms there at one time or another had links with local research bodies and 90 per cent of these were with the university.

Creating New Forms of R&D Linkage

Interest in R&D linkages between universities and industries is growing. Consequently, the more traditional forms of interaction such as consulting and research contracts are taking place more frequently. At the same time, many novel forms of R&D linkage are appearing. University offices for technology transfer, science parks, and incubators are some examples. Such experimentation will undoubtedly increase as universities and industries search for effective and mutually beneficial ways of interacting.

Canada is not alone in testing new kinds of relationships with business. Other countries have developed forms of linkage that Canada might adopt with profit. One of these is the successful British Teaching Company Scheme. The discussion paper *The Teaching Company Scheme: A Study of its Application in Canada* reviews the British program and assesses how receptive Canadian industry might be to a version of it.

Under the Teaching Company Scheme (TCS), a university (or college) and a commercial firm form a partnership for the duration of a particular project. The TCS represents a joint venture because there is

an agreement between the university and the firm to achieve objectives that benefit both parties. It is also a personnel transfer program in that recent university graduates, at the bachelor's or at most master's level, work for the firm on its premises and may eventually be hired by the company. Funding comes from government and from the firms involved.

Some of the TCS's features are similar to existing Canadian programs, for example, aspects of the Natural Sciences and Engineering Research Council's industrial research fellowships, one of the elements (contributions to firms employing undergraduates) of the Industrial Research Assistance Program of the National Research Council, and cooperative education. But, overall, the TCS is substantially different, in particular because of the formal partnership between a university (or college) and a firm.

As the discussion paper notes, a TCS in Canada would help firms to recruit and select employees and to undertake projects that were previously impossible because of a lack of expertise, personnel, or other resources. It would also facilitate the transfer of technical and other know-how from faculty members to the firm and vice versa. A TCS in Canada might prove especially valuable for small and medium-sized firms or for those with little R&D activity.

Through a TCS, a university (or college) and its graduates gain a chance to interact with the business world. This benefit, however, in itself is not always sufficient to guarantee the TCS's acceptance. A review of the British scheme, while noting its success, concluded that "academic institutions as a whole, as distinct from individuals and groups, have not risen to the industrial-linkage opportunities offered by TCS."[62] Moreover, since many of the activities under the program would focus on exploiting existing science and technology, many research-oriented faculty might be reluctant to participate. Faculty of colleges would be less reluctant because they are not expected to do research. Perhaps the program should be regarded as fulfilling the service component of the university teacher's role.

The discussion paper concludes that the TCS concept is appropriate for Canada. It suggests that the Canadian version be known as the "Corporate-University Partnership Program." In addition, it argues that the Canadian program should be broader than the British one in that it should include projects aimed at enhancing the management and entrepreneurial aspects of Canadian business. The discussion paper noted enthusiasm for the idea among Canadian executives of firms asked for comments. Most said that the program would be especially valuable if it provided for both engineering/technology and business/management types of projects.

Educational Linkages

> If Canada is to maintain and develop her position in world trade with manufactured goods, the use of highly trained brain power by both large and small industries will be the most important factor in such development.
>
> Technical Service Council
> *First Annual Report* (1929)

Arguments for closer ties between universities and industries often stress the advantages of knowledge transfer through research. Most business people, however, are more concerned with the education and training that universities provide for future employees. Canadian business has long recognized the importance of "highly trained brain power" for its competitiveness. Now, at a time when there is much discussion of closer university-industry ties, it is not surprising that many business people and their associations have a renewed interest in educational linkages.

Canadian universities have struggled to find a balance between the traditional ideal of a liberal education and the reality of specialized, often career-oriented, studies. The needs of the economy have been only one of the issues in this struggle. For example, many argue that undergraduate education should be more general and less geared to those who want to become researchers. Ontario's Bovey Commission recommended that the university curricula "seek a balance between general and specialized studies aimed at producing graduates who will be adaptable throughout their lifetimes and who will understand their own specialties within a wider context and in relation to new technological developments."[63]

The principle that a university should prepare its students to live socially and economically productive lives is broadly accepted. The problem is to translate this principle into practice. The Science Council reviewed and published papers on three forms of educational linkage between universities and industries. One paper looked at how the curriculum might be broadened in order to promote the application of scientific and engineering knowledge. Another examined a method of teaching in which formal learning is integrated with on-the-job experience. The third paper looked at how universities can extend their educational mission, and serve a broader clientele, by addressing the continuing education needs of firms.

Broadening the Scope of the Curriculum

Increasingly the success of many firms rests on their ability to adopt and use new technologies. As a result there is a growing awareness -

among educators and in the business community - of the need to educate future managers in the process and management of technological innovation. Similarly, as the significance of entrepreneurship for economic development becomes clearer, this subject, and technical entrepreneurship in particular, is also emerging as a priority for the curriculum. Although the need for education in the management of technological innovation and in technical entrepreneurship is apparent, Canadian universities have only recently begun to provide it. The establishment of such courses illustrates one way in which universities are meeting the challenge posed to university curricula by closer ties with industry. It also provides a case study of how universities are responding to the economic challenge to broaden the range of intellectual skills cultivated by their curricula (by encouraging the crossing of disciplinary boundaries) and of the problems that must be overcome in the process.

A course on technological innovation and its management provides information on how an organization develops a technical concept from an idea to a product or process and on into the marketplace, all in a medium-sized to large company context. Among the topics that might be included are corporate innovation strategy, R&D management, technology transfer, technological forecasting, factors that determine successful innovation, and the development and marketing of new products.

A course on technical entrepreneurship provides the management skills and information that enable a scientist or engineer to establish a business based on a technical idea and to increase the probability of success of an entrepreneurial venture. Such a course is oriented toward the problems of small and medium-sized firms, the technological innovation process, venture capital acquisition, and marketing.

Both science and engineering students and business students benefit from these courses. Technically trained professionals gain business skills, and business graduates gain an understanding of the key role that science and technology play in economic performance. The courses increase the ability of all students to put their skills and knowledge to maximum use either as employees or as employers.

The discussion paper, *Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities*, looks at the extent to which Canadian universities offer courses on the management of technological innovation and on technical entrepreneurship to students in science, engineering, and business faculties. It reports the views of the deans of those faculties about such courses, and it discusses the issues involved in offering the courses.

The paper notes that there has been a dramatic growth in the number of courses in the management of technological innovation

and in technical entrepreneurship in the past five years. Such courses are offered at 20 Canadian universities, in business or engineering faculties, with most of them available in central Canada. The paper points out that most of the deans contacted felt that the information contained in the courses ought to be provided as part of a scientific, engineering, or business education. Recently, the government of Ontario announced the establishment of six centres of entrepreneurship at postsecondary institutions.

The discussion paper concludes that specialized technological innovation and technical entrepreneurship courses should be developed and presented within science and engineering faculties, and that they should be taught by experts from these and other faculties as well as from the business community. It also recommends ways to facilitate the spread and improvement of these courses. In particular, the paper argues that:

- academics who see the need for training in this area should be encouraged and provided with the resources they require;
- at least two centres of expertise in the area should be established to provide education and training for future university professors and industry consultants, and to establish a strong Canadian research base in these disciplines.

Integrating Formal Learning and Experience

Closer relations between universities and businesses in Canada challenge the mode of instruction used in universities. Ways must be found to reduce the gap between academic learning and the uses of that knowledge.

Cooperative education is a system of cooperation between institutes of learning and the employers of the graduates these institutes produce. In cooperative education, the student alternates between terms of formal instruction and terms of work experience. Classroom learning and learning-on-the-job are thereby intertwined with the goal of improving both the education of the student and his or her ability to contribute to the world of work.

Cooperative education is a particularly important form of university-industry interaction. It is important because of the large and growing numbers of institutions, employers, and students in such programs. It is also important because it appears to be viewed positively by almost everyone associated with it.

Almost no systematic information about cooperative education has been collected in Canada. For this reason, the Science Council commissioned the discussion paper, *Postsecondary Cooperative Education in Canada.* The paper is based on a survey of three groups involved in cooperative education: universities and colleges, employers, and

senior coop students. It reports their views about the benefits and costs of coop education, its strengths and weaknesses, and how cooperative education programs could be improved.

The survey reveals a high degree of satisfaction with cooperative education among all three groups. For all, the benefits greatly outweigh the costs. Cooperative education enables colleges and universities to attract good students, to enhance their image in the business community, and to produce high-quality graduates. It enables employers to manage human resources more effectively: they are able to evaluate potential full-time employees (and later recruit them) while obtaining highly productive work. And it enables students to develop professionally and personally: they gain insight into their professions, their employers, and themselves. According to the survey, coop students appear to be achieving the kind of personal growth - understanding of self, self-confidence, and the ability to work independently and with others - that should result from a more traditional college or university education. Finally, cooperative education improves the students' ability to finance their education.

What these results attest to is that cooperative education is a remarkably productive means of collaboration for institutions of higher education and employers. It may also lead or contribute to other forms of university-industry linkage. The further development of cooperative education in Canada should be encouraged.

Addressing the Continuing Education Needs of Firms

Competing in a world economy requires more attention to the development of all human resources, including already highly-trained professionals in science and engineering. The need for updating and retraining is forced by the pace of growth in knowledge and in technological change. In addition, there is a greater awareness of the need for upgrading so that highly-skilled practitioners can acquire knowledge and skills related to their work but not acquired during formal schooling. These types of continuing education gain an even greater importance with the realization that most labour force requirements in the next 15 years will have to be met by the current pool of workers. The development of Canada's human resources is a large task and one best tackled by involving all those with a stake in education and training: employers and employees, governments, and providers of education.

The growing need for continuing education challenges the universities to do much more in this field. The challenge provides an opportunity for them to continue broadening their clientele beyond the traditional group of young and full-time students, and to fulfill their educational function in new and important ways. At the same time, if they do not take up the challenge, they risk being supplanted

by the emerging, parallel education system of corporate training centres, proprietary schools, and systems of self-directed learning. Indeed, the very existence of such a large and growing system raises important questions about the idea that universities educate "highly qualified personnel."

To respond to this challenge universities will have to work closely with employers to identify current and future human resource needs, to determine the most suitable means of addressing these needs, and to provide the knowledge and skills necessary to continue performing competently in the workplace. Instead of the piecemeal, reactive approach that now exists, a comprehensive and strategic approach to continuing education is required.

In November 1986 the Science Council, along with the Canadian Association for University Continuing Education and the Canadian Manufacturers' Association, sponsored a workshop on university-industry collaboration in the continuing education of Canada's scientists and engineers. Representatives from higher education, industry, government, and other interested groups shared examples of collaborative efforts and ideas on how such efforts might be encouraged. The summary proceedings of the workshop, *Learning From Each Other: University-Industry Collaboration in the Continuing Education of Scientists and Engineers*, records their views. Since so little is known about continuing education in Canada, the proceedings provide additional examples of collaboration besides those presented during the workshop.

As the proceedings note, Canadian universities are increasingly collaborating with industry to find effective ways of meeting the continuing education needs of scientists and engineers. Many examples of innovative collaboration have emerged and they take a variety of forms. Some are direct links between a firm and a university division of continuing education, faculty, department or centre, at times using distance education; others are indirect links coordinated by outside agencies operating in a "broker" capacity. Among the latter are organizations that have been established to respond to the educational needs of a particular industrial sector, and professional associations that advise on the educational needs of their members and occasionally help to coordinate, design, and deliver continuing education.

Workshop participants offered two suggestions for universities wishing to work more effectively with industry. First, the university could improve its image within industry by being more responsive to the needs of industry in its undergraduate and graduate programming, by adopting a more aggressive and focused marketing strategy in which the university identifies the continuing education needs of industry and transforms that need into a demand, and by working

closely with other providers of continuing education, such as colleges. Second, the university could strengthen its continuing education function. This could be achieved by making that function less of a peripheral activity within the university, by devoting or finding more funds for this activity, and by supporting research within continuing education departments on the learning needs of adults and the effectiveness of different teaching methods and delivery systems in addressing these needs.

Participants felt there could be much more collaboration between universities and firms to provide continuing education for scientists and engineers. Whether this will happen will depend on the commitment of universities and industry to the goal of life-long learning.

The Context for University Science and Technology Linkages

All of the previous forms of linkage with industry involved universities and were examined from the viewpoint of science and technology, since that was the orientation of the Science Council's study. However, in trying to determine how university science and technology might better contribute to economic renewal, the Council looked at current activities involving other branches of learning and other post-secondary institutions. Specifically it looked at university-industry linkages involving the humanities and social sciences, and interactions between industry and community colleges and institutes. Each topic deserves much more attention than was possible in the overviews produced for the Council. Nevertheless, the overviews did provide useful counterpoints to the main line of research and contributed to this report's recommendations on how to develop more effective linkages between universities and industries in Canada.

Promoting Humanities and Social Sciences Linkages

The humanities and social sciences are usually thought of as performing essentially cultural and critical functions. This view reflects a general underestimation of the utilitarian or economic contribution of that knowledge. In fact, the humanities and social sciences embrace a wide variety of disciplines and fields of study, many of which - economics, business administration and commerce, communications, social work, and urban studies, for example - obviously produce knowledge and train individuals who are needed by the Canadian economy. Moreover, portraying the humanities and social sciences as essentially concerned with culture is no longer quite as accurate as it once may have been. In a knowledge-intensive economy there is an

increasing need for many branches of knowledge and not just those that are scientific or technical. A number of fields in the humanities and social sciences have growing commercial value, for example, those that help business by offering insights into cultural, political, social and economic conditions; conduct productivity analyses for firms; or explore the impact of technological innovation within the workplace as well as on society.

The discussion paper, *University-Industry Interaction in the Social Sciences and Humanities: A Threshold of Opportunity,* found examples of linkages in Canada involving a variety of humanities and social sciences, although most are concentrated in the business disciplines. The paper also found that the forms of collaboration with business undertaken in the humanities and social sciences are as diverse as those taking place in science and engineering. Furthermore, this collaboration is more extensive than often assumed and occurs with firms of varying sizes operating in almost all sectors of the economy. On the whole, however, the linkages are more fragile, fragmented, and lacking in support than those in science and engineering. Much of the collaborative activity is arranged and managed on an ad hoc basis by individual faculty members without the involvement of the university.

The discussion paper presents examples of various forms of linkage. Some universities offer cooperative education programs in the humanities and social sciences. Most offer continuing education in these areas. Some faculty conduct market studies for firms or give advice to Canadian firms on conditions in other countries that may help them conduct business abroad. Other faculty carry out research for firms on topics such as the social impact of large-scale resource development projects, decision-making in organizations, and how firms can increase commitment and improve productivity. In addition some university research centres offer subscribers economic forecasts, policy analyses, and special studies.

University-industry linkages in the humanities and social sciences provide financial rewards for the university and the firms involved. In addition, linkages help promote the credibility of the university and of faculty and generate good will betweeen the university and the outside community. The discussion paper notes that the humanities and social sciences as disciplines also benefit because they do not grow simply as a result of internal dynamics; attempts to apply knowledge can provide a healthy input into the further development of that knowledge.

The paper makes a number of proposals to promote linkages in the humanities and social sciences. Many of the proposals are aimed at making the linkages less of an underground activity. For example, innovative mechanisms to foster collaboration and better financing

for such interaction are all called for. Taking humanities and social sciences linkages much more seriously and generating public recognition of the increasingly important contributions of those disciplines will be key factors in more effective interaction between the university and industry.

Collaborating with Community Colleges and Institutes

Knowledge-intensive economies place a high value on all types of useful knowledge. They also seek such knowledge wherever it may be found. The same general economic forces that are contributing to a greater interest in university-industry linkages are also drawing the other part of higher education, community colleges and institutes, into closer touch with industry. These institutions, collectively referred to as colleges in the following text, already do as much collaborative work with industry as the universities if not more. Now they are expanding their missions and shifting their priorities even more in the direction of meeting the needs of employers.

College-industry linkages, like those involving universities, occur in a variety of forms. Traditionally, colleges have consulted with employers about full-time programs and other services usually through their boards or through various committees. Program advisory committees, for example, monitor the curriculum and learning environment to ensure a match with the needs of employers. Like the universities, colleges engage in continuing and cooperative education. They are also providing more customized training. The majority of colleges have - or are in the process of setting up - contracts with a wide variety of clients to deliver educational services such as needs assessment, curriculum development, and specially developed courses. Although most industry linkages are educational, reflecting the priorities of the colleges, examples of applied research and technology transfer services are increasing. Colleges are more and more using such terms as "applied research," "incubators," and "technology transfer" to describe their roles.

The discussion paper, *Employer Interaction with Public Colleges and Institutes in Canada,* provides background information on colleges, gives examples of the kinds of linkages they have with employers, notes the forces affecting this interaction, and suggests some ways to make interaction for economic purposes more effective. It also argues for an increased level of collaboration between colleges and industries. To encourage better use of college resources in this area, the paper calls for a national training strategy directed to the achievement of national economic goals. Government policy needs to treat colleges not simply as social costs but chiefly as contributors to national wealth. Industry, although beginning to see the advantages of linkages, should make

more use of colleges, especially for training and retraining to facilitate technology transfer. And colleges must continue making opportunities for dialogue with industry.

The discussion paper offers some comparisons between colleges and universities. Colleges, for example, are usually more community-directed and industry-oriented than are universities, are located in more parts of the country, deal with a broader clientele, and do more to meet the needs of the labour market. These differences, however, tend to be ones of emphasis and priority rather than substance. The paper points out that colleges and universities each have their own strengths and that these could complement each other. Unfortunately the two institutions often operate in isolation. The paper suggests that linkages with business and industry will be most effective if colleges and universities coordinate their activities and cooperate as required.

Notes

1. Statistics Canada derives this figure from data on university research sponsored by outside sources (federal granting councils, other federal sources, provincial governments, business, and others) and from an estimate of R&D expenditures by universities (based on numbers of faculty in each discipline and operating expenditures).
2. "How to think about the economy, Part 3," *John Kettle's FutureLetter* (30 April 1987).
3. Ibid.
4. Statistics Canada, Science, Technology and Capital Stock Division, "International Trade in 'High-Tech' Products 1978-1986," (Ottawa, 1987), 18.
5. Ministry of State for Science and Technology, *Science, Technology and Economic Development. A Working Paper* (Ottawa, 1985), 38.
6. Joseph R. D'Cruz and James D. Fleck, "The 1986 EMF Scorecard on Canada: Mixed, but Encouraging," *Business Quarterly* 51:2 (Summer 1986), 78-87, 84-85.
7. Michael L. Skolnik and Norman S. Rowen, *"Please sir, I want some more" —: Canadian Universities and Financial Restraint* (Toronto: Ontario Institute for Studies in Education, 1984), 4.
8. Ronald L. Watts, *The Challenges and Opportunities Facing Post-Secondary Education in Canada* (Ottawa: National Forum on Post-Secondary Education Committee, 1987), 11.
9. Nathan Rosenberg, "How exogenous is science?" in his *Inside the Black Box: Technology and Economics* (Cambridge: Cambridge University Press, 1982), 143.
10. University of Guelph, *Research Policies and Information Handbook* (Guelph, 1984), A1.
11. Ernest A. Lynton and Sandra E. Elman, *New Priorities for the University. Meeting Society's Needs for Applied Knowledge and Competent Individuals* (San Francisco: Jossey-Bass, 1987), 162-163.
12. "Sponsored research" is defined by the Canadian Association of University Business Officers as funds paid to the university in the form of grants or by means of a contract from sources external to the university.
13. Statistics Canada, *Financial Statistics of Education 1982-83* (81-208) (Ottawa: Department of Supply and Services, 1987), 71.
14. Skolnik, op. cit. (note 7), 49.
15. Statistics Canada, *University Finance Trend Analysis, 1974-75 to 1983-84* (81-260) (Ottawa: Department of Supply and Services, 1984), 104.
16. Statistics Canada, op. cit. (note 13), 62.
17. *A Statistical Portrait of Higher Education in Canada* (Ottawa: National Forum on Post-Secondary Education Secretariat, 1987), 7.
18. Statistics Canada estimates that there were 28 910 full-time teachers at community colleges in postsecondary programs in 1984-85. Statistics Canada, *Education in Canada* (81-229) (Ottawa: Department of Supply and Services, 1985), 226.
19. Statistics Canada, *Teachers in Universities, 1984-85* (81-241) (Ottawa: Department of Supply and Services, 1986), 14. The number of social science faculty has grown the most, from 21.4 per cent in 1970-71 to form

25.8 per cent of the total in 1984-85. Science and engineering faculty (including health professions) have been increasing more slowly, from 42.4 per cent in 1970-71 to 44.4 per cent of the total in 1984-85. Those in the humanities and fine arts declined from 26.8 per cent to 20.6 per cent in the same time period, while those in education declined only slightly from 9.4 to 9.2 per cent. The distribution of students has many similarities to that of their teachers. The social sciences have been recording steady increases in the number of students and formed 28.5 per cent of the total student population in 1984-85. The science and engineering (including health sciences) student body has been growing more slowly and declined somewhat after 1984-85 to 24.8 per cent. Those in the humanities and fine arts have been declining since 1974-75, but staged a modest recovery after 1983-84 to form 10.7 per cent in 1984-85. Students in education declined from 15.5 per cent in 1972-73 to 10.9 per cent in 1984-85. Those enrolled in general arts and science degrees or undeclared make up the rest of the student body.

20. National Science Foundation, Division of Science Resources Studies Remote Bulletin Board System, May 1987, (Table B-40 divided by Table B-38).
21. Howard R. Bowen and Jock H. Schuster, *American Professors. A Natural Resource Imperiled* (Oxford: Oxford University Press, 1986), 73.
22. Statistics Canada uses American estimates like these to determine the proportion of costs that should be attributed to research and development.
23. Community college full-time enrolment in postsecondary programs was 318 930 in 1985-86. Statistics Canada, *Advance Statistics of Education 1986-87* (81-220) (Ottawa: Department of Supply and Services, 1986). Enrolment in pre-vocational and trades-level vocational courses at the colleges (and similar institutions) comprised another 266 805 persons in that year.
24. Statistics Canada, Education, Culture and Tourism Division.
25. Statistics Canada, *Universities Enrolment and Degrees 1984* (81-204) (Ottawa: Ministry of Supply and Services, 1986), 5.
26. Statistics Canada, Education, Culture and Tourism Division.
27. Statistics Canada, op. cit. (note 25), xiv.
28. Ibid, 5.
29. Statistics Canada, Education, Culture and Tourism Division.
30. Margaret A. Denton et al., *Employment Survey of 1985 Graduates of Ontario Universities, Summary Report* (Toronto: Queen's Printer for Ontario, 1987), 17.
31. Statistics Canada, op. cit. (note 13), 75-77.
32. R.M. Bird and M.W. Bucovetsky, *Private Support for Universities*, discussion paper prepared for the Commission on the Future Development of the Universities of Ontario, 1984.
33. Corporate-Higher Education Forum, *Spending Smarter: Corporate-University Cooperation in Research and Development* (Montreal: Corporate-Higher Education Forum, 1985), 62.
34. Ibid, 72.
35. *Chemical Week* 139:9 (27 August 1986), 16.
36. *The Chronicle of Higher Education* (10 December 1986), 8.
37. Michael Kenward, "On Ivory Towers, Muck and Brass," *New Scientist* 1517 (17 July 1986), 48.
38. Frank A. Darknell, "Pilot study of consulting by Science and Engineering faculty at the University of Montreal, the University of Waterloo, and the

University of Alberta (1986)," unpublished.

39. Frank A. Darknell and David Nasatir, *Consulting as a Science Indicator: A Method for Measuring and Monitoring Scientific and Technology Input or Transfer by Science and Engineering Faculty in the United States,* National Science Foundation, unpublished, 1987.
40. Natural Sciences and Engineering Research Council, *Completing the Bridge to the 90's: A Second Five-Year Plan for the Programs of the Natural Sciences and Engineering Research Council* (Ottawa, 1985), 58.
41. Data from the Natural Sciences and Engineering Research Council indicate that 39.6 per cent of science and engineering faculty received operating grants from NSERC in 1982-83.
42. Queen's University Archives, memoirs of R.B. Taylor, 317.
43. James P. Hull, "Science and the Canadian Pulp and Paper Industry 1903-1933," PhD dissertation, York University, 1985.
44. Marni de Pencier, "Ideas of the English-Speaking Universities in Canada to 1920," PhD dissertation, University of Toronto, 1977.
45. The Commission on the Future Development of the Universities of Ontario, *Ontario Universities: Options and Futures* (Toronto, 1984), 3.
46. Howard R. Bowen, *Investment in Learning: The Individual and Social Value of American Higher Education* (San Francisco: Jossey-Bass Publishers, 1977), 8, 453.
47. Quoted in *Issues and Options: Discussion Paper* (Saskatoon: University of Saskatchewan, 1986), 10.
48. Patricia H. Crosson, *Public Service in Higher Education: Practices and Priorities* (Washington, D.C.: Association for the Study of Higher Education, 1983).
49. Jana B. Matthews and Rolf Norgaard, *Managing the Partnership between Higher Education and Industry* (Boulder, Colorado: National Center for Higher Education Management Systems, 1984), 111.
50. Robert S. Morison, "Some Aspects of Policy-Making in the American University," *Daedalus* 99:3 (Summer 1970), 609-644.
51. Skolnik, op. cit. (note 7), 166.
52. George Wise, "Science and Technology," *Osiris* 1 (1985), 229-246; Nathan Rosenberg, "How exogenous is science?" in his *Inside the Black Box: Technology and Economics* (Cambridge: Cambridge University Press, 1982), 141-159; and Deborah Shapley and Rustum Roy, *Lost At The Frontier: U.S. Science and Technology Policy Adrift* (Philadelphia: ISI Press, 1985), 18-20.
53. James B. MacAulay, *An Indicator of Excellence in Canadian Science* (Ottawa: Statistics Canada, 1985), 24.
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57. The issue of university funding was not part of the scope of this study. The Science Council, however, has commented on this question in the

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58. J.R.M. Gordon et al., "Commercializing University Inventions," paper prepared for the Department of Regional Industrial Expansion, 1986; Canadian Manufacturers' Association, *Improving our Industrial Competitiveness: A Science Policy for Canada* (Toronto: 1986), 8.
59. For example, Al Johnson's, "Sizing Up the System: The University at Mid-Decade," talk for the Conference Board of Canada's national conference on Innovation through Partnership: Moving New Technology, New Products and New Skills from Campus to Workplace, 4 December 1985. Unpublished.
60. David Keeble, "Entrepreneurship, High-Technology Industry and Regional Development in the United Kingdom: The Case of the Cambridge Phenomenon," paper presented at a seminar on Technology and Territory: Innovation Diffusion in the Regional Experience of Europe and the USA, Instituto Universitario Orientale, University of Naples, 20-21 February 1987, 21.
61. Jérôme Doutriaux, "Growth Pattern of Academic Entrepreneurial Firms," University of Ottawa, Faculty of Administration Working Paper 86-56, 1986.
62. As quoted in James G. Barnes and G. Ross Peters, *The Teaching Company Scheme: A Study of its Application in Canada* (Ottawa: Science Council of Canada, 1987), 15.
63. The Commission on the Future Development of the Universities of Ontario, op. cit. (note 45), 37.

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The Science Council of Canada is Canada's national advisory agency on science and technology policy. Its primary responsibilities are to

- analyse science and technology policy issues;
- recommend policy directions to government;
- alert Canadians to the impact of science and technology on their lives;
- stimulate discussion of science and technology policy among governments, industry and academic institutions.

Science Council of Canada
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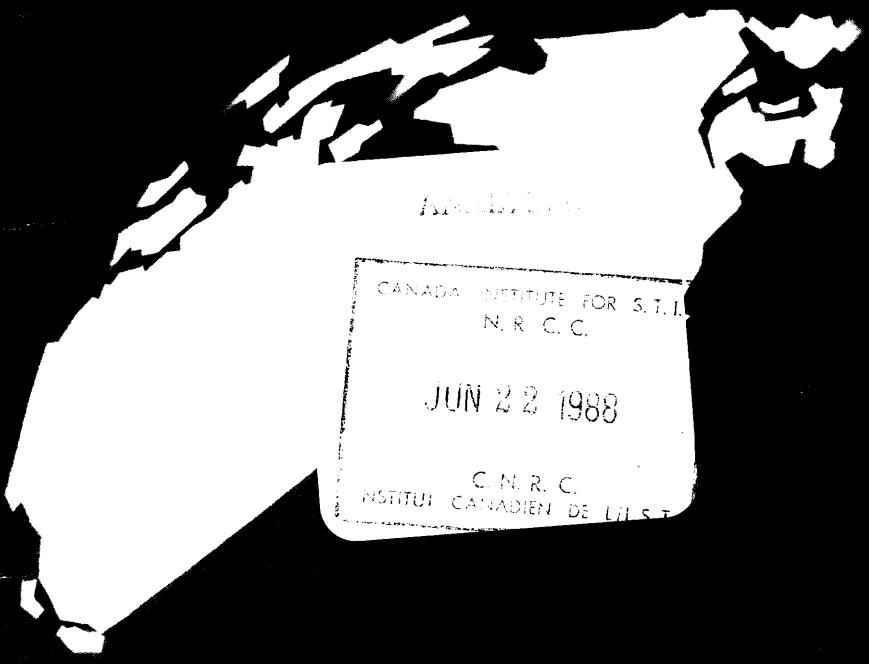
Summary of Report 39

Winning in a World Economy

University-Industry Interaction and Economic Renewal in Canada



Science Council of Canada
Conseil des sciences du Canada

Summary of Report 39

Winning in a World Economy

University-Industry Interaction and Economic Renewal in Canada

April 1988

The Science Council of Canada believes that the intellectual resources of Canada's universities have a critical role to play in economic renewal. Because of the significance of university collaboration with industry and since so little was known about whether the country's universities were achieving their full potential in this area, the Science Council undertook a comprehensive, three-year research project to investigate university-industry linkages and develop recommendations for their improvement.

The research program reviewed the important forms of university-industry collaboration for Canada, focusing on both research and educational linkages. Ten background discussion papers and workshop proceedings were prepared and have been published by the Council. Although the Council's research program centred on university linkages involving science and engineering, two of the background publications concentrate on important, related topics. One of these examines linkages in the humanities and social sciences, and the other surveys industry collaboration with community colleges and institutes.

The findings and recommendations presented in Report 39 and summarized here are based on this comprehensive research program. *Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada* aims to contribute to Canada's economic renewal by promoting closer and more effective collaboration between universities and industry.

Around the world, technological innovation has become the driving force in economic development. A new economic order based on global competition in knowledge-intensive industries is emerging.

A new economic order based on global competition in knowledge-intensive industries is emerging rapidly.

But while Canada, like other advanced economies, is undergoing a transformation to a knowledge-based economy, it is not keeping pace with competitors. In fact, Canada continues to increase its reliance on the export of raw materials and the import of manufactured goods at an alarming rate. Between 1978 and 1986, the country's high-technology trade deficit grew from under $3 billion to more than $7 billion.

Canada's deteriorating competitive position in knowledge-intensive industries poses a clear threat to its economic future and to its status as an industrialized nation.

The reversal of this trend depends on a more productive and efficient use being made of the country's research and development resources. To maintain and strengthen its competitive position, Canada needs to apply new technologies to the revitalization of existing industries and to the development of new ones. Research must be transformed quickly into useful and marketable products and services.

Canada needs to apply new technologies to the revitalization of existing industries and to the development of new ones.

University-Industry Collaboration Is Vital for Economic Renewal

In an age when international economic success increasingly depends on knowledge and technological innovation, universities need to engage more actively in economic renewal in Canada. Almost 25 per cent ($1.7 billion in 1987*) of total Canadian R&D is performed by universities. This proportion - larger than that in many other industrialized countries - reflects the low level of Canada's industrial R&D compared to its competitors. As a result, universities are being called on to help strengthen our industrial R&D by improving their collaboration with industry in both research and education.

The Science Council of Canada believes that if Canadian industry is to improve its international competitiveness, ways must be found to strengthen the role universities play in the economy. "Knowledge and technology transfer," which aims at the effective assimilation by industry

*Statistics Canada derives this figure from data on university research sponsored by outside sources (federal granting councils, other federal sources, provincial governments, business and others) and from an estimate of R&D expenditures by universities (based on numbers of faculty in each discipline and operating expenditures).

Universities must recognize that the transfer of knowledge and technology to industry is a legitimate activity and give it a high priority.

of intellectual property held or developed in universities, must be recognized as a legitimate activity and given a high institutional priority within universities (recommendation 1). Universities must reorient some of their activities to provide the teaching and research required by the private sector.

The demand to improve their linkages with industry comes, however, at a difficult time for universities. They face increasing external criticism about their isolation from society, criticism that is reflected in tensions within the universities themselves. Fundamental questions concerning the role of the university in society are being hotly debated: the pursuit of knowledge for its own sake versus knowledge developed to serve economic or social purposes, autonomy versus accountability, and individual academic freedom versus institutional planning and management.

Universities are also suffering from the consequences of more than a decade of stringent financial restraint. In Canada, as in many other countries, enrolments have grown much faster than funding for higher education. Between 1970 and 1983, enrolment rose 62.2 per cent while real public expenditures increased only 3.9 per cent. The consequences are readily apparent in dilapidated buildings, obsolete equipment, and overcrowded lecture rooms. The spirit of scholarship may be alive but quality and excellence are in peril.

A reassessment of the university's mission is necessary in order to resolve the tensions inside and outside the university's walls. Although financial constraints are important and must be dealt with, the Council's focus here is on the improvement of university-industry linkages. This is not fundamentally a financial question. The primary deterrent to better linkages is the common notion that universities function best when they are detached from society and the economy. Priority among university activities is now typically given to liberal education and fundamental research. These must remain important mandates of the university. At the same time, however, universities must contribute more effectively to economic renewal; they are the primary source of the people and knowledge so urgently needed for industrial revitalization.

The primary deterrent to better linkages is the common notion that universities function best when they are detached from society and the economy.

The Council found that some universities have begun developing programs aimed at making them more active participants in the transfer of knowledge and technology. Through these new programs, universities are reorienting their activities to become more deeply involved in the

community. They are broadening their instructional objectives to encompass both practical and theoretical experience, and emphasizing multidisciplinary research.

These programs point to the emergence of a new type of university, one that considers the entire range of professorial activity - from basic research through applied research to technological assistance and public information - as legitimate and important. As a part of this thrust, hiring, tenure, and promotion systems should increasingly recognize, support, and reward the transfer of knowledge and technology (recommendation 5).

Hiring, tenure, and promotion systems should recognize and reward the transfer of knowledge and technology to industry.

Raising the importance of the transfer of knowledge and technology to industry does not mean that universities abandon liberal education and research for the advancement of knowledge. Nevertheless, the new programs point the way to the future and Canadian universities as a whole have little choice but to follow their example. If universities do not reach out to meet the needs of society, these needs will be satisfied elsewhere and universities will diminish in importance.

Universities Have Made Progress in Improving Industry Linkages

University-industry collaboration not only contributes to local and national economies, it also fosters a climate of entrepreneurship, technological innovation, and economic diversification. For the universities, greater exposure to society and the economy contributes to a new degree of intellectual vitality. In addition, industry funding can help develop new activities and enhance the quality of existing programs.

University-industry collaboration fosters economic growth and contributes to the intellectual vitality of the universities.

Canadian universities are employing a number of different strategies to transfer knowledge and technology to industry. They are pursuing traditional forms of linkage such as consulting, contract research, and cooperative education more vigorously, and they are developing new forms of linkage such as joint ventures, research chairs sponsored by industry and the Natural Sciences and Engineering Research Council, science parks, and incubators.

The Science Council's study identified three fundamental and successful ways in which universities engage in and foster scientific and technological collaboration with industry: university services to support linkages, R&D linkages, and educational linkages.

University Services to Support Linkages

In recent years, Canadian universities have established a number of offices aimed specifically at promoting and supporting the transfer of knowledge and technology from the university to industry. The wide-ranging activities of these technology transfer offices include identifying commercially significant research, assisting in commercialization and marketing, and aiding in the establishment of spin-off companies. Typically, they maintain ties with outside private and governmental groups.

Universities should provide knowledge and technology transfer services and ensure that they are adequately staffed and funded.

Universities should provide special services for knowledge and technology transfer and ensure that these services are adequately staffed and funded (recommendation 6). Moreover, by establishing offices for technology transfer, universities not only provide a range of useful services, they also send a signal to business that they recognize the importance of technology transfer and the need to become more fully involved.

R&D Linkages

Traditionally, direct R&D linkages to commercial companies have been established by faculty acting independently. But as universities create more formal mechanisms to foster and facilitate collaboration, they should also ensure that the new linkages are evaluated for their effectiveness and continually improved (recommendation 9).

University-industry research centres offer a cutting-edge environment to researchers and provide industrial clients with R&D to enhance their competitive performance.

University-industry research centres are one of the more pervasive and successful mechanisms. These are interface institutions that cut across university disciplinary boundaries to address the particular needs of firms. The number of centres has increased rapidly in recent years and they are now found throughout the country. University-industry research centres can offer a cutting-edge environment to the researchers involved and, at the same time, provide industrial clients with R&D to enhance their competitive performance. Because of the valuable role these centres play in fostering knowledge and technology transfer, universities and governments should place a priority on their establishment and funding (recommendation 14).

Creating new firms based on university research and technology has proved an exciting but challenging method of knowledge transfer. The Council found examples of spin-off companies established by academic entrepreneurs in all parts of the country. Spin-offs, particularly those that are high-tech firms, can have great significance for regional and national economic prosperity.

The British Teaching Company Scheme provides a

model of another effective type of mechanism for encouraging university-industry cooperation. Under this program, an institution of higher education and a commercial firm enter into a contractual agreement to achieve specific R&D objectives that will benefit both parties.

The British Teaching Company Scheme has proven highly successful in transferring knowledge and technology to industry. The Science Council's study found that Canadian executives responded enthusiastically to the possibility of a similar program here. The Council therefore recommends that the Department of Industry, Science and Technology fund a pilot project (recommendation 15). The Canadian version, known as the Corporate-University Partnership Program, would broaden the scope of the British scheme to include business management as well as technology projects.

A Corporate-University Partnership Program should be piloted in Canada.

Educational Linkages

In a world economy increasingly driven by technological innovation, scientifically educated and technologically trained people are essential for Canada's industrial competitiveness. Universities have a key role to play in providing Canadian students and workers with the skills and knowledge needed to develop, adapt, apply, and manage new technologies. The Science Council found three key areas where university educational efforts can be highly productive: courses in technical entrepreneurship and the management of technological innovation, cooperative education, and continuing education.

Universities have a key role to play in providing the skills and knowledge needed to develop, adapt, apply, and manage new technologies.

Technically trained professionals often lack business skills, while business graduates may not adequately understand or appreciate the role science and technology play in economic performance. Many universities have risen to this educational challenge. In the past five years, they have dramatically increased the number of courses in the management of technological innovation and in technical entrepreneurship. Such courses are offered in the business and engineering faculties of 20 Canadian universities, primarily in central Canada.

Universities are also being challenged to reduce the gap between academic learning and its applications. In cooperative education, students bridge this gap by alternating between terms of formal instruction and terms of work experience. The Science Council's surveys found rapid growth in cooperative education programs and that all three groups involved - the students, the universities and colleges, and the employers - are very satisfied with them.

Accelerating technological change and growth in knowledge requires that more attention be paid to the job-related updating and retraining of all workers, including already highly-trained professionals in science and engineering. Universities are already collaborating with industry to help meet the continuing education needs of workers, thereby also fulfilling their educational function in new and important ways. But much remains to be done. In particular, we must adopt a strategic approach to lifelong learning.

Although universities have made significant progress in all three of the key educational areas identified - courses in technical entrepreneurship and the management of technological innovation, cooperative education, and continuing education - these efforts need to be strengthened if universities are to meet the educational needs of Canadian students and workers (recommendations 10, 11, and 12).

The Humanities, Social Sciences, and Colleges Need Stronger Linkages

The focus of the Council's study was university-industry linkages in science and technology. But it is important to put that focus in context by examining two important and closely related topics: university-industry linkages involving the humanities and social sciences, and interactions between industry and community colleges and institutes.

The humanities and social sciences become more important in a complex, knowledge-intensive economy.

The humanities and social sciences embrace a wide variety of disciplines, many of which - economics, business administration, and communications, for example - have much to contribute in a complex, knowledge-intensive economy.

Linkages in the humanities and social sciences exist in forms as diverse as those in science and engineering. For example, individual faculty may conduct market and productivity studies for firms or explore the impact of technological innovation in the workplace. In addition, some university research centres focus on economic issues and a few offer subscribers economic forecasts and policy analyses.

Generally, however, the humanities and social sciences linkages are more informal and receive less attention than those in science and engineering. There is a need for universities to build upon the existing links in the humanities and social sciences, and to develop new types of linkages especially suited to these disciplines (recommendation 2).

The same economic forces that are forging closer university-industry linkages are also drawing community colleges and institutes nearer to industry. These institutions are already more community-directed and industry-oriented than universities. They consult with employers about programs through their boards or through program advisory committees. They supply customized training to clients. Now the community colleges and institutions are shifting their priorities to provide even more support to industry. In addition to supplying educational services, they are expanding into collaborative research projects with industry.

Although they have a broader mandate than community colleges and institutes, universities can learn a good deal from them. Moreover, linkages with industry would be more effective if all parts of higher education in Canada cooperated and coordinated their industrial support activities (recommendation 13).

Linkages with industry would be more effective if all parts of higher education in Canada coordinated their industrial support activities.

Universities Must Overcome Deterrents and Forge New Linkages

There is some apprehension that an emphasis on knowledge and technology transfer to industry will limit the freedom of academics to advance knowledge for its own sake, threaten the university's function as an objective and dispassionate critic, and impede the free flow of information. As university-industry interactions intensify, university faculty and administrators will need to safeguard and promote fundamental academic values. Universities should no more be harnessed to industry than they should be isolated ivory towers.

However, the concern that industry might use its financial clout to threaten academic values seems unwarranted given the current low level of industry funding. In 1985, business support for R&D represented only 3.9 per cent ($60 million) of the total R&D funding available at Canadian institutions of higher education. At the same time, university R&D is concentrated in relatively few institutions: 15 per cent of institutions carry out 75 per cent of the R&D.

Universities are, in fact, far more at risk from the lack of participation by industry than from too much collaboration. The full participation of industry is necessary if linkages are to be effective and if the needed changes in universities are to take root. Unfortunately, industry often lacks awareness of the existing intellectual capital and

The full participation of industry is necessary if linkages are to be effective.

diverse range of advanced research in Canadian universities. Universities can ensure that industry understands their capabilities by establishing effective communications channels and consultation mechanisms with industry (recommendation 7). They can encourage closer collaboration by improving the marketing of their teaching and research capabilities (recommendation 8).

Increased government funding is required to give universities the flexibility they need to reorient their activities.

The universities' financial constraints are a major deterrent to effective university-industry interaction. But even a significant increase in industry financing would have little impact given its low current levels. Increased government funding is essential to give universities the flexibility they need to reorient their activities and engage in effective knowledge and technology transfer to industry.

Governments are already moving to provide additional financial incentives for collaboration. For example, the federal government recently increased its matching funding for the granting councils.* Federal and provincial governments should expand their incentive programs for existing educational and research linkages and for experimenting with new ones (recommendation 3). The universities also have a responsibility to encourage collaboration by ensuring that programs that effectively meet market or social needs receive an adequate share of university resources (recommendation 4).

Much progress has been made in linking universities and industries, and a new, positive attitude has emerged about the role universities can play in the economy. Yet the future of linkages is by no means assured. Most have not taken full root in the cultural ethos of the university and the level of interaction is still far from what is needed and from what the universities are capable of in terms of the talents and ideas within them.

There can be no single blueprint for all universities to follow. But Canadian universities must place a greater emphasis on the transfer of knowledge and technology to industry. It is essential that a flexible and supportive environment for industry collaboration be fostered within the universities so that they can fulfill their potential in contributing to Canada's economic renewal. Collaboration with industry, far from being a distraction, is a necessary part of the university's destiny.

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*The matching funding policy appears to have generated substantial amounts of money for collaborative research. Just how much new research has actually resulted remains to be seen.

Recommendations

Acknowledging Transfer in the University's Mission

1. Given that almost 25 per cent (an estimated $1.7 billion in 1987) of total Canadian R&D is performed by universities, they must ensure that the transfer of knowledge and technology to industry be developed as an integral and valued extension of their teaching and research mission.

Involving the Humanities and Social Sciences

2. Universities should make special efforts to build upon the already widespread practice of individual consulting by faculty in the humanities and social sciences, and to develop other types of links between that expertise and the needs of the private sector and society.

Financing University-Industry Linkages

3. Federal and provincial governments, in particular ministries of industry and higher education, should provide further special funds for supporting existing university-industry research and educational linkages, for experimenting with new ones, and for assessing their effectiveness.

4. Resource allocation both within and among universities should recognize and reward the transfer of knowledge and technology as one of the university sector's essential functions. Furthermore, goals for transfer activities should be established and the results evaluated on a regular basis.

Supporting Knowledge and Technology Transfer through University Policies and Services

5. University policies, especially those touching on hiring, tenure, and promotion, should recognize and reward the transfer of knowledge and technology as an acceptable and desirable function of the professor.

6. Universities should provide services to promote the transfer of knowledge and technology, such as those commonly offered by technology transfer offices, innovation foundations, distance education offices,

and continuing education services. These services must be adequately financed and staffed with the needed professional expertise.

Improving University-Industry Dialogue

7. Universities should formally and periodically assess the need for and performance of formal mechanisms (such as advisory boards, personnel exchange programs, and joint participation in research, education, and training projects) that increase consultation and the interchange of personnel with the private and public sectors.

8. Universities should ensure they successfully communicate and market their expertise to the private and public sectors. In particular, each university should maintain an accessible, up-to-date inventory of its research and teaching expertise and of its business opportunities.

9. Sponsors of university-industry linkages should ensure that the linkages are evaluated for effectiveness.

Developing Educational and Research Linkages

10. Canadian universities should continually assess their potential to expand and strengthen cooperative education, and actively search for new ways to fund such programs. Financial support from government and industry for cooperative education must be increased.

11. Courses in technical entrepreneurship and the management of technological innovation should be offered by universities to their science, engineering, and management undergraduates.

12. Universities and industry need to work together more closely to identify and develop mechanisms for responding to the continuing education needs of employees.

13. Universities and community colleges and institutes should coordinate their efforts in providing both degree/certificate courses and short-term courses for business and industry.

14. Universities should establish organizational units that transcend university disciplinary structures and address particular needs of the private sector, such as centres of excellence or university-industry research centres. For the next few years the units should be a priority for government funding.

15. The Department of Industry, Science and Technology should fund and assume overall national responsibility for a Corporate-University Partnership Program pilot project.

Background Discussion Papers and Workshop Proceedings

Ten discussion papers and workshop proceedings have been published during 1986-1988 by the Science Council as background for *Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada.*

- *University Offices for Technology Transfer: Toward the Service University*
- *University Spin-Off Firms: Helping the Ivory Tower go to Market*
- *University-Industry Research Centres: An Interface between University and Industry*
- *Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities*
- *The Teaching Company Scheme: A Study of its Application in Canada*
- *Postsecondary Cooperative Education in Canada*
- *R&D Links between Firms and Universities: Six Case Studies*
- *Learning from Each Other: University-Industry Collaboration in the Continuing Education of Scientists and Engineers*
- *Employer Interaction with Public Colleges and Institutes in Canada*
- *University-Industry Interaction in the Social Sciences and Humanities: A Threshold of Opportunity*

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Copies of the discussion papers listed on page 13 are available without charge from:

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