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THE UNIVERSITY-INDUSTRY RELATIONSHIP IN SCIENCE AND TECHNOLOGY

Occasional Paper Number 11
August 1995

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THE UNIVERSITY-INDUSTRY RELATIONSHIP IN SCIENCE AND TECHNOLOGY

by Jérôme Doutriaux et Margaret Barker
University of Ottawa et Meg Barker Consulting
Under contract to Industry Canada
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EXECUTIVE SUMMARY

This paper updates and improves our understanding of university–industry (U–I) relations in Canada. It begins with the volume of literature produced on this topic in the late 1980s and strengthens some of the initial, and perhaps, intuitive conclusions of this literature with findings from recent studies and some surveys. Benefiting from recent scholarship, the paper places significant emphasis on regional approaches to technology transfer. It insists that a variety of organizations — not just universities and industry — have important roles to play in technology transfer and local economic development, and suggests that both different sources of funding and approaches are important and should be complementary.

Standard indicators show that the quality of research effort at Canadian universities is high and has a respectable international profile. Given that Canadian universities perform a major share of Canada's research and development (R&D) — with the per capita expenditures being among the highest of the Organization for Economic Co-operation and Development (OECD) countries, academic research takes on a special significance, and its efficient transfer to industry is important. This is a challenge for Canada: the overall propensity of Canadian business to locate, adapt and assimilate new ideas and technology is low. This leads to a lower probability for innovation and growth. To assess whether strengthening university–industry links in Canada will improve the tendency of firms to innovate, more information is needed on the socio-economic impact of the academic sector on the economy.

The socio-economic impact of the higher-education sector on the economy includes three areas.

- Fundamental and applied research activities of universities contribute to the stock of knowledge in the economy.
- Universities provide highly trained human resources.
- The sector supplies ideas and inventions through technology transfer.

To analyze socio-economic impact, economists are obliged to dissociate variables, and the most commonly known work is that which focuses on the impact of academic knowledge creation on samples of firms. Research of this nature in the United States indicates that both university and university–industry R&D links have strong rates of return in terms of social impact. Estimates reach as high as 40 percent, although different industry sectors rely on university research in various degrees, with the more R&D-intensive sectors developing closer links. Analyses point to increased probability for innovation, profitability and growth among firms which form linkages with universities, but, to locate and assimilate knowledge, expertise and technology, such firms must already have in-house technical capabilities.

Our compilation of the statistics on industry sponsorship of university-based R&D in

Canada indicates a rising trend, similar to findings in the United States, although Canadian data on this topic must be used with extreme caution as they are not sufficiently standardized nor subject to rigorous quality control. Industry sponsorship of university R&D in Canada was estimated at four percent in 1980, rising to 7.5 percent in 1992. It jumped to an estimated 11 percent in 1993 following an influx of funding for pharmaceutical R&D in the wake of the *Patent Act* (Bill C-91) which eliminated compulsory licensing and extended patent protection for Canadian-based pharmaceutical firms. In the United States, industrial sponsorship of academic research represented less than four percent of total funding in 1980, and this figure had risen to just over seven percent in 1993. These results point to a growing tendency of firms to use universities for their research needs. On the basis of surveys carried out by Canadian organizations, we conclude that this is mainly the result of the activities of large, R&D-intensive companies in Canada. For the most part, Canadian small- and medium-sized enterprises (SMEs) do not avail themselves of the technology and ideas coming from the universities. It is, therefore, important to discover how to improve this situation. To do this, we examine the literature on the place of U–I collaboration in regional economic growth.

Studies of fast-growing high-technology regions have shown that even if universities are not a direct causal factor, they are certainly one of the catalysts for effective regional economic development. Successful innovation-based regional growth depends on a number of conditions which facilitate university–industry and firm-to-firm communications and collaboration, including:

- a regional knowledge-base, founded on a mix of universities, colleges and research laboratories;
- clusters of large and small high-technology firms;
- proactive support groups and organizations, such as networks, intermediary organizations and business service units working jointly with the regional government;
- adequate local communication and transportation infrastructure which permits access to international, national and local sites;
- a physical closeness between the relevant institutions; and
- complementary federal, provincial and local policies supportive of university–industry links based on research and development and training.

Unfortunately, there appear to be very few recent analytical studies on the impact of Canadian regional organizations on U–I interaction and local economic development. Studies discussed in this paper concern the Ottawa-Carleton area and the Waterloo-Kitchener-Guelph-Cambridge region.

Governments of OECD countries have been introducing different forms of U–I programs since the 1960s, but these have received more emphasis in the last decade. In Canada, federal and provincial governments have developed a number of programs to promote U–I relationships in science and technology. Relevant Canadian agencies have been developing some innovative programming in this area to meet changing circumstances and demands. Matching-fund programs developed in the 1970s and 1980s tended to meet the needs of large corporations which look to the universities for basic and pre-competitive research. New programs being introduced by federal and provincial agencies seem to meet the needs of high-technology SMEs better, although an emphasis on colleges in some regions, together with a national technology extension initiative (the Canadian Technology Network) and the development of new electronic tools, indicate a more broad-based approach. The challenge remains to reach SMEs in traditional sectors. In British Columbia, Quebec and Ontario, this problem is being partially tackled with an emphasis on technology diffusion and transfer at colleges and technical institutes, and includes student industrial projects and contract technology training and development. Networking, including electronic, provides an element of co-ordination to these provincial efforts.

In the United States, federal funds have successfully supported U–I collaboration, according to recent investigations on this topic. While overall support of university R&D by industry is just over seven percent, industrial support of these research centres alone is in the neighbourhood of 31 percent. Approximately 15 percent of the academic research staff (faculty and other doctoral-level scientists) are involved in these centres. In Canada, analyses of this nature are not available, and future work in this area is recommended.

In other countries, various programs exist to encourage U–I collaboration. In some, the emphasis seems to be on training, with joint supervision of graduate students and their eventual absorption by industry. In others, U–I research centres combined with integrated U–I training are important, and colleges are being assigned important roles in local economic development and in technology diffusion to SMEs. In many countries, national electronic technology extension networks are being supported, capitalizing on information technology to enhance a national system of innovation.

Examination of the literature on the U–I interface from the perspective of the actors and agencies, supported with anecdotal evidence from a small survey, gives depth to the earlier discussion on regional economic development. The interface is examined in three areas: teaching and training linkages, research relationships and organizations relevant to U–I collaboration. There are various forms of teaching and training links, and circumstantial evidence indicates both sides of the relationship benefit from these mechanisms, but rigorous statistics to support this assertion are lacking.

Similarly, data on research-oriented linkages, of which there are many different types, are inadequate and unreliable but do indicate some general trends. Measures include the extent of industrial sponsorship of research and development at universities, invention disclosures, patents issued, active licences, biological agreements, royalties earned and spinoff companies generated. The data show large differences between universities in Canada, with some achieving substantial success in negotiating licensing agreements and generating spinoffs. Some of these differences, such as royalty income and the number of spinoffs, can be partly explained by the age and orientation of the university's research commercialization office, by its culture and by the personalities of those in charge of U–I activities. Other differences, such as the industrial funding of university research, can be explained at least partially by provincial variations.

Several organizations are relevant to U–I collaboration at the local level, including industry liaison offices (ILOs) at universities, colleges and technical institutes; the firms themselves and a subset of these, the university spinoff companies; regional development organizations; research parks; and industrial or academic consortia.

Unlike the situation a decade ago, most Canadian universities have an industrial liaison or technology transfer office or unit. Very few university ILOs are self-supporting financially, although the royalties are becoming significant for some universities. A rule of thumb is that such offices may expect to be self-financing by the end of 10 years. Large universities in the United States have realized significant revenue returns from royalties collected on inventions. There is reason to believe that such success could be achieved by many Canadian ILOs with adequate support for their activities. Indeed, in cases where sufficient resources and professional personnel have been assigned to university technology transfer, substantial activity has occurred. Interviews with survey participants suggest that a lack of funding hampers their activities, and that more support should be forthcoming from budgets set aside for economic development and job creation, rather than education budgets.

Firms on the U–I interface may be divided into a four types — large firms in either high-technology or traditional industrial sectors and small firms in high-technology or traditional industrial sectors. In the course of the small survey conducted for this study, representatives from large firms, and university ILOs alike, stressed the importance of sustaining basic research excellence at Canadian universities.

The literature in Canada suggests that spinoff companies form as a result of a lack of receptor capacity of local firms, despite the higher financial stakes involved in licensing. Academics who start companies do not always have the time, skills or motivation to manage companies. They must prevail against the traditional norms of, and barriers in, universities which, in career decisions, value researchers for publications rather than for inventive or entrepreneurial activity. Despite the odds, recent analysis on spinoff companies in Canada indicates that there could be as many as 300 of them, and that they have made a significant contribution to economic activity and job creation. Other, complementary research shows that those spinoff companies with the highest rates of initial growth come from research-intensive faculties with an external orientation, such as co-op programs, research networks and co-operative arrangements with regional development organizations, as well as being located in universities with a well-established ILO.

We draw several conclusions from this study.

- University research and development and U–I linkages generate a high social rate of return.
- Basic research should continue to be adequately supported at universities. Research

excellence was reported by firms and ILOs alike to be one of the primary factors underlying technology transfer and the supply of personnel to industry.

- Because Canadian universities perform a large share of domestic research and development and Canadian firms are not, on the whole, highly innovative, the efficient transfer of technology to the domestic market is important.
- University and college ILOs, when professionally staffed and allocated sufficient resources, are an important asset for U–I linkages and technology transfer. A well-run office appears to have a significant impact on the commercial activity generated by a given university.
- Other intermediary organizations, such as networks, consortia and regional economic development organizations also have critical roles to play in local U–I linkages and technology transfer and diffusion activities, and SMEs find them more approachable. Local economic development, including the forming of U–I links, appears to operate effectively when the different organizations, including ILOs, co-ordinate their activities and complement one another. The most effective technology-transfer and -diffusion activity seems to take place where the initiative arises locally.
- Industrial sponsorship of university-based R&D is on the rise in Canada. It is critical that sufficient resources are available to improve statistics and analyze this phenomenon, and that policy implications of this trend, such as the impact on the free exchange of knowledge, are thoroughly explored.

One finding of this background study is that the topic of U–I relations does not appear to attract a great deal of scholarly interest in Canada, despite the seeming importance of the subject area. To repair this lack of knowledge, the following areas are suggested for further research:

- estimations of the social rate of return of U–I links in Canada, giving attention to the probable differences among industrial sectors and geographical regions;
- analyses of the role of the higher-education sector in regional economic growth in Canada, using a case-study approach to generate role models;
- determination on the extent of, and trends in, industrial sponsorship of university-based R&D in Canada, based on improved statistical information and analysis;
- analysis of the relationship between university training activities (traditional and externally oriented) and the cultivation of U–I linkages, across all sizes of firms;
- investigation of the commercialization activities of Canadian industry liaison offices (ILOs) at universities, related research institutes, technical institutes and colleges, including the development of standardized measures; and
- exploration of the econonomic benefits generated by university spinoff companies, including testing the notion that such companies are building technological receptor capacity in Canada.

INTRODUCTION

The Context

The notion that domestic industry should benefit from university-based research and expertise has a long history in Canada. Such findings as the demand of the Canadian Manufacturers' Association in 1900 for closer ties between business and higher education,[1] and records of public debate on the issue by the Cronyn Commission in 1919,[2] indicate that the idea has had some currency since the beginning of this century. On the basis of this and other reseach, some investigators have argued that the history of university–industry (U–I) interaction in Canada has been distinguished by some significant commitments by the two partners, and that it is incorrect to assume a situation of "the two solitudes."[3] It is certainly true that many university–industry research centres have existed for some time.[4]

In contrast, other researchers insist that, up until the early 1980s, the relationship between firms and universities in Canada could be characterized as traditional and minimalist, involving a few large firms in economically important industrial sectors.[5] Before that time, it is suggested, interaction between Canadian-based firms and universities typically assumed forms such as corporate donations, the appointment of corporate representatives on university boards of governors, the hiring of graduates by firms and the periodic enrolment of professionals from industry.[6]

No rigorous historical account of Canadian U–I relationships exists which could settle the debate, although a recent study carried out for the United States may spur interest in such an

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[1] Science Council of Canada, *University Offices for Technology Transfer: Toward the Service University*, by Philip Enros and Michael Farley, discussion paper, 1986, p. 12.

[2] *A Science Policy for Canada*, Report of the Senate Special Committee on Science Policy, Chaired by the Hon. Maurice Lamontagne. vol. 1, 1970.

[3] Science Council of Canada, *University Offices*, op. cit., p. 12.

[4] Science Council of Canada, "University-Industry Research Centres: An Interface Between University and Industry," by Frances Anderson, proceedings of a workshop held in Montreal 22 to 23 May 1986, Science Council of Canada, 1987, p. 5.

[5] Alex Curran, "Academic-industrial collaboration: Is it worth the effort?" *Industry and Higher Education*, December 1993, p. 205; Corporate-Higher Education Forum (C-HEF), *Partnership for Growth: Corporate-University Cooperation in Canada*, a report prepared by Judith Maxwell and Stephanie Currie, 1984, pp. 9-19.

[6] C-HEF, *Partnership for Growth*, ibid., pp. 9-19.

undertaking.[7] What is generally agreed is that, whatever the real extent of Canadian U–I relations, the issue did not draw substantial attention with regards to public policy in the first two or three decades after World War II. Prevailing economic conditions, with growth and corporate profit the common experience in Canada up to the end of the 1960s, did not generate a cohesive, vocal, political agenda for forging U–I linkages. Indeed, the economic context was more conducive to business and institutional expansion and autonomy.

Challenges to Canada's pattern of economic growth began to appear in the 1970s. The entry of newly industrialized countries to the global stage with their competitive manufactured goods, the saturation of international markets with primary commodities and declining terms of trade for primary producers, together with a decline in productivity growth among Western industrialized countries beginning in the late 1970s were the important features of the changing international market. Related to these developments was a declining government revenue-base, a growing deficit and a corresponding financial squeeze on universities.

In the late 1970s, the idea that greater and more direct economic returns should be realized from public sector investment in research began to attract attention in the policy debates of the time. The tendency of universities to restrict themselves to the roles of providing highly trained personnel and to expanding the frontiers of knowledge began to be questioned. The issues of U–I interaction and the commercialization of academic research began to be vigorously pursued by a variety of public and private policy bodies in domestic and international spheres, and a large number of reports on this subject were produced. In Canada, public sources of literature on the subject for the 1980s and early 1990s included the Science Council of Canada,[8] the Corporate-Higher Education Forum,[9] the National Advisory Board on Science and Technology (NABST),[10] and the federal industry department.[11] The issue has also been debated by deans of engineering and business faculties, academic researchers and industry R&D

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[7] Nathan Rosenberg and Richard Nelson, "American universities and technical advance in industry," *Research Policy*, vol. 23, 1994, pp. 323-348.

[8] *Challenge of the Research Complex* (1981), *University-Industry Interaction* (1981), *The Machine in the Garden: The Advent of Industrial Research Infrastructure in the Academic Milieu* (1984); a series of background papers and conference /workshop proceedings for the review of U–I linkages, "University Science and Technology and the Canadian Economy," launched in 1984 and including *University Offices for Technology Transfer: Toward the Service University* (1986), "University Spin-Off Firms: Helping the Ivory Tower Go to Market" (workshop proceedings, 1987), "University-Industry Research Centres," op. cit., *R&D Links between Firms and Universities: Six Case Studies* (1987), "Learning from Each Other: University-Industry Collaboration in the Continuing Education of Scientists and Engineers," (workshop proceedings, 1987), *Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada* (1988).

[9] *Partnership for Growth*, op. cit., *Spending Smarter* (1985), *From Patrons to Partners* (1987).

[10] *University Committee* (1988), *Committee on Technology Acquisition and Diffusion* (1992).

[11] In 1992, it was called Industry and Science Canada, and the relevant report was called *The Whole Enterprise Strategy for the Acquisition and Diffusion of Technology* (1992).

managers at several technology-management workshops since the late 1980s. Finally, U–I collaboration has been a preoccupation of the Organization for Economic Co-operation and Development (OECD),[12] and has been explored in the academic literature.

Current economic theory is preoccupied with the notion that technological application accounts for the major strides in productivity growth.[13] Recent policy statements by the Canadian federal government emphasize the importance of technology diffusion to Canadian industry for economic growth, and the need to devise a ". . . systematic approach to move new ideas from conception through to development of commercial products and services." Emphasis is placed on technology adoption by small- and medium-sized enterprises (SMEs), who ". . . grow the most by use of new technologies," although raising the level of research and development (R&D) by large firms is also judged as desirable.[14] Institutions of higher education have the potential to play a positive role in enhancing Canada's "national system of innovation," along with other stakeholders, at a critical period in Canada's economic development.[15] There is also evidence of a commitment by Canadian universities to be active contributors to this "renewal," including applying efforts to improve U–I linkages, with special attention to SMEs.[16]

Recent presentations by American executives of large R&D-intensive firms indicate that industry is increasingly open to the idea of obtaining some of its research and development externally, from universities among other sources. A former vice-president of DuPont Company has stated that a process of rationalization and strategic pruning is taking place among large, research-intensive U.S. firms, who, faced with intense international competition, are containing costs by reaching out to existing sources of expertise rather than building their own internally.[17] The executive director of the U.S. Industrial Research Institute (IRI) recently stated that "Industrial R&D spending in the U.S. has been virtually flat since 1986." He cited a 1993 survey which indicated that member companies (260 major industrial firms) of the Institute were intending to reduce in-house basic research, and that they were ". . . turning more to universities

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[12] For example, *Industry and University: New Forms of Co-operation and Communication* (1984).

[13] For example, see the publications and working papers of the Canadian Institute for Advanced Research (CIAR), Program in Economic Growth.

[14] Canada, *Agenda: Jobs and Growth. Building a More Innovative Economy*, November 1994, pp. 61-62. See chapters 3 and 6.

[15] John de la Mothe, "Canada and the National System of Innovation," in *Resource Book for Science and Technology Consultations*, vol. II, August 1994, p. 18.

[16] Association of Universities and Colleges of Canada (AUCC), "Building on Our Strengths: Canada's Universities and the Renewal of the National System of Innovation," a brief submitted to the Secretariat for the National Science and Technology Policy Review, September 1994, pp. 7-9.

[17] Presentatation by Dr. Alexander MacLachlan, former senior vice-president and CEO of DuPont Co. and a participant of the Industrial Research Institute, at a June 1994 symposium, reported by Philip Abelson, "Evolution of Industrial Research," (editorial), *Science*, vol. 265, 15 July 1994, p. 299.

to provide basic research."[18] Our investigation for Canada indicates a similar trend. This and other issues related to U–I relations will be explored more fully in this paper.

Thus, it seems reasonable to suggest that internationally competitive forces obliging firms to innovate, combined with pressures on universities to seek financial support beyond that provided by government, throw up a strong stimulus for greater, but perhaps more strategic, interaction between the academic and corporate sectors in the 1990s and on into the 21st century. Events have moved the debate on U–I links beyond the assertion that there is a need for more. Rather, public- and private-sector agencies with an interest in U–I collaboration are focusing efforts on deriving best principles and practices in such a way as to contribute to domestic economic growth while safeguarding the traditional roles of the university to educate and to undertake research. As noted by the OECD, "Any observer of the current system of university-enterprise relations . . . will note that our understanding of these ties needs to be improved. The wide variety of the many relations which they can develop implies that their effects may widely differ from case to case."[19] It is in this spirit that the paper proceeds.

Objectives

This paper intends to update and improve understanding of the Canadian experience with U–I relations and, in the process, to direct attention to areas deserving policy interventions. The report begins with a review of the literature on the socio-economic impact of universities and of their linkages with industry in Chapter 1. An overview of U–I programs supported by public and private agencies, in Canada and elsewhere, follows in Chapter 2. Summaries of recent evaluations or analyses are included where available. Chapter 3 is a review of the current practices of the main actors in U–I linkages. The last section of this report, Chapter 4, gives our conclusions and recommendations, comments on the limits of the state of knowledge and suggests studies that could provide the information needed for a better evaluation of U–I linkages.

Methodology

This report was based on a detailed review of the recent literature, research reports and other analyses on the topic, on a limited number of face-to-face interviews with government officials responsible for various U–I programs in Canada and on a small number of telephone

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[18] Presentation made by Charles F. Larson, executive director of the Institute Research Institute (IRI), to the 1994 Colloquium on Science & Technology Policy sponsored by the American Association for the Advancement of Science (AAAS), reported by David J. Hanson, *Chemical & Engineering News*, 25 April 1994, p. 38.

[19] OECD, *University-enterprise relations in OECD member countries*, (DSTI/SPR/89.37), Paris, 1990.

interviews with representatives of small and large firms, university–industry liaison offices, industry and university consortia and networks, and regional development organizations.

Limits of the Analysis

The small amount of time available for this study (June to August 1994) limited the scope for original research work based on formal surveys of universities and business firms. In addition, the necessity of conducting research during the summer made access to university and industry officials involved in university–industry liaison or technology transfer problematic.

1. SOCIO-ECONOMIC IMPACT OF UNIVERSITY–INDUSTRY LINKAGES

Over the last decade, a diversity of interactions between institutions of higher education and firms has developed, ranging from such arrangements as graduate scholarships in industry, to industrial research chairs, to licensing of university technology to firms. The different types of U–I mechanisms are described in Chapter 3, Management of the University–Industry Interface.

The development of new forms of collaboration, while praiseworthy, is not sufficient to merit private or public support in and of itself. Increasing constraints on the public sector budget have generated a more pointed demand for accountability, including evaluations of the cost-effectiveness of universities.

Unfortunately, relatively few analytical studies have been undertaken to quantify the socio-economic returns from public investment in university research, or the impact of U–I collaboration on the economy. This is not because this research is not deemed important by academic researchers and policy analysts, but rather, the complexity of the subject defies conventional approaches. These challenges will be discussed in more detail, below.

University Contribution to Science and Technology Output, Canada and Other Countries

Canadian universities performed 26 percent of Canada's domestic R&D in 1993,[20] a proportion higher than in most other OECD countries (Table 1). Canada is among the top spenders in terms of gross domestic expenditure on R&D (GERD) at universities on a per capita basis, trailing only the United States and Japan. Because of limited GERD in Canada, small defence R&D spending, and low industrial R&D expenditures (Table 2), university research takes on a special significance. The quality of academic research and its efficient transfer to industry are, therefore, especially important.

[20] Statistics Canada, "Science Statistics," as cited in Canada, *Resource Book for Science and Technology Consultations*, vol. I. Ottawa: 1994. pp. 3-5.

Table 1
R&D Performed in Higher Education

	As percentage of Gross Domestic Expenditure on R&D (GERD)			In C$ per capita
	1981	1986	1991	1991
United States	14	14	16.4	100
Japan	24	20	17.5	95
Germany	15.5	14	15.9	71
France	16.5	15	14.5	64
Great Britain	13.2	14.5	14.7	48
Italy	18	20	19.8	48
Canada	25.5	22.5	26	75
Netherlands	23	22	n.d.	n.d.

Source: estimated from OECD 1992 TEP report, Figure 3, page 34, and, for 1991, *Indicateurs de l'activité scientifique et technologique du Québec, Compendium 1994*, table 3.4 and Government of Canada, *Resource Book for Science and Technology Consultations*, vol. I, June 1994, table 4.1 and 4.2, page 24.

Keeping in mind that indicators of scientific activity have their drawbacks,[21] the following points may be made about the quality of university research in Canada. Judged on their research credentials, Canada's university scientists are competent, productive and recognized by their internationational peers. In 1990, Canada, with 858 publications per million inhabitants, came sixth in the world on the measure of scientific publication output.[22] Canada came third in terms of publications per million of dollars of Gross Domestic Expenditure on

[21] Weaknesses are dealt with in turn.

[22] After Israel (1189), Switzerland (1136), Sweden (1078), the Netherlands (918) and Denmark (860), and before the United States (698), the United Kingdom (664) and Japan (326). From *Indicateurs de l'activité scientifique et technologique du Québec, Compendium 1994*, Québec, Ministère de l'industrie, du commerce, de la science et de la technologie, tableau 5.2.

A reluctance to publish research results of potential commercial value has apparently been noted for the United States: "Notwithstanding the increase in R&D expenditures, a significant reduction in the number of scientific publications has been observed in the United States," from *La Recherche*, 1989, p. 429, but cited in Carlos M. Correa, "Trends in technology transfer: implications for developing countries," *Science and Public Policy*, vol. 21, no. 6, December 1994, p. 376. A related OECD extract is cited in the same article (page 376): ". . . the norm of rapid and total disclosure of new knowledge has been subjected to extraordinary strains. Great financial awards can be earned by keeping certain vital scientific knowledge secret and by moving with it to the business enterprise sector . . .," from OECD, *Technology and the Economy, The Key Relationships*, Paris, 1992, p. 35.

Research and Development (GERD) at 3.13.[23] As for quality, Canadian scientific publications accounted for 4.35 percent of the world's output in 1986, and 4.13 percent of world scientific citations in the same year,[24] indicating an average performance.[25]

Canada has slightly fewer scientifically trained people than the average among OECD countries,[26] but awards slightly more university degrees, although these tend to be less in the natural sciences and engineering than in other areas.[27]

The problem for Canada, however, as for many other industrial countries, is that assimilation by the domestic economy of the results from research, including those emanating from the academic sector, is, on the whole, unimpressive. Using the number of patents as a proximate index of technological productivity, Canada is lagging behind most of its trading partners. With an average of one patent registered in Canada by Canadian residents per 10 000 inhabitants between 1985 and 1990, it comes well after Japan (27), the United States (3.6), the United Kingdom (3.4) and France (2.3). Data on the proportion of patents which may be

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[23] After Denmark (3.54) and Australia (3.38), before the Netherlands (2.83), Sweden (2.34), the United States (1.17), France (1.08), the United Kingdom (1.89), Japan (0.60). From *Indicateurs de l'activité scientifique et technologique du Québec*, op. cit., tableau 5.2.

[24] Comparable numbers are 35.6 percent and 51.4 percent respectively for the United States, which is the world leader in citation ratios, 7.69 percent and 5.89 percent for Japan, 4.87 percent and 4.26 percent for France. B.R. Martin et al., "Recent Trends in the Output and Impact of British Science," *Science and Public Policy*, 19, 5, February 1990, cited in Canada, *Manuel de référence pour les consultations sur les sciences et la technologie*, vol. I, June 1994, p. 28.

[25] Citation analysis, like any performance measure of scientific productivity and quality, must be used with caution, taking into account the following limitations: i) high numbers may indicate a rash of critical comment on a contentious article as well as papers making positive contributions to the field, ii) the potential for self-citation or citation circles (mutual group citations), iii) "obliteration phenomenon" where breakthroughs become so well accepted they are no longer cited, and iv) the fact that citations are "lagging indicators," i.e., up to two years out of date by the time the work is published (from Garfield and Welljams-Dorof, "Citation data: their use as quantitative indicators for science and technology evaluation and policy-making," *Science and Public Policy*, 19, 5, October 1992, pp. 325-326). One other limitation must be noted, that is a striking American bias of current indices, published by the U.S.-based Institute for Scientific Information, which does not necessarily monitor journals which are of limited interest to Americans (from G.T. Harris, "Research Output in Australian University Economics Departments," *Australian Economic Papers*, 27, 50, pp. 102-110).

[26] *Manuel de référence*, op. cit, tableau 4.7. Figures for scientific and research manpower per 10 000 inhabitants are as follows: Canada 4.6, United States 7.6, Japan 7.3, United Kingdon 4.6, Sweden 5.5, France 5.0, Italy 3.1.

[27] *Indicateurs de l'activité scientifique*, op. cit., tableaux 9.9, 9.10. Among OECD countries, university degrees awarded per 10 000 inhabitants in 1990 were as follows: Canada 3.6, Japan 7.3, United States 4.2, United Kingdom 4.8, France 2.8, Germany 3.1. The percentage of the total number of degrees awarded in natural science and engineering are as follows: Canada 16 percent, Japan 26 percent, United States 18 percent, France 26 percent, United Kingdom 29 percent, Germany 13 percent, Sweden 26 percent.

ascribed to universities are, unfortunately, lacking in Canada.[28]

Similarly, in terms of self-sufficiency,[29] with its seven percent claim on its own domestic market, Canada was far behind Japan (88 percent), the United States (52 percent), the United Kingdom (21 percent) and France (16 percent).[30] While it is true that patents are inexact indicators of technological productivity,[31] the trend of these values indicates a relatively less-developed system of national innovation. Indeed, with the generation of countless studies on the subject, it is widely recognized that ". . . Canada is not a nation of innovators,"[32] and that, although business expenditure on R&D has been growing, the country still ". . . has an extremely narrow business base doing R&D . . . and that diffusion of advanced manufacturing is also low."[33]

To sum up, given the large share of domestic R&D activity conducted within the academic sector, and its high quality, universities are potentially very important to the country's scientific and technological development. As was shown, Canadian academic scientists are very active in terms of publications. Unfortunately, the Canadian record in terms of patents is relatively poor, indicating, perhaps, a well-developed domestic theoretical research capability located mainly at universities, but less domestic activity in applied research and engineering. Earlier it was pointed out that industrial R&D spending in Canada is relatively low compared to other OECD countries (Table 2). This leads us to ask if there is any evidence that enhanced U–I

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[28] In Canada, it has proven difficult to obtain accurate statistics on the number of patents issued to inventors resident in Canadian universities. Patent applications do not require university scientists to list the institutions in which they work, for universities across Canada have different policies and practices with regard to the ownership and management of intellectual property (IP). Personal communication with Ed Rymek, Director, Information and Technology Exploitation, Canadian Intellectual Property Office (CIPO), 7 March 1995.

[29] Percentage of patent applications by residents within their country.

[30] *Indicateurs de l'activité scientifique*, op. cit., tableaux 6.2, 6.3.

[31] Although patents are often used as an indirect measure of industrial innovations, the relationship is not always straightforward, in particular because of their heterogeneity; indeed, not all patents filed actually lead to commercialized inventions. Second, not all intellectual property is technically patentable, most notably software, which is protected in most countries by copyright. Third, the inclination to patent varies substantially across technological areas and industries. For example, patents are vitally important to the pharmaceutical industry, where lead times average about 10 years. However, they are not significant in nuclear physics, which is conducted not by firms but by government agencies in a highly regulated environment. The estimated time between discovery and commercial activity is about 20 years, exceeding the life of the patent. Finally, patent applications by a firm in any given market are a reflection of its perception of achieving a profitable market share and are dependent on its orientation toward international trade. Consequently, large foreign markets may attract more patenting activity than the domestic market of origin for any given firm. For more on this topic, see, for example, D. Archibugi, "Patenting as an indicator of technological innovation: a review," *Science and Public Policy*, 19, 6, 1992, pp. 357-368.

[32] Canada, *Resource Book*, op. cit., p. 2.

[33] Ibid.

linkages can lead to more innovative activity and improve economic growth.

University–Industry Impact on Aggregate Economic Activity

Three types of university contribution to the economy should be considered in the analysis of the impact of U–I interactions:

- the fundamental and applied research activities of universities which contribute to the stock of scientific and technical knowledge in the economy;
- the training activities of universities which supply human resources with knowledge, technical and managerial skills; and
- U–I technology-transfer activities which facilitate industry's access to the academic stock of technical knowledge.

Table 2
Gross Domestic Expenditures on R&D, Per Capita and by Source, 1991

	GERD per capita ($)	GERD/GDP (%)	GERD/GDP (%), per source			
			Government (civil)	Government (military)	Industry	Other
United States	611	2.75	0.51	.78	1.40	0.06
Japan	544	2.87	0.43	.03	2.22	0.19
Germany	446	2.66	0.86	.11	1.61	0.08
France	439	2.42	0.74	.44	1.03	0.21
Great Britain	325	2.08	0.39	.32	1.04	0.33
Italy	226	1.32	0.56	.05	0.63	0.08
Canada	288	1.50	0.61	.05	0.61	0.23
Netherlands	315	1.91	0.75	.03	0.98	0.15
Sweden	485	2.90	0.80	.30	1.74	0.06

Source: Canada, *Resource Book for Science and Technology Consultations*, vol. I, June 1994, tables 4.1 and 4.2.

Table 3
Gross Domestic Expenditures on R&D by Source and Sector of Execution, 1993
($, million)

	Sector of Execution						
Source of financing	Federal government	Provincial government*	Indus-try	Universities	Non-profit organizations	Total	%
Federal government	1676	7	437	868	25	3013	28
Provincial government*	-	282	108	330	18	738	7
Industry	-	28	4101	206	15	4350	41
Universities	-	-	-	1133	-	1133	11
Non-profit organizations	-	-	-	213	59	272	3
Foreign sources	-	6	1027	11	10	1054	10
Total	1676	323	5673	2761	127	10 560	100
Percentage	16	3	54	26	1	100	

* includes other provincial organizations
Source: Canada, *Resource Book for Science and Technology Consultations*, vol. I, June 1994, table 1.1, page 3.

While there is little doubt that universities have a positive socio-economic impact on the economy, there are only a few studies which have tried to evaluate it. The first difficulty in this type of analysis is that, as pointed out above, U–I relationships are multidimensional. Second, their effect varies with the sector of activity. A third challenge is that the U–I interaction process is influenced by the personality and culture of the persons and groups involved and by a number of other actors in the environment: governments and their policies (local, regional, national), business conditions and resources, local and international competition, technology and product life cycles, local socio-economic conditions, to name just a few. Finally, the fact that the innovation process is not linear[34] presents a third problem for analyses of the impact of U–I linkages; how to account for the efficiency of a project which did not lead to the expected outcome ("it failed"), but which, indirectly, through skills development, knowledge or new inter-organizational linkages, led to another successful result. The outcome of investment in university research and development cannot be traced back to a source; socio-economic benefits, though substantial, are indirect. Consequently, the construction of models to analyze the socio-

[34] S.J. Kline and N. Rosenberg, 1986, "An overview of innovation," in National Academy of Engineering, *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, Washington: The National Academy Press, cited in OECD's *Technology and the Economy*, op. cit., p. 25.

economic impact of U–I interactions presents some unusual challenges. This complexity is compounded by a lack of appropriate standard, national and publicly available data.

Some researchers have tried to estimate multipliers to evaluate the aggregate economic effect, for example, in terms of jobs, the economic activity of a specific university, U–I activity such as R&D spending, and the number of researchers or students. The results of this approach are subject to such a high degree of uncertainty that the reliability of the method is questionable.[35]

The most useful measures of the economic impact of U–I linkages seem to come from studies focused on one of the three areas mentioned above, the impact of university R&D on industry. These analyses are based on an evaluation of the social rate of return of both university and industry-financed university research and development. Mansfield's work is among the better known. Basing his investigation on a random sample of 76 major American firms from seven different sectors, including information processing, electrical equipment, chemicals, instruments, drugs, metals and oil, he estimated that ". . . the social rate of return from academic research during 1975-78 is 28%, a figure that is based on crude (but seemingly conservative) calculations . . . ."[36] Mansfield estimated his social rate of return very conservatively, ". . . assuming that new products and processes based on recent academic research result in no social benefits other than to the innovator, which is ridiculously conservative."[37] A later study by Mansfield showed that "the social rate of return from academic research and industrial R&D combined . . . is about 40%" when the costs of the industrial plant, equipment and start-up are included,[38] which means that, together, academic research and industrial R&D are very productive investments.

A study on effects of U–I collaboration by Link and Rees[39] found a rate of return on R&D of 34.5 percent for firms with university links compared with 13.2 percent for firms without

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[35] Informal communication, Brian Guthrie, Hickling Corporation, 18 July 1994.

[36] E. Mansfield, "Academic research and industrial innovation," *Research Policy*, 20, 1991, p. 11.

[37] The "social rate of return" in Mansfield's work refers to the benefits derived from new U.S. sales and reduced production costs minus the annual funding of academic research worldwide. In other words, Mansfield chooses not to quantify benefits other than those accruing to the innovating firm. See Mansfield, ibid., pp. 9, 10, and U.S. Congressional Budget Office, "A Review of Edwin Mansfield's Estimate of the Rate of Return From Academic Research and its Relevance to the Federal Budget Process," p. 5.

[38] E. Mansfield, "Academic research and industrial innovation: A further note," *Research Policy*, 21, 1992, p. 296. This rate of return is of the same magnitude as the rates found for "total" industrial R&D by a number of researchers in the 1970s; see, for example, W.H. Gauvin, "Contribution of Research and Development to Economic Growth," *Chemistry in Canada*, May 1981, p. 19.

[39] A.N. Link and J. Rees, "Firm size, university-based research and the returns to R&D," *Small Business Economics*, 2, 1990, p. 25-31, cited by A. Webster, *Science and Public Policy*, April 1994, 21, 2, p. 75.

such links. Berman[40] has found evidence that the ". . . effect of collaboration on industry research is lagged by about five years . . . [which is] shorter than . . . the use of undirected academic science which results in a lag of about 12 years . . ."

Also relevant to the present discussion is Mansfield's finding that the degree of reliance on academic research varied considerably among industrial sectors in the sample. About one tenth of the new products and processes commercialized during 1975 to 1985 in the firms selected ". . . could not have been developed (without substantial delay) [Footnote: "substantial delay" refers to a year or more ...] without recent academic research."[41] More R&D-intensive sectors, such as pharmaceuticals, rely substantially on academic R&D whereas others, such as the chemical and oil industries, do not. If the R&D-intensity of firms is held constant, there is no statistically significant difference among them in their propensity to use academic research.

Similar sectoral differences were obtained in a study by Jaffe in an analysis of 29 American states: "A significant effect of university research on corporate patents is found, particularly in the areas of drugs and medical technology, and electronics, optics and nuclear technology."[42] Jaffe's work pointed to an indirect effect of university research on local innovation by inducing industrial R&D spending. Although the precise nature of this relationship and its motivating forces are not revealed by Jaffe's approach, there is at least some indication that the U–I relationship is mutually beneficial and reinforcing, as opposed to a mere substitute for industry-funded R&D. Efficient use by industry of U–I research linkages requires qualified people and an appropriate company culture. As noted by Webster, referring to a 1990 study by Lefever and Seaton, ". . . evidence shows that only those firms which have a solid grasp of their own technological competencies and needs are actually capable of the most effective linkages with external agencies, such as universities or other firms."[43]

To recap, the analyses above point to increased probability for innovation, profitability and growth among firms which form linkages with universities. In order to locate and assimilate knowledge, expertise and technology, such firms must already possess in-house technical capabilities. These analyses are based on U.S. data. Comparable studies, providing indications on return on investment for Canadian university R&D, are not available. That there is some benefit to industry, unmeasured though it may be, is clear from observations on the sponsorship of Canadian university R&D by business enterprise.

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[40] E.M. Berman, "The economic impact of industry-funded university R&D," *Research Policy*, 19, 1990, p. 353.

[41] Mansfield, "Academic research," 1991, op. cit. pp. 1-12.

[42] A.B. Jaffe, "Real Effects of Academic Research," *The American Economic Review*, December 1989, p. 957.

[43] A. Webster, "International evaluation of academic-industry relations: contexts and analysis," *Science and Public Policy*, 21, 2, April 1994, p. 74.

Data on sponsored research at Canadian universities can be obtained from Statistics Canada and the Canadian Association of University Business Officers (CAUBO). The quality of the data from some of these and other sources is, unfortunately, questionable, due to a lack of common definitions (e.g., disclosure, university spinoff) and insufficient quality control.[44]

Like most countries, academic research in Canada is financed mainly by the public sector (Table 3). According to a 1993 publication of Statistics Canada,[45] 41 percent of the $2.76 billion spent by universities on R&D in 1992 came from university operating funds, 31 percent came from the federal government, 12 percent from provincial governments and nearly 7.5 percent from industry.

In 1992, an influx of industrial funds, mainly to Quebec universities, caused a noticeable rise in industry-sponsored R&D at universities. Changes to the *Patent Act* (Bill C-91), which eliminated compulsory licensing and extended patent protection for pharmaceuticals from 17 to 20 years, was predicated on the commitment of pharmaceutical companies to carry out more R&D in Canada — which they did, especially in Quebec, where generous R&D tax incentives were in place, among other attractive features.[46] Thus, in a 1994 Statistics Canada publication,[47] industry support had increased to slightly more than 11 percent in 1993, with the federal government providing 31 percent, provincial governments 11.7 percent and university operating funds 37.6 percent out of a total amount of $2.75 billion.

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[44] For example, a recent survey by *Re$earch Money* on the question of R&D tax shelters indicated that in Quebec, McGill reported *net* inflow of private R&D research funding whereas Université de Montréal reported *gross* inflow (*Re$earch Money*, "Quebec's R&D tax shelters weigh heavily in ranking of Canada's top research universities during fiscal/92," 9 February 1994, pp. 6-7); the 1993 Association of University Technology Managers (AUTM) survey indicates only $3.5 million of federal government R&D sponsored at the University of British Columbia instead of the $83 million reported by CAUBO; AUTM reports $1.9 million of industry-sponsored R&D at University of Western Ontario, instead of the $15 million reported by CUIPG (*The AUTM Licensing Survey, Fiscal Years 1991 and 1992*, AUTM: Norwalk, Connecticut, October 1993, p. 76; and Canadian University Intellectual Property Group, "Program Proposal: Accelerating Utilisation of University Research by Canadian Industry," 6 June 1993, Table 1); and finally, in the same AUTM survey, the data on "federal" R&D funding for the University of Waterloo also include provincial funding. Even if the data were of good quality, its interpretation would have to take account of the inflow and outflow of research funds from and to other universities — Centres of Excellence funding being, for example, attributed by the granting agency, to the university managing the Centre rather than to the university actually performing the research.

[45] Statistics Canada, "Science Statistics," Cat. No. 88, vol. 17, no. 5, cited as the source of data for Table 1.1, "Expenditures on R&D, by Performing and Funding Sectors, 1993," in Canada, *Resource Book*, op. cit., p. 3.

[46] Bert Plaus, Project Leader, Public Sector Services, Science and Technology Division, Statistics Canada, personal communication, 6 March 1995. Member companies of the Pharmaceutical Manufacturers' Association of Canada (PMAC) invested $538 million into R&D in Canada in 1993, according to a survey by Peat Marwick Thorne, compared to $251 million allocated by the Medical Research Council. The PMAC investment ". . . represents a cumulative increase of 225% since 1988." Survey cited and discussed in *Re$earch Money*, "PMAC deflects generic industry's assault on drug patent changes with release of impressive new R&D spending data," vol. 8, no. 8, 11 May 1994, p. 1.

[47] Statistics Canada, "Science Statistics," Service Bulletin, vol. 18, no. 4, September 1994, p. 3, Table 2.

Comparable numbers for the United States in 1993 are 20.2 percent for academic institutions, 55.5 percent for federal funding, nine percent for state and local governments and just over seven percent ($1.5 billion) for funding by industry, indicating significantly more direct federal funding than in Canada.[48]

There are big regional differences in industrial funding of university R&D (13.2 percent in Quebec, 3.1 percent in Manitoba and Saskatchewan — see Table 4), which are due in part to industrial economic structure and, as noted above (and discussed in Chapter 2 on government programs), to provincial fiscal polices.

With total industry support representing slightly less than four percent of the funding for university R&D in 1980, increasing to slightly over 11 percent in 1993,[49] one may observe that the growth rate over the period has been substantial in Canada. By means of comparison, industrial sponsorship of academic research in the United States represented just under four percent of total funding in 1980, which comprised less than one percent of all industry-funded research. In 1993, when industrially sponsored university R&D reached 7.3 percent, it represented 1.8 percent of all industrially supported R&D.[50] Industrial support of university research has increased dramatically in the United States in the last 15 years, at a rate of approximately 300 percent in constant dollars from 1978 to 1993, compared to an approximate doubling for other sources of support. It is interesting that the rate of growth in industrial sponsorship has slowed from its high of 12.3 percent in the early years, 1978 to 1986, to its current rate of 7.8 percent.[51] Whether or not this recent slowing of the growth rate for total industrial support of university R&D in the United States is reflective of the prudent R&D spending of the larger U.S. firms referred to earlier is not known.[52] Recent studies of U.S. university–industry research centres, partially funded by public sector sources, show that industry support to these centres is much higher than the national total, notwithstanding the recent deceleration in the overall growth rate.[53] We will discuss these trends in more detail in Chapter 2, where the focus is on public sector programs for U–I collaborations and evaluations of their impact.

The results of the AUTM surveys (Table 4), which included only a non-random sample of some of the largest and most research-intensive Canadian and U.S. universities, are noteworthy: average federal government support comes out to 57 percent of university research

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[48] National Science Foundation, *Science and Engineering Indicators 1993*, Table 5.2.

[49] Ibid.

[50] Ibid., p. 136.

[51] Ibid., p. 121.

[52] See Introduction to this paper, pp. 3-4, and related notes 17 and 18.

[53] Christine Mlot, "University-Industry Collaboration: Huge," *Science*, vol. 263, 4 March 1994, p. 1227.

expenditures in Canada and 71 percent in the United States, and industrial support comes to about 10 percent in Canada compared with nine percent in the United States. The average R&D budget of the U.S. universities in the sample is $158 million compared with $65 million for the Canadian universities, so the average flow of industrial funds into surveyed universities is slightly more than twice as high in the United States than in Canada, even if Canada has a slight comparative advantage with regards to percentage. Furthermore, the U.S. universities received about three times more funds in 1991 and 1992 from their federal government than their Canadian counterparts, a significantly higher share of their R&D expenditures than for Canadian respondents. The survey was not detailed enough to provide information on what was considered "federal" and "industrial" by university technology managers, nor did it indicate state or provincial flows of research funds, but it does tend to indicate that the ratio of federal to industrial research funds is higher in the United States than in Canada.

A few private sector organizations have estimated the importance of academic research to industry in Canada for non-random samples of companies by surveying firms, rather than universities. The Conference Board of Canada's annual survey of large Canadian companies (locally and foreign-owned), called the *R&D Outlook*,[54] has consistently identified universities as the first source of externally purchased R&D for member companies (before "other companies" and "industry research institutes to which company contributes financially"). Canadian universities were a source of purchased R&D in 64.6 percent of the cases in 1990, 68.3 percent in 1991 and 63 percent in 1992 (15 percent and 18 percent from universities outside Canada in 1991 and 1992 respectively). The Conference Board's survey consists of over 30 of the top-50 firms identified by the *Financial Post*, and the majority of these firms are the largest R&D-performing companies in Canada. No assessment of the cost-effectiveness of these purchases, however, is available.

The Conference Board results are consistent with the findings of a Canadian Research Management Association (CRMA) survey[55] that, in the case of larger firms (over 100 employees), 63 percent carried out some of their research and development by means of contractual arrangements with universities or government laboratories. Only 15 percent of the small firms included in the survey reported that they had made such arrangements for R&D with universities.

Some measures of specific U–I technology transfer activities are described in Chapter 3, Management of the U–I Interface. Again, data are incomplete, but the result is partial information on the socio-economic impact of U–I linkages. In a recent survey, the Association of University Technology Managers (AUTM) found that the 98 U.S. respondents to the survey had

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[54] Conference Board of Canada, Management of Innovation and Technology Program, *R&D Outlook*, 1992 (Table B-10), 1993 and 1994 (Table B-14); sample sizes (number of firms having purchased R&D outside) were 120 in 1991 and 100 in 1992.

[55] Canadian Research Management Association, *Effectiveness of University and Government Research Funded by Industrial Corporations*, 1991, p. 12.

received US$260 million in royalties in 1992 from 5518 active licences and that the nine Canadian respondents had received C$4.2 million from 261 active licences.[56] Another U.S. survey of 45 American universities identified 177 new products originating from university laboratories, which have led to 440 licences (264 to small businesses and 176 to large firms), as well as, since 1980, 357 start-ups created to exploit licences from the

Table 4
Industry Support to University R&D by Province, and Comparison with the U.S., 1991

	Total University R&D expenditures (C$, million)	Funding: Percentage from Industry	Funding: Percentage from Federal Government	Funding: Percentage from Provincial Government
Atlantic Provinces	183	3.2	42.1	6.5
Quebec	765	13.2	29.6	14.9
Ontario	1021	5.6	29.2	11.3
Manitoba/ Saskatchewan	191	3.1	28.8	8.9
Alberta	258	5.0	27.1	14.0
British Columbia	224	6.2	47.3	9.4
Total, Canada	2642	7.5	31.5	11.9
Total, U.S. (US$)	17 620	6.9	58	8.4
AUTM survey, Total 9 Canadian Universities	1991: 580	9.5	57.0*	
	1992: 588	10.0	57.8*	
AUTM survey, Total 98 U.S. Universities	1991: 14 409	8.8	71.5	
	1992: 16 224	8.9	71.9	

* After correction of federal funding numbers for UBC.
Source: *Resource Book for Science and Technology Consultations*, tableau 2.7, source cited as "Statistics Canada estimates"; NSF, *Science and Engineering Indicators* 1993, Table 5.2; AUTM, *The AUTM Licensing Survey, Fiscal Years 1991 and 1992*, pp. 20, 24, 75, 76 for last lines.

universities.[57] In Canada, a significant number of spinoffs and licences have also been created or negotiated by university Industry Liaison Offices (ILOs).[58] It is, however, difficult to estimate

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56 *The AUTM Licensing Survey*, op. cit., note 4, p. 3, p. 11 and p. 73.

57 Association of University Technology Managers, *Public Benefits Survey, Summary of Results*, AUTM: Norwalk, Connecticut, April 1994.

58 See Chapter 3 of this paper, the section on the universities and their Industry Liaison Offices.

the global socio-economic impact of these spinoffs and licences. Estimates of the value of the industrial sales and of the number of jobs created to generate these royalty flows[59] or economic multipliers for spinoff activity can be very misleading because they do not take into account the incremental effect of university research and the volatility of multipliers. These estimates of industrial sales of US$9 billion and 53 000 industrial jobs in the United States (effect of the patents of the 98 universities in the AUTM sample) and C$834 million and 6372 jobs in British Columbia (UBC patents and spinoffs) are, however, indicative for their order of magnitude.

Other approaches are being developed which may help to measure the contribution of university R&D to industry in Canada. For example, under the sponsorship of the OECD's Technology Economy Program (TEP), Canada, through Statistics Canada, is co-ordinating its activities with other OECD countries to standardize national surveys of sources of innovation for firms. The 1992 Technology and Innovation Survey, to be released in 1995, will include universities as a line item in questions relating to external sources of ideas for the adoption of technologically advanced equipment and software.

Finally, the Association of University Technology Managers (AUTM) has developed a licensing survey of its 260 members in Canada and the United States, and is attempting to construct a model which would measure economic multiplier effects of a given investment in technology transfer.[60]

To summarize the data on industry sponsorship of university R&D, indications are that domestically based business enterprise is responsible for a significant inflow of funds to Canadian universities, though amounts remain vague (between 7.5 and 11 percent) and growth rates are unknown. It appears that large firms provide much of this funding. Consistent with the literature above, these larger Canadian firms have their own in-house R&D capability and are in a position to acquire some of their R&D and technology needs from universities. The issue for current public policy, described earlier, is how to ensure that returns from public investment in research and development are also captured by domestically based SMEs. The regional approach

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[59] L. Berneman and A. Stevens (Dana-Farber Cancer Institute, Boston), "Technology Transfer and Economic Development," cited by R. Armit in his report on the 1994 annual meeting of the Association of University Technology Managers, The Technology Transfer Office in Changing Times, Phoenix, February 1994 (Carleton University Development Corporation, *The Technology Transfer Office in Changing Times: The 1994 Annual Meeting of the Association of University Technology Managers; A Summary Report,* 2 August 1994); and University of British Columbia, "The Economic Impact of the University of British Columbia," 1994.

[60] AUTM Annual Meeting, The Technology Transfer Office in Changing Times, Phoenix, Arizona, 26 February to 1 March 1994. The presentation, "Technology Transfer and Economic Development," included a description of work spearheaded by Ashley Stevens, Director, Office of Technology Transfer, Dana-Farber Cancer Institute, Boston. This approach for measuring return on public investment uses royalties to estimate product sales, employment generated and tax revenue earned. Royalty and other technology transfer data have been collected by AUTM from among its 260 full and affiliate members, and published in October 1993 as *The AUTM Licensing Survey, Fiscal Years 1991 and 1992*. A detailed summary of the meeting is available in a consultant report prepared by R. Armit, *The Technology Transfer Office*, op. cit.

to this problem is our next topic.

University–Industry Collaboration and Regional Development

It has long been observed, by the OECD[61] among others, that, even if no causal relationship has been found between proximity to a university and the location of research-intensive high-technology firms,[62] recognized centres of commercial innovation generally profit from links with universities. This observation has provoked a certain amount of international interest in the role of universities and regional economic growth, including a number of conferences.[63] Local U–I links, be they personal relations, industrial consulting by academics, exchanges of personnel between industry and university, or others, are often forerunners of direct technology-transfer activities involving the licensing of patents or other intellectual property to industry, or the creation of new business through spinoff companies.[64] It is by now conventional wisdom, for instance, that Silicon Valley near San Jose, California, and the historical Route 128 near Boston developed their entrepreneurial renown by relying on networks of relations developed with Stanford University and Massachusetts Institute of Technology (MIT), respectively. The assertion that universities have a role to play, albeit not necessarily a direct one, has been reinforced by David Birch's observation of the exceptional rate of development of the regions surrounding certain American technical universities in the 1970s and 1980s.[65]

We are thus led to ask: what are the ingredients of successful high-technology regional development? The existence of many case studies, including attempts to replicate the American

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[61] OECD, *Industry and University*, op. cit.

[62] "The locational concentration of R&D . . . favours established regions . . . where universities, industrial R&D, and national government R&D facilities and contracts are plentiful," but ". . . universities, an almost universally cited 'factor' accounting for the location of R&D . . . must be considered an overstated ingredient," E.J. Malecki, *Technology and Economic Development, The Dynamism of Local, Regional and National Change*, Longman Scientific and Technical, pp. 222 and 225.

[63] Such as Universities, Technology Development, Business Competitiveness, European/North American Regional Comparison, Grenoble, France, October 1990. The issue has also received a high profile in recent conferences in Canada, such as Management of Technology and Regional Development in a Global Environment, Montréal (École Polytechnique), October 1993, Technology-based Innovation in Business Strategy, joint conference CRMA/ADRIQ, Montréal, September 1993, and at the 1994 Vancouver joint LES/AUTM spring meeting which had a workshop on "The Role of Technology Transfer in Economic Development," with a presentation by A.G. Fowler of the UBC/Vancouver case.

[64] John T. Preston, Director of the Technology Licensing Office of MIT, "The Role of the University Licensing Office in Transferring Intellectual Property to Industry," paper distributed at a luncheon address of the Annual Meeting of the Ontario Centre for Materials Research, 15 May 1992.

[65] D. Birch, *Job Creation in America: How Our Smallest Companies Put the Most People to Work*, New York, The Free Press, 1987.

experience, help to answer this question. In the case of Silicon Valley in California, studies have noted the importance of the local entrepreneurial spirit, the availability of venture capital, the existence of very active information networks among experts, the presence of the Stanford Industrial Park, the talents, information and new technologies in local universities, the chance occurrence of a major new innovation (semi-conductors),[66] and government spending on defence research activities.[67] Similar factors were behind the development of Route 128 in Massachusetts.

Outside North America, one of the first major studies on the topic was by the consulting firm of Segal Quince & Partners[68] which noted that the emergence of several hundred high-tech firms in the Cambridge, England area[69] "is being driven by small local enterprises, and that other local resources — the university, banks, business community and so on — have been inextricably involved in various ways in the whole development process."[70] A number of relevant points from the Cambridge study are worth citing:

- Because of the presence of Cambridge University, the region has a large number of technical people, a high quality of life, opportunities for interdisciplinary contacts and networking, and a general spirit of quality and individualism.
- Because of its international stature as a research institution and its "culture of excellence and openness," the university has attracted top researchers.
- Its hands-off policy and "liberal attitude towards the ownership and exploitation of intellectual property"[71] have encouraged entrepreneurship and business venturing (17 percent of the firms in Segal Quince Wicksteed's sample of 261 firms were direct university spinoffs[72]).

Brighton, Smilor and Wallmark conducted a comparative study of Chalmers Institute of Technology (Sweden), the University of Texas at Austin (United States) and the University of

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[66] R.A. Joseph, "Silicon Valley myth and the origins of technology parks in Australia," *Science and Public Policy*, 16, 6, December 1989, p. 355.

[67] H. Lawton-Smith, "The location of innovative industry: The case of advanced technology industry in Oxfordshire," Research Paper 44, School of Geography, University of Oxford, 1990, p. 5.

[68] Segal Quince & Partners, *The Cambridge Phenomenon: the growth of high-technology industry in a university town*, Cambridge, 1985.

[69] There were about 450 firms with a total of 17 500 jobs (13.5 percent of the total employment of this region of 250 000 inhabitants) by 1987 (Segal Quince Wicksteed, *Universities, Enterprise and Local Economic Development*, a report for the Manpower Services Commission, London, England, 1988).

[70] Ibid., p. 14.

[71] Ibid., p. 16.

[72] Segal Quince Wicksteed, op. cit, p. 32.

Warwick (United Kingdom). They observed significant regional impact by the universities resulting from "direct employment and expenditure . . . provision of R&D, consultancy, testing services, etc. to local firms, recruitment of graduates by local firms, provision of training services, helping to attract companies to locate in the region, academic spin-out companies, science parks and innovation centers, and enhancing the quality of life in the region through provision of cultural, sporting and other similar facilities."[73] Emerging in this study, as in others, is the finding that the positive regional impact of universities was more the result of the quality of their research activities, their flexibility and their support for U–I interaction than of their definite intention to be proactive in the region. Partnership with local governments was also observed to be important.

Acs has stated that, ". . . while world class universities are necessary for high technology economic development, they have not proven sufficient."[74] Communication and networking are key factors for the development of a regional high-technology base. In samples of high-technology firms in the Ottawa and Waterloo areas, Houle found that 54.5 percent of business collaborators and 41.5 percent of university collaborators were in their immediate region.[75] Lawton Smith found that 16 percent of the firms in her sample of high-technology firms in Oxfordshire had been created to exploit inventions or innovations from universities and that universities were important sources of technical information (albeit not the most important direct one, coming after informal personal contacts, journals, customers and conferences).[76] Other researchers have also noted the significance of information networks between experts and the regional pull of universities.[77] These findings are supported by the literature on technological innovation, which documents the critical role of networks of formal and informal communication between firms (clients, suppliers, financial backers, university, public and private research laboratories). Their significance has also been noted in a recent survey in France.[78]

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[73] R. Brighton, R. Smilor and T. Wallmark, "Comparisons between Three Universities: Synopsis," *Proceedings, Universities, Technology Development, Business Competitiveness: European/North American Regional Comparisons, Conference*, Grenoble, 1990.

[74] Z.J. Acs, "High technology networks in Maryland: a case study," *Science and Public Policy*, 17, 5, October 1990, p. 315.

[75] F. Houle, "Chercheurs universitaires et entreprises: synergie et haute technologie dans deux régions ontariennes," communication, Canadian Association of Political Science, Charlottetown, June 1992.

[76] [76] H. Lawton-Smith, "Innovation and technical links: the case of advanced technology industry in Oxfordshire," *Area*, 22, 2, 1990, p. 6.

[77] See, for example, K.S. Louis, D. Blumenthal, M.E. Gluck and M.A. Stoto, "Entrepreneurs in Academe: an Exploration of Behavior among Life Scientists," *Administrative Science Quarterly*, 34, 1989, pp. 110-131; and Joseph, "Silicon Valley myth" op. cit., p. 355.

[78] A. Letwoski (France's Agence Nationale pour la Création d'Emplois), "Création innovante: un profil plus porté vers le partenariat inter-entreprise," communication at Entretiens Jacques Cartier, France-Quebec perspectives

In 1989, Smilor, Gibson and Kozmetsky[79] proposed the following list of major elements contributing to the research, communication, infrastructure and cultural needs of an emerging high-tech region:

- universities — excellence in research, availability of new technology, quality of training (technology, management), contribution to local quality of life and culture;
- local support groups — networking, communication, informal support groups;
- local government — infrastructure, quality of life, long-term vision;
- general government (provincial, federal, local) — R&D funding, funding for training, general R&D support, U–I encouragement, stable and consistent industrial technology policies;
- large corporation and large research laboratories — links with universities, attracting smaller firms and a source of talent for the emergence of new firms; and
- small emerging firms — commercialization of research, broadening of the local economic base, opportunities for venture capital, examples for spinoff firms.

Findings from recent studies of Ottawa and Waterloo tend to support the schematic structure above, although some regional variations occur. High-technology development in the Ottawa region[80] has benefited from the presence of government laboratories and of some large, R&D-intensive private research organizations, in particular Bell Northern Research (BNR). The region is described as a high-tech centre by its two regional economic development units, the Ottawa-Carleton Economic Development Corporation (OCEDCO) and the Société d'Aménagement de l'Outaouais (SAO). The Ottawa-Carleton Research Institute (OCRI), created by the regional municipality of Ottawa-Carleton, was a major stimulus for regional development. OCRI is a consortium of local firms, universities and colleges which encourages and supports co-operation, communication and networking among universities, colleges, private firms, public laboratories and other government agencies. It has been very successful in developing linkages between universities and local firms, links which had been relatively weak in the mid-1970s and almost exclusively with BNR.

Provincial and federal government programs have also contributed to Ottawa-Carleton regional development. For example, Ontario's Centre of Excellence program has led to the creation of the Telecommunication Research Institute of Ontario (TRIO), involving local university professors and companies in joint research activities. Support from the Natural

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on new approaches for the creation and the development of high-tech innovative firms, Lyon, France, December 1993.

[79] R.W. Smilor, D.V. Gibson and G. Kozmetsky, "Creating the Technopolis: High-Technology Development in Austin Texas," *Journal of Business Venturing*, 4, 1, January 1989, pp. 49-68.

[80] H. Lawton-Smith and M. Atkinson, "Industry-academic links and local development, the case of Ottawa," *Industry and Higher Education*, September 1992, pp. 151-160; C. Andrew, F. Houle and J.Y. Thériault, "La définition du local dans les nouvelles stratégies de développement," *Canadian Journal of Regional Science*, 15, 3, Autumn 1992.

Sciences and Engineering Research Council (NSERC) for industrial chairs (see Chapter 2) has resulted in more joint U–I work.

Of special note is the fact that very few spinoff firms in the Ottawa-Carleton region originated from the academic sector but, instead, from government labs and BNR. Another important feature in this regional high-tech development is that it began without much university involvement.[81] However, the situation has now changed and both universities and local firms profit from their joint activities and co-operation.

A similar type of multiparty co-operation has been observed in the Waterloo area, which has united the efforts of universities, governments and local corporations,[82] but in this case the initiative came from different sources. The University of Waterloo, with its distinct industrial orientation supported by a successful co-op program, and its productive and durable relations with such large private corporations as International Business Machines (IBM) and Digital Equipment Corporation (DEC), plays a major role in regional high-tech development. The university claims credit in the development of a significant number of spinoff corporations. Although two thirds of the sample of 33 key technology firms interviewed in 1988 listed the availability of skilled labour as their most important location decision factor, the other third reported "strong links with the local universities."[83] The course of regional development has been encouraged by local municipalities — Waterloo, Kitchener, Guelph and Cambridge, and by a co-ordinating structure, the "Technology Triangle" which promotes the region as a whole. Similar to the Ottawa-Carleton example, U–I activities have been encouraged by provincial and federal government programs promoting collaboration in research such as NSERC's industrial chairs, the Ontario Centres of Excellence and the national Networks of Centres of Excellence.

A study based on the Rhônes-Alpes regional experience in France draws attention to the important role of local development organizations and government in regional economic growth. Bertholon noted that universities are increasingly connected with industry through a series of partnerships and joint activities, but that the involvement of the government and local development organizations can significantly increase their effects for the regional economy. He concluded that a supportive role for government is to assist with communications and the dissemination of information in the public- and private-sector divide. Effective interventions by local development organizations should consist of enhancing the flow of technical information within the region and of providing the physical infrastructure, such as industrial parks, "business

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[81] G. Steed, “Policy and High Technology Complexes: Ottawa's 'Silicon Valley North,” in *Industrial Change in Advanced Economics*, F.E.I. Hamilton (ed.), Croom Helm, 1987, p. 264.

[82] Andrew, Houle and Thériault, op. cit.

[83] H. Bathelt, and A. Hecht, “Key Technology Industries in the Waterloo Region: Canada's Technology Triangle (CTT),” *The Canadian Geographer/Le géographe canadien*, 34, no. 3, 1990, p. 228.

incubators" and an appropriate tax regime attractive to in-coming firms and start-ups.[84]

In summary, these studies point to a number of successful interactions between small and large firms, institutions of higher education and government. Universities have the potential to be important catalysts in regional high-tech development.[85]

Conclusions, Limitations of Current Analyses and Recommendations

Canadian universities have a critical role to play in the development of technological capability and of international competitiveness for Canadian industry. Canadian university research is a significant component of the national R&D effort, and its quality and quantity are internationally competitive. However, this domestic research effort is not being adequately captured by the Canadian market.

The socio-economic impact of the higher-education sector on the economy has three characteristics: the fundamental and applied research activities of universities contributing to the stock of knowledge in the economy; the provision of highly trained human resources; and the supply of ideas and inventions through technology-transfer activities.

Achieving a more precise understanding of how university research contributes to socio-economic development has proven to be a challenge for academics and public policy analysts. Studies which have attempted to do this may be classified into three groups:

- the social rate of return of U–I linkages in terms of their impact on industry;
- the extent of reliance of firms on external sources of research and development, including universities; and
- the nature and blend of conditions necessary for effective regional U–I technology transfer.

Measurements of the social rate of return of university research have shown that returns may be as high as 40 percent, and that different industry sectors rely on university research in varying degrees, with the more R&D-intensive sectors developing closer U–I links. One limitation in this type of analysis is that, in attempting to measure a direct effect, it focuses on the knowledge output of university research, and how this is incorporated into industrial products and processes. This analysis cannot take account of other aspects such as the

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[84] G. Bertholon, "Emergence d'entreprises: environnement local et universitaire," communication at Entretiens Jacques Cartier, France-Quebec perspectives on new approaches for the creation and the development of high-tech innovative firms, Lyon, France, December 1993.

[85] J. Doutriaux, "L'université une pépinière d'entreprises?" communication at Entretiens Jacques Cartier, France-Quebec perspectives on new approaches for the creation and the development of high-tech innovative firms, Lyon, France, December 1993.

incorporation of academic knowledge in other social entities (e.g., government) or the training of new scientists and engineers. Despite the limitations, this form of analysis is a valuable contribution to academic and policy debates on the roles of universities in the economy. Because no comprensive studies of this nature, based on Canadian data, exist, these types of studies should be encouraged.

The collection of reliable statistical information and analyses on the extent of industrial sponsorship of university-based R&D in Canada is critical for achieving an accurate understanding of current trends. Organizations which normally collect the basic data, including the Canadian Association of University Business Offices (CAUBO) and Statistics Canada, do not necessarily have the resources for this important work. There is a related area deserving more study, the need to determine the extent to which firms, especially SMEs, rely on external sources such as universities and colleges for R&D, technology and technology training.

Effective U–I linkages tend to correlate with regions having clusters of high-technology firms. Research on this issue shows the success of high-technology regional development depends partly on a number of conditions which facilitate university–industry and firm-to-firm communications and collaboration, including:

- a rich, regional knowledge-base, founded on a mix of universities, colleges and research laboratories;
- clusters of large and small high-technology firms;
- local government and other support groups to provide leadership, vision and the appropriate local infrastructure;
- well-developed communication and transportation systems which permit easy access to international, national and local sites;
- physical closeness among research institutions for formal and informal exchanges and for networking; and
- in Canada, at least, complement among different levels and types of government support for university R&D and U–I collaboration.

While some conclusions may be drawn from these studies of successful regional socio-economic growth in Canada and elsewhere, it is evident that attempts to replicate these experiences must take into account the variations among localities. Industrial structure, regional research intensity and socio-economic fabric are just a few of the variables to consider.

2. GOVERNMENT PROGRAMS TO ENCOURAGE UNIVERSITY–INDUSTRY WORKING RELATIONSHIPS

This study recognizes that university research and training, across the spectrum from basic to applied, are critical to economic development. However, as the previous chapter shows, there are major challenges in quantifying the economic contribution that university research and training, together, make to the economy. Studies can only point to a general conclusion that there are positive economic benefits generated by U–I links. For these reasons, this chapter focuses on specific initiatives and programs intended to promote U–I relations. The review is not complete, but covers the most important federally supported programs, some provincial initiatives and some approaches being tried in foreign countries. Results from evaluations, where available, are included.

Federal Government Programs

Federal funding for university research, across the spectrum from basic to applied and including scholarships and fellowships, is largely administered by the granting councils. In 1969, the Medical Research Council (MRC) was created to promote basic, applied and clinical research in the health sciences. The Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC) were created in 1978 to promote research in the natural sciences and engineering, and the social sciences and humanities, respectively.

The Industrial Research Assistance Program (IRAP) of the National Research Council (NRC) is also discussed. It has played a role in forging U–I links and is a key federal agency in promoting the transfer of technology, knowledge and expertise from public-sector laboratories, and other sources, to business.

Space and time limitations here do not permit a detailed look at other federal programs relevant to U–I relations. However, it should be mentioned that, aside from the granting councils, there are a number of other federal agencies having an interest in U–I relations, as part of a larger concern to promote more technology transfer and diffusion in Canada. Indeed, direct federal support for U–I collaboration as a distinct activity was available as early as the late 1960s through the Department of Industry, Trade and Commerce. It began the Institutional Assistance Program (IAP), whose mission was to assist in the foundation of institutes to promote technology and knowledge transfer from research organizations, including universities, to Canadian industry. Seed financing was provided, with the expectation that the institutes would operate independently after a number of years. Transport Canada and the Department of

External Affairs also contributed to the financing of university–industry institutes.[86]

The tradition of assisting privately managed organizations in the transfer and diffusion of technology continued with the Technology Outreach Program (TOP) of Industry, Science and Technology Canada (now called Industry Canada), launched eight years ago.[87] Technology centres, administered by industry associations, provincial research organizations or centres associated with universities and colleges or institutes, engage in activities which ". . . accelerate the acquisition, development and diffusion of technology and critical managment skills."[88] Most of the 19 TOP-funded centres are specific to particular sectors, but some provide more general services. Two of these provide advice and assistance in the commercialization of research and inventions: the Montreal Industrial Innovation Centre and the Canadian Industrial Innovation Centre based in Waterloo. Some university technology transfer offices rely on the these centres for advice.

Industry Canada has recently launched a project to assist offices of technology transfer and industrial liaison at institutions of higher education. Trans-Forum is an information and communication tool which capitalizes on existing Internet connections in much of the Canadian academic sector. The program will deliver services such as on-line corporate data-base searches to help these offices market technology opportunities to Canadian firms and to provide a means for higher-education institutions to exchange useful information and advice.

The granting councils had some partnership programs in place before the 1980s. These programs were given a boost with the introduction of the Matching Policy program by the federal government in 1986. It was intended to promote more joint U–I research in Canada and to motivate the private sector to share the costs of funding university research. Granting councils could receive up to $369.2 million over the four fiscal years 1987-1988 to 1990-1991, to match cash and in-kind contributions from the private sector. These funds would have enabled the councils' budgets to grow by an average of six percent per annum if sufficient funds were provided to the universities by the private sector. The councils did secure the matching funds, but an evaluation of the policy made it clear that it was a cumbersome instrument, and it was terminated in 1991. The matching funds were added to the base budgets of the councils, partly to enable them to continue investing in university–industry programs — which the evaluation

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[86] C-HEF, *Partnership for Growth*, op. cit. pp. 29, 98-100. Examples of U–I institutes established with seed money provided by the Department of Regional and Industrial Expansion include the Canadian Industrial Innovation Centre in Waterloo and the Centre d'innovation industrielle in Montréal, but there are a great many others, totalling more than 25. Transport Canada assisted with the establishment of 11 centres, and External Affairs, four.

[87] *Re$earch Money*, "Technology Outreach Competition to Intensify as New Candidates Battle with Existing Centres for Limited Funds," 10 November 1993, p. 4.

[88] "Technology Outreach Program," program brochure, 1991, p. 1.

found directly contributed to meeting the objective of the matching policy.[89] Each of the three granting councils has its own programs.

Partnership Programs at NSERC

The Research Partnerships programs of NSERC encourage direct U–I collaboration by matching industry contributions to university basic and applied research.[90] In 1993, the Research Partnerships programs totalled $43 million, or about nine percent of NSERC's budget.

The Collaborative Research and Development (CRD) program supports defined R&D projects directed by a university professor and sponsored by industry through cash or in-kind contributions. NSERC's matching support is normally for three years. Since 1983, the CRD program has funded 1050 research proposals, with the total NSERC contribution to date reaching more than $159 million. The CRD has a long history; it was preceded by a Project Research Applicable in Industry (PRAI) program whose origins go back to NRC in 1970.[91]

The Industrial Research Chairs (IRC) program supports the salary of a senior university researcher, a research program and, eventually, the salary of other researchers for five-to-10 years in an area of interest to the industrial sponsor and of high priority to the university. Its goal is to help the university attain the critical mass needed to become a recognized research pole in the domain concerned. Since its beginning in 1983, the IRC program has supported the creation of 113 chairs at 29 universities involving 147 chair-holders.[92] NSERC support to date totals nearly $110 million; industrial support is at least equal to that.

The CRD and the IRC programs were evaluated in 1991.[93] The evaluation was based on 27 case studies of CRDs and 17 of IRCs from large and small universities across Canada. All disciplines were covered, with 44 percent of the cases in engineering and 23 percent in pure science. These percentages are representative of NSERC's actual Research Partnerships awards since 1990.[94] University researchers and their industrial sponsors have found both programs very

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[89] Nora Hockin (ISC), personal communication, 1 October 1993.

[90] The text on the Research Partnerships programs is adapted from documents and lists of NSERC awards received from Margaret Caughey, Research Partnerships programs, NSERC, 8 July 1994.

[91] Paul Latour, Director, Research Partnerships Programs, NSERC, Personal communication, 9 November 1994.

[92] At five of the 29 universities there are more than six chairs; at seven universities there are four to six chairs.

[93] ARA Consulting Group, "NSERC Research Partnership Program Evaluation," final report, 7 October 1991, and follow-up study, 21 January 1991.

[94] Ibid., final report, p. 10.

useful in bridging basic research and product development. The survey indicated that 25 percent of CRD grant-holders and two thirds of chair-holders would not have undertaken their partnership projects without these programs.[95]

Fifty-seven percent of the industrial sponsors reported that the CRD program led to increases in their R&D activities, another 69 percent noted that it increased the research capability of their firm, and 93 percent said that it increased their firm's expertise.[96] However, only an estimated 15 percent of cases led to measurable industrial benefits. More benefits were expected to come in the medium to long term as "all the projects . . . were considered industrially relevant by both university and industry participants. The most important benefit . . . is . . . the transfer of knowledge and/or technology from university to industry."[97] One recommendation, based on the finding that more university than business people were familiar with it, was increasing awareness of the program among Canadian firms.

NSERC supports a Request for Applications program within the Research Partnerships group. This program encourages consortia of firms or industry associations to define and put forward research priorities and needs. Academic scientists respond with proposals for generic, pre-competitive research projects, suitable for conduct in a university setting.[98] This program, which funded the first projects in 1994, is specifically oriented toward SMEs.

A pilot study to determine appropriate means of encouraging SMEs' interest in university technology was sponsored by NSERC and carried out by the Association of Provincial Research Organizations (APRO) and the Saskatchewan Research Council. The focus of the study was in the area of medical devices. One finding was that high-technology SMEs tend to make decisions on short-term considerations, and that the overriding characteristic of these firms, at least in the medical-devices sector, is competitiveness and individual pursuit of market shares. Building alliances which adhere to the industry-led principle of the Request for Applications may prove a challenge in some sectors, but with time, payoffs from consortia may become recognized among more SMEs.[99]

Technology-transfer and -diffusion activities at NSERC designed to facilitate industry's access to university research fall under the general title Intellectual Property Management

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[95] Ibid., final report, p. iii.

[96] Ibid., follow-up study, p. i.

[97] Ibid., final report, p. 29.

[98] NSERC, "Research Partnerships Program, Request for Applications (RFA) Program, 1994-95, Calls for Letters of Intent," Spring 1994.

[99] Paul Latour, Director, Research Partnerships Programs, NSERC, Personal communication, 13 September 1994.

Initiatives (IPMI).[100] They are intended to address a "commercialization gap" which refers to the lack of resources of SMEs to locate university technology, to build prototypes or pilot projects and further to develop the technology for its commercialization. At present there are two components, both of them under development.

The first is a proposed "Intellectual Property Assessment" grants program to enable universities to develop or expand their technology-transfer activities. (Contract intellectual property management personnel, identify potential industrial partners, support prototype or pilot plant-development work, support marketing analyses and commercialization feasibility studies, and assist with the financing of patent applications.) NSERC approved this initiative in principle in October 1993 and is expected to consider a plan for implementation of an intellectual property management program in late 1994.[101]

The second is a Technology Partnerships program, which was first announced in the February 1994 federal budget. The new program, launched in late 1994, will support the co-development of technology from university laboratories by SMEs on a shared costs basis, with firms contributing a minimum of 50 percent. It will be a tri-council program but will encompass a management structure including IRAP and Industry Canada.

IRAP has provided a measure of support for the new Intellectual Property Management Initiatives by offering to help locate industrial partners for university projects. It will circulate descriptions of appropriate projects across IRAPnet, the electronic network which links the Industrial Technology Advisors (ITAs), whose mandate is to provide technical assistance to firms, mainly SMEs (see below).

Other matching-grant programs include the funding of shared equipment and facilities to help university and industry set up a facility or acquire a piece of equipment which neither could purchase alone, and industrially oriented research grants, matching grants from industry.

NSERC's Strategic Grants program is intended to support research likely to be useful to industry or government in the short or long term. Although research support is awarded to investigator-led research projects, evidence of industrial relevance must be supplied and is part of the selection criteria. In 1993-1994, the budget for this program was $46 million.

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[100] NSERC, *Research Partnerships Program: Intellectual Property Management Initiative*, draft by M. Caughey, 6 October 1993.

[101] M. Caughey, Program Officer, Research Partnerships Programs, NSERC, personal communication, 26 September 1994.

A pilot study to evaluate the cost-effectiveness of the program was carried out in 1987.[102] Six projects, which together comprised about 40 percent of the funds committed in the program, were included in the sample. The evaluation was based on an analytical formula which attempted to measure the net present value of socio-economic benefits directly attributed to earlier strategic grants by measuring the marginal gain in terms of past and present increased-sales revenue. Investment was calculated as the total of research, production and end-user costs over a reasonable time limit. This measure is conservative, as it cannot capture other possible benefits, such as training and spinoffs, presumably because of not being able to assign a direct attribution to a particular grant, a problem discussed earlier in this paper.

The net present value estimated for the sample was $360 million (1986 dollars), with benefits of $743 million projected for the period 1983 to 2012. Research costs of $14 million, and production and end-user costs of $369 million, for a total of $385 million, constituted the investment. The study concludes that the Strategic Grants program is cost effective. A survey supported this conclusion, for it indicated that 60 percent of the strategic research projects had produced results used by industry, and 40 percent of these seemed to have generated economic benefits.[103]

Time and again, industry representatives report that, for them, appropriately trained human resources are the most important output of universities. However, few firms, in particular SMEs, can devote specialized training resources to recent graduates. The Industrial Research Fellowship (IRF) program of NSERC addresses this problem. It covers, for two years, part of the industrial salary of recent Ph.D. graduates hired by Canadian companies, in particular, small firms.

Along with NSERC's other scholarship and fellowship programs, the IRF program was evaluated in 1992-1993.[104] It found that the IRF had made substantial contributions to industrial research, with ". . . about 72 percent of [all] firms, [and 92 percent of small firms] indicat[ing] that the award holder or IRF program had influenced or allowed them to do R&D in a different area or in a different way than would have been possible otherwise." Spending on R&D remained the same for 53 percent of all the firms, but increased for 40 percent of the SMEs. On average, fellows in small firms spent less time on R&D activities than their counterparts in larger firms. Finally, in the large firms, significantly fewer in management noted an increase in U–I interaction as a result of the program.

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[102] The DPA Group, "Evaluation of the cost-effectiveness of NSERC's Strategic Grants Program," Appendix C, June 1988.

[103] Ibid., p. 4.13.

[104] ARA Consulting Group, "Evaluation of the Scholarship and Fellowships Programs for the Natural Sciences and Engineering Research Council, final report, March 1993.

Partnership Programs at MRC

Partnership programs at MRC were introduced in 1987 and currently account for about four percent of MRC's budget (about $10 million). Within its University–Industry program area, 207 projects have been funded to date, comprising MRC support totalling $33 million and industry support of $57 million. Currently, the MRC:industry funding ratio is 1:2.[105] Between 30 and 40 new projects have been funded in each of the last five years, which represents an average success rate of 43 percent. No formal evaluation of the projects has been conducted. However, indications are that the program is mainly "investigator driven,"[106] and that projects arise as a result of the proactive stance of some university–industry liaison offices at large, research-intensive universities. The lack of funding for university overhead on MRC's contribution is becoming a problem for cash-starved universities, a development which applies not only for MRC but for the other granting councils as well. Consequently, the universities may be obliged to compensate by charging higher overhead costs to the industry partner. This may have a negative impact on U–I relations, despite the present overall appeal of the program for business.

Scholarship and fellowship programs in the university–industry area are also supported by MRC, but little evaluative data is available.

Over and above MRC's regular partnership programs is its new Health Partnership program with the Pharmaceutical Manufacturers Association of Canada (PMAC). The MRC-PMAC Health Partnership is a five-year program, launched in 1993, and supported with $200 million from PMAC and $50 million from MRC. A joint PMAC-MRC board manages the partnership, while MRC supplies the secretariat and access to its peer review system for the adjudication of proposals. A number of U–I programs and initiatives are being considered, including studentships, fellowships and scholarships, clinical trials networks to be distributed across Canada, specialized chairs, research development grants and the development of a medical expertise data base.[107]

PMAC is a consortium of 65 pharmaceutical companies, some of which are very large; others are in the R&D stage with no sales, and a few are university spinoffs. For PMAC, access to the peer-review system will ensure quality in its research projects, and will allow it to profit from relatively cheap, but high-quality, extramural research expertise in the conduct of clinical

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[105] Derived from aggregate data received from I. Schimd, U–I Partnerships, MRC, 5 August, 1994. The MRC:industry funding ratio which is now 1:2 used to be 1:1. By February 1993, 184 projects had been funded, 75 in Ontario (with $8.8 million from MRC), 69 in Quebec ($10.2 million), 21 in Alberta ($3.1 million), 11 in British Columbia ($2.4 million), five in Nova Scotia ($990 000) and three in Manitoba ($420 000).

[106] I. Schmid, personal communication, 5 August 1994.

[107] MRC, "The MRC/PMAC Health Partnership Fact Sheet," 17 May 1993; and MRC, "$200 Million MRC/PMAC Health Program," press release, 29 October 1993.

trials and research. For MRC, the MRC-PMAC agreement presents an opening to leverage its funds. In the larger context, the new health partnership is intended partially to meet the pharmaceutical industry's commitment to spend at least 10 percent of sales in R&D in Canada following the passage of the *Patent Act* (Bill C-91), which extended patent protection from 17 to 20 years.

To date, 28 operating grants have been approved, comprising $14 million by PMAC and $3.5 million by MRC. The submission success rate has been close to 50 percent. Most requests for funding are still initiated by university investigators (90 percent) rather than by industry (10 percent).[108] Evaluation of the new Health Partnership is some years away. At minimum, one can expect an increase of U–I linkages with the development of the data base and the involvement of the Director of the Health Partnership, a PMAC employee, in MRC activities.

Partnerships at SSHRC

At SSHRC, research partnerships are managed primarily within the Strategic Grants program area, with many projects featuring some form of partnership with one or more public, private non-profit or business organization.[109] Two sub-program areas comprise the Strategic Grants program: the theme programs and the joint initiatives programs. The Managing for Global Competitiveness Theme program has attracted the interest of business. Approximately 100 projects have been funded in this area over the last five years, and nearly half of these involved partnerships, primarily with firms.[110] Where partners are involved, they are not required to contribute financially to the projects, but must, at least, contribute in kind to an extent indicative of full participation.

Under its Strategic Joint Initiatives programs, SSHRC encourages collaboration with other public and private sector organizations to co-develop and co-fund new programs for research of high social relevance and need. Eleven joint initiatives have been established to date.[111] One of these is Science Culture in Canada, which is supported by SSHRC and Northern Telecom. The budget for the program is $100 000 per year for the period 1991 to 1995. To date, eight projects have been supported. These look at various aspects influencing career choices among students, at what factors dispose students toward more science and engineering training,

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108 G. Ross, Director PMAC/MRC, personal communication, 5 August 1994.

109 SSHRC, *SSHRC Granting Programs: Detailed Guide*, August 1993, pp. 19-33.

110 A-M. Majtenyi, SSHRC, personal communication, 9 November 1994.

111 *SSHRC Granting Programs*, op. cit., p. 33.

and at ways to improve science training and literacy in Canada.[112]

A second Strategic Joint Initiative involving private sector partnerships is that of the NSERC/SSHRC Chairs in the Management of Technological Change. For this particular initiative, participating industrial sponsors must be willing to pledge funds to match federal contributions, which in practice has amounted to $100 000 to $150 000 a year, for five years, to any given project.

Financed jointly by NSERC, SSHRC and industrial sponsors, this program was introduced in 1989 to investigate the reasons behind Canada's apparent weakness in technological management by private enterprise, and to draw on the expertise of university engineering faculties, business and the faculties of management and administration. These Chairs deal with management of technological issues, from the management of innovation, of research and development projects and of R&D professionals to the management of technological change in the corporation, or the impact of technology on manufacturing, business organization and management, or international competitiveness, including sectoral issues. Ten Chairs have been funded to date, amounting to an NSERC-SSHRC contribution of $4.5 million. Large and small firms are involved in the program, with SMEs forming consortia for their contributions to, and management of, the projects.

It is too early to assess the results of this program. However, it is clear that industry attaches importance to it, as it has made an investment of well over $4.5 million to the program despite economic uncertainty and pressures on finance. This indicates that the research projects proposed by the universities do correspond to real industrial concerns.

Finally, there is the Tri-Council Eco-Research program, which is administered jointly by the three granting councils and Environment Canada, and whose secretariat is based within the Strategic Grants program of SSHRC. The Eco-Research program supports large research projects, chairs and doctoral fellowships. Public- or private-sector sponsors, including private sector firms are required for the chairs.[113]

NSERC/MRC/SSHRC Networks of Centres of Excellence Program

In the late 1980s, a novel program was established to stimulate more university–industry partnership and multisectoral, multidisciplinary co-operation in research projects in the effort to ". . . enhanc[e] Canada's industrial competitiveness and social well-being in a new global

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[112] SSHRC, "Science Culture in Canada: A Joint Initiative of the Social Sciences and Humanities Research Council and Northern Telecom Canada Limited," program description, July 1994; and "SSHRC and Northern Telecom award $200 000 for science culture research," press release, 21 June 1994.

[113] Majtenyi, personal communication, 9 November 1994.

economy."[114] This was the national Networks of Centres of Excellence (NCE) program. It was introduced shortly after the federal government committed itself to a federal science and technology strategy and major investments, under the banner "InnovAction." Funding for the NCE research program came from this source. Policy responsibility for the distribution of these funds was assigned to the Minister of State (Science and Technology). Drawing on the recommendations of the National Advisory Board on Science and Technology, which were consistent with policy directions being pursued by the then Department of Industry, Science and Technology, the Department drew up the policy outlines for the new NCE program, which subsequently was administered by the three granting councils through a Tri-Council Steering Committee.[115]

The NCE program was announced in 1989 and, in 1990, 15 different networks were awarded a total of $240 million for the first four years of operation. It is a direct-funding program, not based on a matching-funds formula. The NCE program began a second phase with a total budget of $197 million to provide four-year funding for new and renewed networks, in April 1994.

Objectives of the first phase of the NCE program were "(i) . . . to stimulate leading-edge fundamental and long-term applied research of importance to Canada; (ii) to train and retain world-class scientists and engineers in fields that are critical to Canada's industrial competitiveness and quality of life; (iii) to integrate excellent Canadian research and technology development efforts into national networks with the participation and partnership of universities, the private sector, the federal government and the provinces; and iv) to develop strong university-industry partnerships to accelerate the diffusion of advanced knowledge to industry."[116] The selection criteria for the first phase of the NCE program were weighted more to scientific excellence (50 percent) than to other elements, such as industrial relevance (20 percent) and networking (20 percent). Of the 15 networks which were funded, 13 were administered by academic centres while two were administered by industrial organizations, though only academic scientists were eligible to receive federal research funds.

By 1992, there were 173 companies involved with the program, along with 35 universities, 66 federal and provincial government units, 800 researchers, 1300 graduate students

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[114] Canada, *Networks of Centres of Excellence: Powerful Partnerships*, Ottawa, 1992, p. 1.

[115] Networks of Centres of Excellence Evaluation Steering Committee, "Networks of Centres of Excellence: Interim Program Evaluation Summary Report," 11 February 1993, p. 1; and NCE Program Evaluation Steering Committee, "Networks of Centres of Excellence Program Evaluation Assessment", final report, June 1992, p. 8.

[116] Canada, *Networks of Centres of Excellence*, op. cit., p. 2.

and 415 postdoctoral fellows.[117] The interim program evaluation, undertaken in 1992,[118] found that the networks were properly managed by their network administrators, that they afforded useful and valuable collaboration and exchange of information among researchers and that their research activities were of good quality. The evaluation noted also, however, that although the networks led to more U–I linkages than the usual operating grants, the mechanisms used to involve industry and government in network management, to inform them of the research, to identify their needs and to help them use research results were only marginally effective. While 13 networks were judged to have the potential to produce significant Canadian economic benefits, "only six have the potential to make a significant contribution to increased Canadian competitiveness in the near-term . . . because of the limited state of development of Canadian industry in many sectors."[119] Competitiveness was narrowly defined by the consultants: "Canadian industrial competitiveness is increased when one or more Canadian firms succeeds in developing a new or improved product or process or in increasing its efficiency. (Canadian firms being those firms that are controlled by Canadian interests and whose operations are based in Canada.)"[120]

For the second phase of the NCE program, the objectives were slightly rephrased to emphasize the importance of involving the private sector and of establishing stronger links with industry.[121] The objectives of Phase II are as follows:

> "i) Stimulate leading-edge fundamental and applied research, based on excellence as measured by international standards, in areas critical to Canadian economic development; ii) develop and retain world-class scientists and engineers in technologies that are essential to Canada's productivity and economic growth; iii) manage multidisciplinary, multisectoral research programs of nationwide scope and develop partnerships that integrate the research and development priorities of all participants; iv) accelerate the exchange of research results within the network and facilitate the transfer of this knowledge to, and its absorption by, organizations in Canada that can harness it to advance Canadian economic and social

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[117] NSERC, *Networks of Centres of Excellence in Canada—A Novel Concept, But Is It Working?* by J. Walden, conference presentation, 1992, p. 4.

[118] ARA Consulting Group, "NCE Interim Evaluation," final report, February 1993, pp. i-iv.

[119] Ibid., p. iv.

[120] NCE Program Evaluation Steering Committee, "Interim Program Evaluation," Ottawa, 11 February 1993, p. 6.

[121] Canada, House of Commons, *Beyond Excellence, The Future of Canada's Network of Centres of Excellence*, report of the Standing Committee on Industry, Science and Technology, Ottawa, May 1993, pp. 12-13.

development."[122]

Selection criteria were adjusted to reflect these objectives, and all five were weighted equally, in contrast to the first phase which assigned more weight to scientific excellence. Fourteen of the original networks applied for renewed support, and it was announced on 28 March 1994 that 10 had been awarded this support, for a total budget figure of $142 million. The networks which did not receive new funding were doing excellent research but did not meet the threshold level of all five selection criteria. An amount of $48 million has been reserved for the creation of several new networks in priority areas, including trade, competitiveness and sustainability; health research; technology-based learning; advanced technologies (materials, software engineering); and environment. That competition was in progress at the time of writing, with results expected in July 1995.[123]

National Research Council and IRAP

The Industrial Research Assistance Program (IRAP) provides support to SMEs across Canada to enhance their technological competence and competitiveness. Its clientele consists mainly of small firms, with 80 percent having fewer than 50 employees.[124] It assists firms to acquire, develop and adapt new technologies from a variety of sources. In addition, it provides advice on sources of R&D funding. Its $62 million annual budget is used to leverage other public and private sources of funds, and the firms' own resources, to support their technology-development activities.

To carry out its mission, IRAP operates a network of between 260 and 265 Industrial Technology Advisors (ITAs) located throughout Canada, and works co-operatively with various agencies and ministries. ITAs are located at a variety of sites appropriate for technical assistance delivery, including such organizations and institutions as provincial research organizations, the Association of Consulting Engineers of Canada, community colleges and technical institutes, universities, government labs and specialized technology centres such as those supported by Industry Canada's Technology Outreach Program. About a third of the ITAs are NRC employees, while the remainder are hired by other organizations with some salary support shared with IRAP. Over 60 ITAs are located in universities, often directly in engineering faculties rather than in U–I liaison offices, apparently to maximize the opportunities for contact

[122] Canada, *Phase II Networks of Centres of Excellence Policies and Guidelines*, July 1993, p. 2.

[123] Sue Milne, Acting Director, Strategic Grants and Networks Program, NSERC, personal communication, 8 March 1995.

[124] *Profit Magazine*, March 1994, p. 11.

with the researchers. Another 27 ITAs are in colleges and technical institutes.[125]

IRAP was created early in 1962 to help industry perform research and development.[126] Originally focused on large firms, IRAP began a conscious effort to reach out to small firms in 1981, creating program elements dedicated to SMEs and building up its regional staff. In 1975, a second NRC program, the Program for Industry/Laboratory Projects (PILP), was set up to encourage technology transfer between government laboratories and industry. Project managers were drawn from NRC staff and from each of the major federal science-based departments and agencies. In 1984, NRC expanded the scope of the PILP program beyond government labs and business to include universities. PILP helped establish several of Canada's university technology-transfer offices outside Ontario. (Ontario had its own program of funding for this purpose.[127]) Later, the PILP program was merged with IRAP.

In March 1994, IRAP was selected as "Ottawa's best business-aid program" by *Profit Magazine*.[128] That success is attributed to the excellent networking capability of its ITAs, to their level of technical competence and industrial experience, and to the program's flexibility with little restriction in terms of sector, regions and technologies. However, no systematic cost-benefit analysis of the project has been done because of the difficulty in properly assessing the real, direct and indirect, effect of individual projects.

Anecdotal evidence on IRAP is very positive. For example, a study conducted four years ago involving firms which participated in the Biotechnology Contribution Program (mid-1980s) showed that 19 percent of IRAP's investment had flowed back to universities as research money. Also, preliminary results from an ongoing review of IRAP grants to high-tech start-up companies indicate that about 10 percent of the firms have a high, early, growth rate, with the first three years of sales more than 30 times the IRAP grant.[129]

Also, although U–I links are not IRAP's primary responsibility, its role has been

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[125] Doug Colley, Technology Assessment and National Co-ordination, IRAP, personal communication, 13 September 1994.

[126] Bill Coderre of Industry Canada, former Director General, Industrial Development Office (of which IRAP was a part), personal communication, December 1994; and N.B. Booth. "History of the Industry Development Office's Industrial Programs (IRAP & PILP)," paper prepared for NRC, 3 July 1985, p. 3.

[127] Bill Coderre, Industry Canada, personal communication, 8 July 1993. Ultimately 50 percent of PILP/IRAP matching funds were spent in university-based technology transfer projects, i.e., to a total of approximately $12 million.

[128] *Profit Magazine*, op. cit., p. 11.

[129] Denys Cooper, Director, Technology Assessment and National Co-ordination, IRAP, personal communication, 13 July 1994.

important.[130] In quantitative terms, 447 students have been identified as having had summer jobs in industry because of IRAP projects and over 300 direct U–I linkages are traceable to at least partial support by IRAP. (These include technology transfer, university spinoff firms and academic assistance to small firms.) At least 120 of a sample of Canadian university spinoff firms have received IRAP funding. In qualitative terms, the presence of the ITAs on university and college campuses contributes to communication and networking between researchers and small business. Co-operation between institutions of higher education and the IRAP ITA network is excellent in some locales, but needs improvement in others.

A new initiative, promising a broadening of IRAP's scope to meet the needs of SMEs better and to assist them in gaining access to Canadian and international technology is the Canadian Technology Network (CTN).[131] Announced in the federal budget, February 1994, the CTN design has been developed jointly by Industry Canada and IRAP, with IRAP assuming primary responsibility for its implementation. Key to the success of the CTN will be its multi-agency management through national and regional advisory boards, which include representatives from the universities and, in some cases, colleges. The CTN will be supported by a budget of $19 million over 1994-1995 to 1996-1997.

With the intent to capitalize on, and link together, the many business and technological services already in existence at local, provincial and national levels, the idea is to provide one-stop delivery of a variety of services to Canadian firms, including technological services. This network, with initial funding of $19 million, will, at the outset, focus on enhancing the linkages among current service providers and extending those links to other organizations, whose technology expertise could be more adequately provided to Canadian firms. In subsequent years, activities will be oriented toward filling the gaps and needs identified by clients and network service providers during the first year of operation, and toward strengthening the CTN's links with broader business services, in part through the Canada Business Service Centres.

Some Provincial Government Programs

To attract high-technology enterprises and support their industrial development, all the provinces have introduced a series of programs — which often resemble federal programs, either because they complement or duplicate them, or because they have since been copied by the federal government. In 1991, universities received $315 million from their provincial governments to support their research activities, covering up to 15 percent of university research expenditure in Quebec, 14 percent in Alberta, 11 percent in Ontario and nine percent in British

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[130] Denys Cooper, personal communication, 13 July 1994; and D. Cooper, "University Spin-Off Company," paper presented at the Small Universities Conference, Prince Edward Island, May 1994.

[131] "Government Launches the Canadian Technology Network," press release, Ottawa, 5 August 1994.

Columbia (see Table 5). From the point of view of a U–I relationship, the importance of industrial funding of university R&D in Quebec (13 percent of university research expenditures) compared with the other provinces (five to six percent, see Table 5) is noteworthy. This may be due to the very generous tax treatment given to R&D expenditures in Quebec (Table 6), particularly to university R&D contracts,[132] and to a short-lived R&D Quebec tax shelter in 1992.[133] However, a recent international comparison of R&D tax credits questions their effect on university research funding: in the United States, only about one percent of industrial R&D tax credits apparently comes back to universities as new research money.[134] By giving preferential tax credits to corporations signing formal R&D contracts with universities, Quebec may have been able to increase that percentage significantly, but no formal study is available.

Because Quebec, Ontario, British Columbia and Alberta appear to have secured the high levels of industrial support for university research, it is reasonable to presume that these provinces have some well-developed U–I programs. Limitations on the scope of this study, combined with the data availability, direct attention to just the first three of these provinces.

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[132] Quebec's Synergy program is described in a section below.

[133] *Re$earch Money*, "Quebec's R&D tax shelters," op. cit., pp. 6-7.

[134] As reported by Jean Gagné, Director, Scientific Policies, Government of Quebec, private meeting, 22 August 1994, speaking of a recent article in *Re$earch Money*, mid-August 1994.

Table 5
Financing of University R&D, by Sources, 1991 (million $)

	Federal government	Provincial government	Industry	Self- Funded	Others	Total
Atlantic Provinces	77	12	6	81	7	183
Quebec	226	114	101	263	61	765
Ontario	298	115	57	466	85	1021
Manitoba, Saskatchewan	55	17	6	93	20	191
Alberta	70	36	13	117	22	258
British Columbia	106	21	14	63	20	224
Total	832	315	197	1083	215	2642

Source: *Resource Book for Science and Technology Consultations*, tableau 2.7.

Table 6
Tax Credit for R&D, Selected Provinces, 1989: After-tax Cost of Each R&D Dollar

	Large firms	Small firms
New Brunswick	0.446	0.479
Quebec	0.479	0.394
Ontario	0.507	0.455
Manitoba	0.439	0.452
Alberta*	0.528	0.548
British Columbia	0.514	0.522

* Reduced tax rate (9%) on profits of large manufacturing firms
Source: Conference Board of Canada, *Canadian R&D Tax Treatment*, Report 125.94, Ottawa, 1994, cited in *Resource Book for Science and Technology Consultations*, tableau 2.5.

Ontario

Introduced in 1981, the Board of Industrial Leadership Development (BILD) was Ontario's first program to encourage U–I research co-operation. It was a small, two-year matching-grant program ($5 million) designed to encourage ". . . university faculty to *seek* new research and development contracts with industry that would facilitate technology transfer activity."[135] An evaluation of the program found that ". . . the use of matching grants in the manner employed by the BILD program may not be appropriate . . . [they] do not necessarily contribute to enhanced corporate-university linkages in Ontario . . . for a majority of the sponsoring companies, the availability (or possibility) of a matching grant, barely factored into their decision to undertake the research in a university environment."[136] The program's limited success was blamed on its small size, its limited time span and the lack of information available to corporations on the research activities of universities. The small size of grants ($50 000) may also have been a factor.

Taking account of the experience gained from the BILD program, three new programs were introduced in 1986, financed through the 10-year, $1 billion Ontario Technology Fund. One of these is the University Research Incentive Fund (URIF), which was designed to promote U–I research in any discipline, for fundamental or applied research, with significant potential economic impact in Ontario. As for the BILD program, funding requests must come from the university. There was originally no funding limit on individual projects (some have received up to $1 million between 1986 and 1990), and the funding formula which started with a 2:1 business:government ratio, was rapidly changed to a 1:1 funding ratio. The program was reviewed in 1991, found to be operating well and renewed for five years with only one real change — the introduction of a $200 000 funding limit per project (now increased to $250 000). It was temporarily halted in 1993-1994, the victim of drastic provincial budget cuts and, then, reintroduced in 1994 for a new, five-year term with between $5.5 and $6 million of annual funding.[137]

The second, the Industry Research Program of Ontario, supports collaborative projects between industrial research units and a university or Center of Excellence; this program is intended to support long-term research projects based on industrial need.[138]

Finally, there is the Ontario Centres of Excellence (OCOE) program to encourage the

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[135] S. Bell, "Using Matching Grants to Facilitate Corporate-University Research Linkages: A Preliminary Examination of Outcomes from One Initiative," *The Canadian Journal of Higher Education*, vol. XX-1, 1990, p. 59.

[136] Ibid., pp. 68-70.

[137] Joel Bartczak, Ontario Ministry of Education and Training, personal communication, 14 March 1995.

[138] Lawton-Smith and Atkinson, op. cit., p. 154.

development of strong industry-university-government research partnerships. The OCOE program drew its inspiration from similar university–industry research centres in the United States and other countries. American examples include the 26 University-Industry Cooperative Research Centers and the 17 Engineering Research Centers created by the National Science Foundation in 1977.[139] The objective of the OCOE program was to support world-class research with a long-term perspective, to train world-class researchers and to encourage the transfer of knowledge to industry. Seven centres, funded from the Technology Fund, were selected in 1987 and received a total of $200 million for five years. Each centre is a consortium of universities and large and small firms directed by a board of directors representing university and industry. All but one involve more than one university, and the average number of participating companies is 100.[140] Part of the operation of the centres is financed through membership fees paid by member organizations, public and private. Even where they do not fund the research, industry representatives have a significant role in the orientation of research activities and the approval of specific projects.

In their study of the OCOE program, Bell and Sadlak[141] noted that U–I relationships were promoted by a variety of devices, for example, newsletters, regular seminars and workshops, conferences, training or retraining courses, distribution of research papers and advanced publication of research results for the benefits of industrial members of affiliates.

An evaluation of OCOE in 1990 resulted in the renewal of the centres' funding for five more years, for a total budget of $216 million. The evaluation indicated that the centres were serving their purpose, producing world-class research and interacting well with their industrial members. However, it also noted that industry did not contribute enough in cash or in kind to enable the long-term survival of the centres and the development of strong research projects and industry linkages.[142] The need to find a good balance between long-term research activities and short-term projects financed by industry to meet its immediate needs was stressed.

In preparation for the OCOE program's second evaluation, the Government of Ontario commissioned a study for the development of an evaluation process and criteria. It has been proposed that the evaluation could not be based on classical cost-benefit analyses because of the difficulty in identifying and measuring actual benefits (direct and indirect, current and future), but should use a number of quantitative and qualitative measures to assess and compare the

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[139] Stephen Bell and Jan Sadlak, "Technology Transfer in Canada: Research Parks and Centres of Excellence," *Higher Education Management*, 4, 2, July 1992, p. 237.

[140] ARA Consulting Group, *NCE Interim Evaluation*, op. cit., Appendix C, p. C.43.

[141] Bell and Sadlak, op. cit., p. 237.

[142] ARA Consulting Group, op. cit., p. C.42.

efficacy of the various centres.[143] The measures proposed by the consultant are related to the six most important functions of Centres of Excellence identified by the OECD in its 1992 TEP report: production of knowledge, diffusion of knowledge, diffusion of processes and techniques, innovation-related networking and supply of trained personnel.

Recognizing the role that colleges can play in the economic development of the province, the Association of Colleges of Applied Arts and Technology of Ontario has recently established a network, CON-NECT (Colleges of Ontario Network for Education and Training), linking 23 colleges in 200 centres across Ontario. It will enable these institutions to deliver, through one point of contact, and in a rationalized manner, leading-edge education and training packages to private- and public-sector organizations.

Quebec

A series of provincial programs, with indirect impact on U–I relationships through their support of the academic research community (training of new researchers, research financing) and unique to Quebec, is supported by its three granting councils which complement and sometimes duplicate their federal equivalents: le Fonds pour la formation des chercheurs et l'aide à la recherche (FCAR), le Fonds de la recherche en santé du Québec (FRSQ), and the Conseil québécois de la recherche sociale (CQRS).

To encourage U–I relationships in science and technology, Quebec has created two types of organization. The first, the Centres de liaison et de transfert, were established to support the development of links between research organizations, including universities and industry. Examples include the Centre francophone de recherche en informatisation des organisations (CEFRIO), the Centre québécois de valorisation de la biomasse (CQVB) and some large research centres located at universities, such as the Centre de caractérisation microscopique des matériaux (CM) located at École Polytechnique and the Pulp and Paper Research Institute of Canada (PAPRICAN) at McGill.

The second type of organization is the specialized Technology Centre which has been established at a number of colleges since 1984. The centres carry out technical development work for firms. There are currently 15 such centres, offering technical training, assistance, information and applied research services to SMEs. They have a strong sectoral orientation (for example, pulp and paper, forestry, textiles, robotics, materials, computer science, etc.) and are generally adapted to the needs of the local industrial base (or of local industrial development plans). Such centres tend to be especially successful at linking with SMEs through the provision of appropriately trained human resources. No formal evaluations are presently available.

The Technology Development Fund programs (TDF), supported by a $350 million fund

[143] Brian Guthrie, Hickling Corporation, personal communication, Ottawa, 18 July 1994.

created in 1991, also has as one of its goals the enhancement of U–I relationships. The Synergy program, in particular, was designed to support the transfer of knowledge from university to industry. Funding requests must be presented by a university researcher and include a contribution (cash or in kind) from an industrial partner, but the relative level of contribution required varies with the size of the firm, making the program especially attractive to SMEs. The favourable tax treatment of R&D performed through contractual agreements with a university rather than in house (refundable tax credit of 40 percent of the full amount of the R&D expenditures incurred)[144] encourages university-based industrial R&D activities. In 1991-1993, Synergy invested $42 million, with a Synergy:industry investment ratio of about 1:2.[145] The program has proven very appealing for Quebec industry because of its flexibility, the type of costs it covers and the generosity of Quebec's R&D tax credits (see also Table 6). No formal evaluations of its industrial benefits have been done, but the program seems to have been extremely well received by both academia and industry, in spite of the fact that it is university-driven.

There are other TDF programs, such as R&D-environment, R&D-SME, TDF-ISF (Information Superhighway Fund, a $50 million, new, two-year initiative) which support U–I partnerships, but this is not their sole aim. Again, formal evaluations of their impact do not seem to be available.

Another provincial government initiative with potential U–I benefits is the INNOVATECH program. It is charged with the creation of fully funded corporations to promote the development of the innovative capacity of a region through the support of partnerships which can include U–I linkages. The Société Innovatech Grand Montréal[146] has received a budget of $300 million over five years to that effect.

The industry liaison offices of the universities (Bureaux de liaison université-enterprises, BLUE) are not directly supported by the Government of Quebec, but indirectly through university operating budgets.

British Columbia

The Science Council of British Columbia (SCBC) supports a number of programs which assist with U–I collaboration. Companies in the province may apply to the Technology B.C.

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[144] Québec, Ministére de l'industrie, du commerce, de la science et de la technologie, *Les PME au Québec, état de la situation 1992-93*, 1994, p. 11.

[145] *Re$earch Money*, "Quebec's new economic strategy may dictate future of $42 million experiment with university-industry R&D alliances," November 1993, p. 6.

[146] There are now three such organizations, Innovatech Grand Montréal, Innovatech Quebec-Chaudière region, Innovatech Estrie (in development) — communication from Jean Gagné, 22 August 1994.

program for funding to support 50 percent of their own costs, and 100 percent of the costs associated with an academic or technical research institute partner in collaborative projects lasting no longer than a year. The average award is $70 000, but awards range between $10 000 and $300 000 per year. In 1993-1994, 89 awards were made, totalling $5.8 million. However, these totals include both awards made to firms conducting their own research and development and collaborative projects. The budget for 1994-1995 is $8.5 million.[147]

Also supported by the SCBC is the Market Assessment of Research and Technology (MART) program, for which British Columbia firms, research and technical institutes, colleges and universities may be eligible. MART awards provide funds contract professional marketing services and can reach a total of $20 000 at a maximum of $500 per day. The budget available for 1994-1995 is $500 000.[148]

The SCBC also administers special scholarship programs for U–I collaboration, called the GREAT Scholarships and the STARS Scholarships. GREAT scholarships provide support for graduate study by a student in collaboration with a British Columbia company willing to provide partial support. STARS scholarships are aimed at employees of firms intending to complete graduate degrees in science and engineering, with the partial support of their firms. Both scholarships are valued at $17 000 with the requirement that collaborating companies contribute $2 500 or make an in-kind contribution. In 1993-1994, 102 Science Council scholarships were awarded, totalling $1.55 million. In 1994-1995 the budget is approximately $1.62 million.[149]

Finally, there are the Industrial Postdoctoral Fellowships supported by the SCBC, to which British Columbia companies are eligible to apply, with special emphasis on SMEs. Recent Ph.D.s hired by companies successful in securing these awards may have up to 75 percent of their salaries paid under this program. Awards are for one year, and renewable for a second year. In 1993-1994, 12 awards were made within a budget of $300 000. In 1994-1995, the program budget is $375 000.[150]

In its March 1993 budget, the British Columbia government announced its B.C. 21 initiative. It is a comprehensive, multiyear plan to invest in the provincial economy and to improve growth prospects. Its three objectives are to:

- accelerate development of the economic tools needed for long term prosperity;

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[147] Science Council of British Columbia, [database online] Internet (World Wide Web) Home Page [cited March 1995] <http://www.bc.irap.nrc.ca/scbc/scbc.htm>, March 1995.

[148] Ibid.

[149] Ibid.

[150] Ibid.

- target government investment to the regions and people that need it most; and
- break new ground by enabling much-needed highways and transportation links to be built more quickly and in a business-like manner.

On 25 July 1994 the provincial government announced that B.C. 21 would provide $500 000 each for offices for technology transfer or university–industry liaison at the University of British Columbia, Simon Fraser University and the University of Victoria.

In addition, in the last few years, the British Columbia government has been focusing attention on the colleges. A major report was commissioned in the summer of 1993 to investigate the role of community colleges and institutes in technology transfer.[151] A Skills Now initiative, announced on 3 May 1994, will provide for the awarding of degree-granting status to six colleges and institutes in the province. Some of these colleges, called "university colleges," are encouraging the conduct of research among faculty.

The new Skills Partnership Program managed by SCBC has modest funding to encourage more skills transfer and technology acquisition and adaptation through student–industry projects.[152] These types of projects have been found to be quite successful at the colleges for promoting skills and knowledge transfer to local firms.[153]

Finally, there is a commitment on the part of the provincial government to construct the Provincial Learning Network, aimed at providing dedicated Internet connections to every education-related institution in British Columbia.[154] The colleges are highly involved in this initiative.

Selected Foreign Experiences

United Kingdom[155]

The United Kingdom has shown remarkable ingenuity in building bridges between universities and industry. Through the intervention of a variety of public and parapublic bodies,

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[151] Ference Weicker & Company, *Increasing the Participation of B.C. Colleges in the Process of Technology Transfer*, consultant's report prepared for the Science Council of B.C. and the National Research Council, August 1993.

[152] Norman Streat, Director, BCIT Technology Centre, personal communication, 8 August 1994.

[153] Ference Weicker & Company, op. cit.

[154] Chris Bywater, IC Regional Office in B.C., personal communication, 12 August 1994.

[155] This section makes extensive use of notes written by professor M.E. Szabo of Concordia University.

Britain has developed programs and schemes that have proven effective in harnessing both university teaching and research for industry and business. This section focuses on a few innovative U–I partnerships in higher education.

The Engineering and Physical Sciences Research Council (EPSRC), Britain's analogue of NSERC, plays a key role in promoting industry-relevant higher education. Some of its programs act as agents for the development of profitable relationships between universities and industry. Its Co-operative Awards in Science and Engineering Program supports students working on projects of between one and three years' duration. Projects are jointly devised and supervised by university departments and participating industrial partners. They have contributed to successful interactions among universities, industry, research council institutes and public laboratories. The Postgraduate Training Partnership Scheme is intended to support industrially related training. Its aim is to test the practicality and benefits of placing groups of students in an industrial research environment. The scheme is a partnership between universities and industrial research organizations. Students carry out their research in these organizations, while receiving academic supervision and course work from the university. The scheme provides research training relevant to careers in industry and fosters closer links between researchers in universities and industry. It involves groups of students carrying out research at the M.Sc. and Ph.D. levels. Other initiatives supported by EPSRC include a number of scholarship programs directed at academic programs with a strong industrial, technological or vocational component, in some cases with a curriculum which must be approved by the Council.

The Teaching Company Scheme (TCS) complements EPSCR programs by providing opportunities for recent university graduates to apply their new knowledge in industry. The programs are co-sponsored by university and industry in order to achieve immediate tangible increases in industrial and commercial productivity. The scheme is jointly financed by EPSRC, the Department of Trade and Industry, the Department of Economic Development in Northern Ireland, the Ministry of Agriculture, Fisheries and Food, and the Department of the Environment.

The mission of the Teaching Company Scheme is to "strengthen the competitiveness and wealth creation of the United Kingdom by the stimulation of innovation in industry through partnerships between academia and business." It does so by facilitating the transfer of technology and the spread of technical and managerial skills, and by encouraging industrial investment in training, research and development.

The central activity of the TCS is the administration of the individual industrial and commercial development programs, carried out by Teaching Company Associates (recent university graduates) under the joint supervision of university professors and industrial researchers. This year, the TCS awarded its 1500th such program. Since it inception, the TCS has become recognized as one of the most effective tools for building lasting university–industry linkages and for encouraging productive technology transfer from universities to industry. It is notable that a number of departments lent their commitment to this program and worked jointly to achieve results. The scheme has been imitated by several countries, including Denmark and Australia.

A variety of other British initiatives encourage university–industry collaboration. The notion of "work-based learning," for example, draws universities into the service of industry and business. Several universities have developed modularized curricula that include provisions for assessing individual portfolios based on academic aspects of a student's daily work for degree credit. This scheme makes it possible to obtain a university degree with a strong vocational component by recognizing work-based learning as an integral activity of a degree program.

For Britain, the described initiatives have turned out to be a catalytic framework and are almost indispensable tools for linking the worlds of industry, business and academia. The nature and success of these activities suggest that it might be profitable to investigate again the relevance of the British experience to Canada. In 1987, Barnes and Peters[156] analyzed the feasibility of implementing the TCS in Canada. Based on the results of a survey of universities and industry, they concluded that the scheme would have been well received with good industrial financing.

Sweden

In Sweden, approximately 45 percent of the central government's expenditure on research and development is allocated to the general advancement of scientific knowledge, and this is carried out almost exclusively by its universities and university colleges.[157] With approximately one quarter of federal expenditure dedicated to military R&D, the amounts remaining for research performed intramurally are comparatively small. Hence the profile of universities in publicly supported R&D in Sweden is high.[158]

Sweden's national board for industrial and technical development (NUTEK), formerly known as STU (Styrelsen for teknisk utveckling), is responsible for proposing and organizing means for carrying out applied research and development of relevance to Swedish industry and economic development. In the past, STU received about eight percent of the public sector R&D

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[156] Science Council of Canada, *Le "Teaching Company Scheme": Un modèle britannique à suivre?* by J.G. Barnes and G.R. Peters, July 1987.

[157] OECD, *Science and Technology Policy — Review and Outlook; Annex: Draft Country Profiles,* draft report: DSTI/STP(93) 19/ANN1 9 August 1993, p. 116.

[158] A direct comparison with Canada is difficult as it would have to account for the distribution of funds between federal and provincial levels of funding of university research in Canada. Public-sector funding of university R&D comes from central government sources in Sweden. For the record, the proportion of federal funding for R&D flowing to universities is 16 percent in 1993-1994. Canada, *Resource Book* op. cit., p. 16.

budget, and about 40 percent of this funding went to universities and university colleges[159] in support of technological research and development proposed by academic and college researchers and engineers.[160] The results from this approach, pursued over the 1980s, were not highly successful. Not all research was of high quality, and even where research results were not of intrinsic value, they were often not relevant to domestic industrial needs.[161] These results were compounded by the finding that industrial sponsorship of university research projects was, at best, minimal.[162]

The new government which took power in 1990 expressed its desire to bring about a greater responsiveness of public sector R&D investment to domestic industrial development and, in particular, to ensure a tighter coupling between institutions of higher education and Swedish industry.[163] Consequently, in its latest science and technology bill, announced in February 1993, the creation of "competence centres" at universities was proposed. These centres would focus on research of long-term industrial relevance, and would require matching industrial funds. They would discriminate in favour of groups of scientists of international reputation. An important feature of the concept was its emphasis on integrated doctoral training,[164] reinforced by an insistence that exchanges of research personnel occur between firms and the academically based centres.[165] Ensuring a match between industrial demand and the supply of young scientists in Sweden is particularly important, given the government's determination to double the number of Ph.D. degrees in 10 years, another feature of its 1993 bill for science and technology.

A competition in May 1994 resulted in the selection of 30 engineering research centres spanning a diversity of technologies. In addition, support has been given to co-operative university–industry programs for the vehicle and aircraft industries.[166] It is interesting that universities will have a new mechanism for setting up spinoff companies, that is, the privilege of

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[159] University colleges are named thus to indicate that both training and research occur at these institutions. The type of research undertaken is usually of local economic relevance.

[160] Lilian Ohrstrom, *Research: The Swedish Approach*, The Swedish Institute, 1991, p. 24.

[161] *Nature*, vol. 360, 10 December 1992, pp. 510, 511.

[162] Vincent Wright, "Global views on managing science and technology: a report from an international workshop," a report prepared for Industry Canada on the International Workshop on S&T Priority-Setting, hosted by the Government of Canada: Ottawa, 25-27 May 1994.

[163] *Nature*, op. cit.

[164] OECD, *Science and Technology Policy*, op. cit., p. 117.

[165] Slide deck presented by the NUTEK representative to the International Workshop on S&T Priority-Setting, May 1994.

[166] Ibid.

setting up corporate entitities to conduct commercially oriented research, with the government partly funding their establishment.[167] The Swedish success in generating spinoff companies, noted by policy researchers elsewhere,[168] coupled with the finding of a 1993 study that approximately 44 percent of the extramural research and development purchased by Swedish firms was supplied by academic spinoffs[169] perhaps provided justification for this policy innovation.

Closer collaboration between universities and university colleges, and the expansion and consolidation of links across the range of higher-education institutions with business and society, merited mention as one of the five priorities of the 1993 S&T bill.[170] University colleges in Sweden have, from the outset, received small amounts of support for research from various sources, including corporate sponsors, local regional councils and foundations, sectoral research agencies, and via universities through faculty grants and banks. A limited amount of competitive funding is available from NUTEK. Since the establishment of the colleges 25 years ago, regional representatives have consistently argued that local economic development depends on the scientific and engineering capabilities of researchers in their area.[171] The 1993 bill recognizes that colleges have an important role to play in promoting innovation among SMEs, and to that end, funding has been set aside for university colleges to establish research networks with universities and with industry.[172] Like universities, university colleges are expected to promote access to their research and training facilities by firms.

United States

There is a great diversity of programs in the United States, at federal and state levels, which provide financial support for university–industry collaboration. Many innovative programs for university–college–SME linkages are being undertaken at the state level. Time and space limitations for the present study, however, must limit our attention to a few federal

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[167] OECD, *Science and Technology Policy*, op cit., p. 115. It is not known how much government support will be available. According to this draft: "Government funds will be made available for the necessary captial to form university-owned corporations for research with a commercial potential."

[168] Described, for example, in Paul Twomey, *Creating Economic Growth Through Enterprise Generation and Industry Research Partnerships: The Role of the Post-Secondary Education Sector*, a report for the Department of Employment, Education and Training, Government of Australia, 26 February 1993, pp. 13-15.

[169] Olofsson and Walbin, "Firms started by university researchers in Sweden — roots, roles, relations, and growth patterns," *Frontiers of Entrepreneurial Research*, 1993, cited in Rikard Stankiewicz, "Spin-off Companies from Universities," *Science and Public Policy*, vol. 21, April 1994, p. 103.

[170] OECD, *Science and Technology Policy*, op. cit., p. 114.

[171] Ohrstrom, op cit., pp. 62-65.

[172] OECD, *Science and Technology Policy*, op. cit., p. 115.

agencies' programs and recent findings from the literature.

The National Science Foundation's (NSF) University–Industry Co-operative Research Centers program was created in the early 1970s and currently supports 45 centres. These centres are almost entirely funded by industrial sponsors and the host university, with a nominal contribution from NSF, although it is university faculty which initiate the centres. In 1992, the NSF program budget was $4 million[173], whereas the total funds levered were in the neighbourhood of $60 million.

The NSF also supports the Engineering Research Centers program. This program has been in place since 1985. These centres are based in university engineering facilities, with strong industrial participation. Funding is provided for up to 11 years, and in 1991, the budget was approximately $55 million.

Finally, the NSF provides funding support to 25 Science and Technology Centers, which conduct basic research but which also promote interdisciplinary research and technology transfer. In 1992, the average budget was $1.9 million for these centres, with a total overall budget for the program of about $28 million.[174]

The Small Business Technology Transfer Research program is sponsored by five federal research agencies, including the NSF, National Institute of Health, the National Aeronautics and Space Administration, the Department of Defense, and the Department of Energy. These departments were authorized by Congress, in the fall of 1992, to withhold a proportion of their grants budget for reallocation to a pilot program called the Small Business Technology Transfer Research program.[175] In the first year, 0.05 percent of their budgets was to be set aside, increasing to 0.15 percent after three years. It was calculated to lead to a total program budget of $25 million over three years.[176]

The purpose of the program is to promote the commercialization of academic research. Funding is provided to academic scientists and is conditional on their partnering with small businesses, with both the financial contributions of the latter and the arrangements for disposition and managment of intellectual property set out under contract.

The U.S. National Institute of Standards and Technology (NIST) has launched a five-

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[173] All figures in this section (United States) are quoted in U.S. dollars.

[174] National Science Foundation, *NSF Science and Technology Centres 1992*, [online] under NSF General Publications, NSF Gopher on Internet.

[175] Jeffrey Mervis, "NSF balks at grants to entrepreneurs," *Science*, vol. 261, 10 September 1993, p. 1384.

[176] MTL Inc., Larel, Maryland, U.S., personal communication, 4 October 1993.

year, US$745 million Advanced Technology Program (ATP) which will be industry-led, but could encourage technology transfer from other sectors, including universities. The goal of the new program is to support the commercialization of technologies which show high promise but the risks deter investment by other financial sources. Five areas of activity have been targeted for support. Proposals are invited from single companies or joint ventures, although should other institutions such as universities or government laboratories choose to participate, they may come in as subcontractors to the applicant. The director of the Massachusetts Institute of Technology licensing office is contesting the eligibility requirements of this program, arguing that the restriction of applications to firms goes against the spirit of the original idea debated in Congress.[177]

Some recent reports on U–I collaboration at joint R&D centres, which usually involve some public-sector financing, are of relevance here. An article in *Nature* reports that there are an estimated 7000 university–industry agreements in place in the United States.[178] Indeed, university–industry collaboration has been proceeding at a high pace in the United States for some time, with reports on activities showing some surprising results. An investigation by Richard Florida and others of Carnegie Mellon University, reported on in *Science*, drew estimates of approximately 15 percent involvement by American faculty and other doctoral-level academic scientists in university–industry research centres.[179] Their survey included 1058 university–industry ventures with research budgets of more than $100 000, located at 203 campuses in 1990.[180] The extent of funding and research activity at university–industry research centres based on U.S. campuses was much larger than the investigators expected. Research and development spending at the centres surveyed was US$2.66 billion, which exceeds the total 1994 budget of the National Science Foundation (US$1.69 billion). Industry support of the total university–industry centre spending (which includes education and training as well as R&D) was 31 percent, compared with federal support at 34 percent.[181] Given that, on average, industry contributes 7.3 percent to research and development performed in university, this high level of industry support of the centres is significant. As the study estimates that the R&D effort at these university–industry centres comprises 43 percent basic, 41 percent applied and 16 percent development, the reasons for the effectiveness of this type of interaction are not necessarily a short-term, contract-research phenomenon.

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[177] Diane Gershon, "U.S. unveils details of $750 million technology plan," *Nature*, vol. 369, no. 6480, 9 June 1994, p. 431.

[178] Helen Gavaghan, ". . . as NIH tightens up on academic-industry deals," *Nature*, vol. 369, no. 6480, 9 June 1994, p. 430.

[179] Mlot, op. cit.

[180] Wesley Cohen, Richard Florida and W. Richard Goe, *University-Industry Research Centers in the United States*, Carnegie-Mellon University, July 1994.

[181] NSF, *Science and Engineering Indicators*, op. cit., pp. 120-121.

Other Countries

Attempts have been made since the early 1980s to promote technology transfer and link researchers with users in Australia. The Australian Research Council (ARC) administers research grants in all fields except the medical sciences. Higher-education institutions, composed of universities and advanced-education institutions were merged in 1988 to create the Unified National System. Funding was allocated according to an agreed profile of teaching and research. In 1992, the criteria for the allocation of higher-education research funding were changed so that, although research excellence and broad national priorities in science and technology play the major role, some weight is also now given to the "requirements of research users, the potential for innovation, and the ability to contribute to effective research training."[182] The 1994-1995 Science and Technology Budget Statement describes activities which will be undertaken to further strengthen links between the science base and industrial innovation. They include increasing the number of co-operative research centres from 51 to 61.[183] Under this program, matching dollars are provided by the government for a minimum period of seven years, to encourage collaboration between business, government agencies and universities. Also envisaged is the creation of a national technology-access and -diffusion network.[184]

In Ireland, industry links with the higher education sector are promoted through a higher education and industry liaison program known as HEIC (Higher Education and Industry Co-operation). The program supports a broad range of initiatives in the area of the commercialization of technology. Universities, colleges and firms are the main actors in these initiatives, with financial support provided for collaboration among firms and colleges or universities. The program supports industrial liaison offices at colleges, and "incubators" and innovation centres at universities.[185]

A number of major changes have recently taken place in Norway, the most significant being the merger, on 1 January 1993, of Norway's five research councils into one, the Research Council of Norway. Co-ordination of research efforts and the improved interaction between organizations responsible for basic and applied research at a political level is matched by a new networking initiative at an institutional level, called the Norway Network. The institutions of higher education, universities and colleges, play the cornerstone role in this network whose purpose is to promote more communication, co-operation and rationalization of human resources

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[182] OECD, *Science and Technology Policy*, op. cit., p. 9.

[183] "Australian S&T budget announced," *Outlook on Science Policy*, July/August 1994, p. 77.

[184] Wright, op. cit.

[185] OECD, *Science and Technology Policy*, op. cit., p. 62.

and a more co-ordinated and efficient delivery of education and research.[186]

A national network more explicitly oriented to technology transfer, linking institutions of higher education, public research institutes and industry, has been established in Spain. Initiated in the wake of the 1989 national R&D plan, it had, as part of its design, the objective of improved communication and the transfer of research results between public sector research institutions and business enterprises. The network, called Offices for Transfer of Research Results (OTRI), links the appropriate offices in universities and public research centres. It is co-ordinated by the Technology Transfer Office (TTO), answerable to the General Secretariat for the national R&D plan. The TTO is responsible for providing technical advice to business enterprises[187] and research centres across the network on patents, contracts and training, in addition to circulating information on European Community (EC) research programs and to assist in the design of projects. [188]

Conclusions

Over the years, and particularly over the last decade, governments in OECD countries have introduced an increasing number of initiatives to promote U–I working relationships in science and technology and to facilitate technology transfer and diffusion. In some of these countries, the emphasis seems to be on U–I training aspects, whereas in others U–I centres (which may support integrated U–I training) seem to attract more public financial support and policy attention. In some countries, colleges are increasingly regarded as being important to local economic development, technology diffusion and technology transfer to local firms, especially SMEs. National electronic-technology extension networks are being constructed in many countries, and institutions of higher education and research are critical players in these networks.

Recent research on U–I centres in the United States indicates that federal funding has a highly significant leverage effect. Whereas overall industrial support for university-based R&D is approximately 7.3 percent, industrial sponsorship of U–I centres is an estimated 31 percent. No comparable studies on Canadian U–I centres have been undertaken. Results from such work would be very useful, and investigations of this nature should be promoted.

In Canada, direct federal support for U–I technology transfer became available in the late

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[186] Ibid., p. 90.

[187] The means by which information is provided to business enterprises is not known at this time; however, this would be an ideal subject for further research.

[188] OECD, *Science and Technology Policy*, op. cit., p. 111.

1960s, but most of the federal granting councils' partnership programs were introduced in the mid-to-late 1980s, as were several provincial programs. Some of the federal and provincial programs have since been evaluated and found to meet their original objectives. Recommendations were made in some cases to modify these objectives to put more emphasis on measurable industrial benefits.

Federal and provincial agencies are responding to changing circumstances with some innovative programming, and some efforts at co-ordinating and rationalizing among federal levels are evident. There are also signs of interest in using the new information technology to improve U–I links and technology transfer.

Many of the long-standing federal and provincial U–I programs seem to be well suited to the needs of large corporations. SMEs, however, have a different dynamic and different needs. Recently, federal government initiatives have focused more on the needs of SMEs. NSERC's Request for Applications program and its IPMI, as well as IRAP's CTN and the increased co-operation between NSERC and IRAP will certainly have a positive effect on high-technology SMEs if they are made aware of their existence. Traditional SMEs, which lack technical "receptor" capacity (defined here as an inability to take advantage of technical advances for reasons of managerial culture, lack of technical training and education, and low investment in technological advances) and are less familiar with or are intimidated by academia, may, however, be left out of the process. Intermediary organizations may be needed to develop receptor capacity and facilitate communication between entrepreneurs and researchers.

More research is required that would distinguish between the different academic organizations which receive industrial research sponsorship, that is, U–I centres as opposed to individuals or faculties. Given the interesting findings emerging from recent U.S. work on the subject, such research in Canada should be encouraged, to determine the differing degrees of leverage by source of public sector funds.

3. MANAGEMENT OF THE UNIVERSITY–INDUSTRY INTERFACE

Interaction between institutions of higher education and industry takes a number of forms and often involves more than just university or college personnel and their industry counterparts. Specific U–I links differ when dealing with training or research issues, and depend also on the business firm's size, research orientation and type of activity, and on the characteristics of the university or college, the local socio-economic infrastructure and other factors. In this chapter, U–I linkages will be discussed along the dimensions of training and research, and then from the perspective of different intermediary organizations, universities, colleges and firms.

Teaching and Training Linkages

"Quality education from the primary to the post-graduate level can be an important factor in attracting prospective entrepreneurs, firms and employees in high-technology fields."[189] Indeed, good training in science and engineering not only increases the potential contribution of the work force to "new initiatives and methods of approach" but also "ensures a competent receptor capacity" to external sources of innovation.[190] U–I collaboration in the training and retraining of scientists and engineers, and in the development of technology-management skills is, therefore, very important. Such specific U–I links vary from institution to institution to university. While no global statistics are available, these linkages appear to fall into one of the following categories.

- Industry participation in academic planning activities and in course design: more and more technical faculties have advisory boards with industry representatives[191] or include local engineers in their program committees.
- Industry support from a physical resource point of view: this includes donations of equipment, student scholarships and teaching grants.
- Industry support through the secondment of staff to universities and colleges: this includes such positions as executives-in-residence, or full- or part-time visiting

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[189] C. Armington, C. Harris and M. Odle, *Formation and Growth in High Technology Businesses: A Regional Assessment*, Brookings Institution, Washington D.C., 1983, cited in Steed, "Policy and High Technology Complexes," op. cit.

[190] Corporate-Higher Education Forum, *Brief to the Minister of Industry Concerning Federal Government Policies to Support Science and Technology*, C-HEF, 27 August 1994, p. 2.

[191] Three quarters of the 48 deans who responded to a survey of faculties of engineering, science and health sciences conducted in 1990-1991 by Jérôme Doutriaux had such advisory boards, and on average, one third of board members were industry representatives.

professors.[192]

- Provision of specialized courses and workshops by universities and colleges: this includes:

  - continuing education activities, offered by almost all universities, on campus, on site or through distance education;[193]
  - specialized academic programs introduced to meet industrial needs, in technical and managerial fields, including technical entrepreneurship[194] (very recent examples include the rejuvenated M.B.A. program offered by Queen's University specializing in management of high-tech firms, and the new certificate program in high-tech entrepreneurship at Montreal's École des Hautes Études Commerciales designed to develop the skills and knowledge of would-be high-tech entrepreneurs);
  - specialized professional and vocational programs; and
  - courses in entrepreneurship and management offered to science and engineering students[195] to increase their technology-management skills.

- Industry provision of real training opportunities: these include summer jobs and the increasingly popular co-op programs.[196]
- Participation of university professors: this is in professional development activities

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[192] Twenty-eight percent of the deans surveyed by Doutriaux (1990-1991) reported having visiting professors from industry.

[193] Science Council of Canada, "Learning from Each Other," op. cit.

[194] Science Council of Canada, *Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities*, by T.E. Clarke and J. Reavley, discussion paper, May 1987.

[195] Entrepreneurship and business courses are compulsory in some programs in six percent of the faculties, available as electives in 49 percent of the faculties and not available in 45 percent of the faculties, as reported by the deans surveyed by Doutriaux (1990-1991, op. cit.).

[196] Forty-two percent of the deans surveyed by Doutriaux (1990-1991) reported having co-op programs. According to a recent survey, nearly 50 000 Canadian students, mainly undergraduates, from 150 colleges and universities currently alternate work and study terms to obtain their degree. This represents 5.2 percent of the 950 300 full-time college and university students in Canada (data on full-time enrolment from Statistics Canada, *Educational Quarterly Review*, #81-003, vol. 2, no. 1, 1994, p. 83). In 1993, there were only 13 master's programs offering the co-op format, and 31 percent of the 864 co-op students enrolled in these programs were in technology-related domains (M.E. Szabo, "Postgraduate Co-operative Education: A Framework for University-Industry Collaboration," *Industry and Higher Education*, February 1995; these 864 co-op students represent 1.2 percent of the country's 70 000 graduate students; the 270 co-op students studying in technology-related domains represent about 1.7 percent of the science and engineering graduate student population). To encourage this type of U–I collaboration and support the training of young graduates with an industrial research orientation, NSERC is introducing a scholarship program for master's students in co-op science and engineering programs. This could be considered Canada's small version of the very successful British "Teaching Company Scheme" which ". . . had a major impact on the development of young graduates . . . [and has] resulted in major gains to industry, academia and associates," (*The Teaching Company Scheme*, Annual Report, 1993-1994, p. 4.).

organized by private business enterprises and professional associations.

Formal evaluations of U–I collaboration in training and professional development are difficult to perform for at least two sets of reasons.

- There is a ". . . lack of relevant and current data on higher education and the labour market"[197] and, in particular, a lack of aggregate data on U–I collaborative activities in the professional training field. Such data are difficult to collect because statistics are not even available at the university level. These activities are generally very decentralized, organized by various units such as continuing education units, faculties and departments, with little internal co-ordination.
- The global effects of these programs are easily described but are difficult to measure with any precision.

There is circumstantial evidence that such U–I collaboration is beneficial to industry, and to universities and colleges. Therefore, contacts between institutions of higher education and industry in this field should be encouraged by measures such as the following.

- Providing incentives and support for increased joint U–I initiatives in the curriculum design and in the delivery of academic, professional and vocational development programs at the undergraduate and graduate levels, through conventional means and distance education (such as the new Knowledge Connection Program proposed by the Telecommunication Research Institute of Ontario, known as TRIO, to support the development of distance "learnware"). For continuing education and professional development activities in particular, these incentives should foster co-operation between industry and the universities and colleges. These incentives should encourage industry to take advantage of their expertise, thus avoiding the dis-economies of creating a parallel, professional training sector disconnected from the academic world, and ensuring that the higher-education sector remains tuned to the professional needs of industrial trainers.
- Providing incentives for the industrial training of young university faculty members in science and engineering. Some professional experience, whether in industrial research or in engineering, would give them a better understanding of the skills and knowledge needed by their students, and would facilitate their access to research funding from industry. This may require modifications to current university promotion and tenure policies, similar to those which business schools are starting to consider to facilitate the changes and continuous improvements needed to meet "demands from schools' customers and constituents for better teaching . . ." and to reduce the effect of current rules which have "insulated faculty from those being served or those the university should be serving"

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[197] D. Fisher, K. Rubenson and H. Schuetze, *The Role of the University in Preparing the Labour Force, A Background Analysis*, Centre for Policy Studies in Education, University of British Columbia, 1994, p. 22.

in a fast-changing professional field.[198] Modifications could include replacement of lifetime tenure by five-to-seven-year contracts and the introduction of a non-tenure track for "clinical professors." Supporters of change do recognize the need to insulate universities from short-term industrial pressures: "part of our funtion is to provide the transmission of knowledge across generations. We can't do that with every fad. We have to have a core of stability, a core of expertise."[199]

- Developing a framework for joint U–I continuing education in science and technology to ensure minimum standards and portability of the training received. College and university involvement in continuing education is becoming more and more important because "professionals [now] need to update their conceptual and practical knowledge throughout their working lives to avoid becoming `professionally obsolete' at an early age . . ."[200]

Research Relationships

U–I research links involve tangible industrial support to university research, the exchange of knowledge between universities and industry, and actual U–I technology transfer for research commercialization.

Tangible industrial support to university research activities (in cash or in kind) includes:

- research grants;
- research contracts;
- funding of research chairs and Centres of Excellence; and
- donations of equipment or use of shared facilities.

The exchange of knowledge occurs with the movement of students and through the contributions of researchers and includes:

- industrial research projects performed by students within their academic workload (theses, course projects);
- hiring of research-oriented university students (co-op, summer jobs) or recent graduates;
- knowledge sharing through scientific and technical publications;
- participation in U–I research conferences and seminars;
- industrial consulting by university staff;
- U–I staff exchanges (university professors spending a sabbatical in industry, industrial

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[198] American Assembly of Collegiate Schools of Business (AACSB), "Volume is turning up on tenure question," *Newsline*, vol. 24, no. 2, Winter 1994, pp. 2-6.

[199] Joseph A. Alutto, Dean, College of Business, Ohio State University, in American Assembly of Collegiate Schools of Business (AACSB), ibid., p. 2.

[200] Ibid., p. 40.

researcher "on loan" to a university laboratory);

- joint U–I research activities in common or separate research laboratories; and
- formal and informal communications on issues of research and technology.

Technology transfer is achieved in several ways:

- the sale or licence of patents;
- joint ventures for the commercialization of joint research outcomes; and
- creation of spinoff firms.

While there is more statistical information on these research-oriented links than on those in the field of training and professional development, its quality is poor. There is no single source of reporting on all U–I liaison activities across Canada. Even within universities, aggregate data are often incomplete because of limited information sharing between departments, faculties and U–I liaison offices. The need for comprehensive, empirical, qualitative and quantitative data on U–I co-operation has been emphasized on different occasions,[201] but organizations or networks which collectively represent all technology-transfer managers and university administrators do not have the resources to gather such data in a methodical way.[202] The situation may improve as communications between U–I liaison offices increase, but it will also require more comprehensive reporting within universities on the research and liaison activities at departmental, faculty and university levels, as well as a common framework for data collection and reporting.

Industry Canada has undertaken studies, recently, on the potential to improve communications among organizations of higher learning by electronic means.[203] At the time of writing, an Internet-based electronic network, called Trans-Forum (see Chapter 2) exists, linking the technology transfer offices of some universities and colleges in Canada. Such a network could be used to spearhead the collection of standardized data.

As noted in Chapter 1, data on sponsored research at Canadian universities are published by the Canadian Association of University Business Officers (CAUBO). Data on the inventive production of universities, on specific U–I indicators, and on the operations of Technology Transfer Offices (TTO) at Canadian universities come from occasional surveys done by

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[201] Robert Armit, Vice-President (Technology), Carleton University Development Corporation in an address at the Workshop on Technology Innovation/Research sponsored by ISC, Ottawa, 10 November 1993.

[202] There are six networks which directly or indirectly have interests in technology transfer: the Canadian Association of University Research Administrators (CAURA), the Association of University Technology Managers (AUTM), the Association of University-Related Research Parks (AURRP), the Society of Research Administrators, the Technology Transfer Society and the Licensing Executive Society.

[203] IGW Canada Inc., "Electronic Networking among Universities to Improve Tech Transfer," final report of a study performed for Industry Canada, 21 April 1994; and Burnside Development, "Canadian Community Colleges/Institutes of Technology and Technology Transfer," consultant report for Industry Canada, 31 March 1994.

academic or government researchers, by the Canadian University Intellectual Property Group (CUIPG) (one survey in 1993) and by the Association of University Technology Managers (AUTM) based in Connecticut (one survey in 1993). As noted in Chapter 1, these surveys are not always comparable.

Table 7 shows the type of information most commonly used by large research-oriented universities to assess their academic "inventiveness" and U–I interactions: industrial funding of R&D, number of invention disclosures, number of patents, royalties earned and number of university spinoff firms. These data, of poor quality and reliability, are a mix of 1992 and 1992-1993 fiscal years. However, they are the only data available for comparative analyses. They show large differences between universities, both in terms of measurable outcomes and sources of funds. Some of these differences, such as the royalty income and the number of spinoffs, can be partly explained by the age and orientation of the university's research commercialization office, by its culture and by the personality of the persons in charge of U–I activities (Appendix I). Other differences, such as the industrial funding of university research, are due to provincial variants.[204] Better data are needed to understand these differences more fully and to provide information for policy decisions.

A comparative examination with the United States is useful here. Although the large, research-intensive U.S. universities[205] have significantly larger research budgets than even the biggest Canadian universities, median levels reported in Table 7 are quite similar: 1992 R&D budgets (all in Canadian dollars) of $61.6 million in Canada and $79 million in the United States, 36 vs. 39 invention disclosures and 15 vs. 13 active licences. There are, however, significant differences in median federal support (51 percent of the total R&D budget in Canada, 70 percent in the United States), median industrial support (12.98 percent of the total R&D budget for 11 Canadian cases, 9.2 percent for the median U.S. respondent), and median royalties income ($200 000 in Canada vs. $500 000 in the United States). Median shares of federal R&D funding are higher in this sample than the averages from official sources[206] reported in Chapter 1 for all universities (31.5 percent in Canada, 58 percent in the United States, Table 4), probably because universities in the sample are among the largest and most research-oriented of the population, but the significantly higher U.S. federal support of university research is consistent with the global data. Median shares of industrial funding are also higher than the averages reported in Chapter 1 for all universities (11 percent in Canada in 1993,[207] compared with 7.3

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[204] This is true, in particular, for Quebec universities which profit from the province's generous R&D tax shelter provisions (Chapter 1).

[205] The 98 universities sampled represent the top U.S. research-intensive universities.

[206] Statistics Canada and the National Science Foundation (United States).

[207] Statistics Canada, "Science Statistics," op. cit., p. 3, Table 2.

percent in the United States[208]) and the higher industrial support of university research activities in Canada is consistent with the global data. Differences in royalty income can probably be attributed to the relatively recent entry of Canadian universities into the licensing business compared with U.S. universities, and the fact that the licences of Canadian universities are newer.

[208] National Science Foundation, *Science and Engineering Indicators*, op. cit., Table 5.2.

Table 7
U–I Technology Transfer Activities, Selected Canadian and U.S. Universities
(**Note**: because several sources of data and different base years are used, not all numbers may be fully comparable)

Canadian Universities	Sponsored research (Canadian $, million): A: Total for university B: Federal government support C: Industry-sponsored research D: Total private (includes industry)				E: # invention disclosures received, 1992 F: # patents issued, 1992 G: # active licences H: # biological agreements I: Royalties (C$, '000), 1992 J: # spinoff firms, total					
	A	B	C	D	E	F	G	H	I	J
Toronto (a)	170	91 (c)	20	33.4 (c)	97	10	26	14	1115	20
McGill (a)	154	70.5 (c)	31	47.6 (c)	57	10	10	12	110	19
Montréal (a)	152	64 (c)	39	96.7 (c)	40	7	11	3	200	3
UBC (a)	120	83 (c)	19	27.6 (c)	80	21	65	60	755	28
Laval (a)	106.2	33 (c)	32	21.2 (c)	30	2	15	0	100	15
Alberta (a)	79.2	42.5 (c)	8	17.5 (c)	40	12	60	20	410	28
McMaster (c)	77.9	31 (c)	n.a.	27.2(c)	n.a.	n.a	n.a	n.a	n.a.	n.a.
Queen's (a)	61.6	39 (c)	8	17 (c)	33	6	23	33	761	12
Waterloo (a)	60	30 (c)	6	11 (c)	n.a.	7	60	22	2000	100
Calgary (c)	59.5	28 (c)	n.a.	16.3 (c)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Western (a)	60	27 (c)	15	13.5 (c)	25	25	3	3	8	2
Guelph (c)	59.2	23.2 (c)	n.a.	8.3 (c)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Ottawa (c)	50.7	29 (c)	n.a.	16 (c)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Carleton (b)	16.5	14 (c)	1	3.5 (c)	10	3	11	n.a.	12	n.a.
Mount Sinai Hosp. (b)	15.3	n.a.	2	n.a.	11	1	5	n.a.	70	n.a.
Concordia (b)	14.5	13.7 (c)	1	1.3 (c)	10	1	0	n.a.	0	n.a.
Median, 15 Canadian U.	61.6	31	15	17	36	7	15	-	200	-
U.S. Universities (exchange rate 1:1.25)										
Stanford (b)	350	306	17.5	n.a.	177	n.a.	165	n.a.	31 812	19(d)
MIT (b)	358	298	60	n.a.	291	n.a.	174	n.a.	14 600	n.a.
California U. System (b)	1700	1275	67.5	n.a.	352	n.a.	254	n.a.	33 000	n.a.
Median, 98 respondents	79	55	7.3	n.a.	39	n.a.	13	n.a.	500	n.a.

Notes:
(a) Data for 1992-1993 fiscal year, from "Program Proposal: Accelerating Utilisation of University Research by Canadian Industry," CUIPG, 6 June 1993, Table 1.
(b) Data for FY 1992, *The AUTM Licensing Survey, Fiscal Years 1991 and 1992*, AUTM, October 1993, various tables.
(c) Data for FY 1992, CAUBO, as reported in *Re$earch Money*, "Quebec's R&D tax shelters..," Feb. 1994, and CAUBO annual financial statistics.
(d) AUTM *Public Benefits Survey, Summary of Results*, AUTM, 1994, Table 2.

Organizations and Their Technology Transfer Mechanisms

To be successful, U–I links must overcome the traditional barriers between university culture and the business world. Differences in culture include such things as academic freedom to focus on almost any research topic vs. research led by market needs; free exchange and publication of research results vs. company secrecy; long-term research orientation vs. short-term problem solving and product development; and emphasis on basic research vs. commercial payoff.[209] This section presents a short review of some of the organizations and offices which are active at the U–I interface, and reports on evaluations where available. These organizations include:

- industry liaison offices (ILOs) at universities;
- colleges;
- industrial organizations;
- spinoff firms;
- regional development organizations;
- research parks affiliated with universities; and
- U–I research consortia, and joint U–I research institutes, research groups and centres of excellence.

Several of these organizations are often referred to as "intermediary organizations" because of their role as facilitators in the U–I technology transfer process. As noted by Gerwin et al., "Private intermediaries . . . short circuit the cumbersome bureaucratic procedures in universities."[210] Some are attached to a Centre of Excellence and have a sectoral orientation, others are attached to a university, such as Queen's PARTEQ corporation (Partners in Technology at Queen's), a fully owned, legally separate, not-for-profit entity). Still others have a regional responsibility, such as the Ottawa-Carleton Research Institute (OCRI), a consortium of the University of Ottawa, Carleton University, Algonquin College, other organizations of higher education and a number of local large and small industrial firms.

Industry Liaison Offices at Universities (ILOs)

Most universities in Canada now have offices dealing with technology transfer. Recent studies[211] have shown that, in 1990, these offices were generally small units (three to four

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[209] J. Doutriaux, "University Culture, Spin-off Strategy, and Success of Academic Entrepreneurs at Canadian Universities," *Frontiers of Entrepreneurship Research*, Babson College, 1991, p. 406-421.

[210] D. Gerwin, V. Kumar and S. Pal, *Transfer of Advanced Manufacturing Technology from University to Industry*, report, School of Business, Carleton University, October 1991, p. 40.

[211] J. Doutriaux, "Intéraction entre l'environnement universitaire et les premières années des entreprises essaimantes canadiennes," *Revue Internationale PME*, 5, 2, 1992, pp. 7-39; and previously unpublished data reported in Appendix I.

technical and clerical staff) set within university research services but reporting directly to a university vice-president, getting on the average 70 percent of their budget from the university, 13 percent from governments and 11 percent from internally generated income. These offices handle industrial research contracts[212] and intellectual property, identify opportunities and market inventions, but are seldom involved with research grants. The Technology Transfer Offices (TTOs) or ILOs act as facilitators in the technology-transfer process, liaising with faculty, providing information to university researchers on technology-transfer opportunities and processes. To industry, they provide information on university research expertise and resources, assisting selected inventors in their search for funds or industrial partners and clients, patenting and licensing, and supporting university spinoff firms.

Past research has shown that the initiative for technology-transfer activities comes more often from the researcher or industry than from the ILO. Limited resources prevent technology managers from doing all the liaison activities that they would like to do. Having said this, a proactive TTO is a definite asset. It is unlikely that the level of technology transfer achieved at the University of Waterloo, at the University of British Columbia, at the University of Toronto, at the Université de Montréal or at McGill would have been achieved if U–I linkages had been left entirely to the individual faculty. The success of the ILO in developing U–I linkages, commercializing university research and spurring industry's interest seems to be more a function of the level of initiative of its staff and of its networking skills than of university policies and structure.[213] In light of these findings, staffing of university and college TTOs or ILOs takes on vital importance, as does the level of resources afforded this effort.

Many of these 1990 results were confirmed by an informal telephone survey conducted during the summer of 1994 with eight Canadian ILOs (at large and small universities — one separate fully owned, not-for-profit corporation, six independent offices reporting directly to a university vice-president, and one a unit of another office). Most of the ILOs emphasized their role as facilitators. They publicize university research capability through conferences, seminars, newsletters, networks and targeted marketing activities. They promote market interest by informing professors of the requests made by, or interest expressed by, potential industrial clients. However, it is still the case that U–I links are made due to the initiative of individual researchers, who then come to the ILO for support and advice.

What is the impact of ILOs on U–I linkages? As noted by Enros and Farley, "An evaluation would require reviewing the effectiveness and efficiency of the offices, determining their major consequences, and interviewing all involved, from students to business people."[214] Evaluations and comparative studies to evaluate the impact of ILOs on universities (teaching,

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[212] In most cases, they handle both industrial and non-industrial research contracts; in some cases, they handle also other academic service contracts (professional development, institutional assistance projects).

[213] Doutriaux, "Interaction," op. cit.

[214] Science Council of Canada, *University Offices*, op. cit, p. 22.

research and university culture), on regional development and on industrial competitiveness, to determine the "most appropriate" organization and policies for a given university and region are further complicated by the lack of common definitions and measurements for basic outcomes. No global impact studies of ILOs have been attempted, but there is ample circumstantial evidence of some positive economic effects on university activities,[215] including the level of contract research, research commercialization through patenting and spinoff firms, and financial returns to the university through royalties and licensing.

The impact of these offices on university culture, on training programs and on the general attitude of the academic community toward industry is more difficult to evaluate. Although there is now more acceptance of U–I linkages than in the early 1980s,[216] it is difficult to ascertain how much of this change is due to the actions of the ILOs.

Despite the problems with data, limited additional aggregate information on Canadian ILOs is available in 1994 (tables 7 and 8). Very few ILOs, if any, are self-supporting from a financial point of view. However, as noted in Table 7, the royalties received by a few universities are becoming significant ($2 million in 1992-1993 at the University of Waterloo).

[215] Ibid., pp. 22, 23.

[216] Doutriaux, "Intéraction," op. cit., p. 10.

Table 8
U–I Technology Transfer Offices, Comparative Statistics, Selected Canadian and U.S. Universities
(**Note**: because of several sources of data are used, all numbers may not be fully comparable)

Canadian Universities	Staffing (FTE) A: Professionals, technology transfer B: Professionals, licensing C: Support staff, tech transfer D: Support staff, licensing E: Total staff					Net legal expenses ($1000) (b)
	A	B	C	D	E	
Toronto (b)	3	3	2	2	10	n.a.
McGill (a)	4		3		7	n.a.
Montréal (a)	4		3		7	n.a.
UBC (b)	11	4	3	0	18	130
Laval (a)	7		5		12	n.a.
Alberta (b)	4.5	3	3	1.5	12	35
Queen's (b)	3	3	1.5	1.5	9	94
Waterloo (b)	1.5	1.5	1	1	5	154
Western (b)	2	.2	1	.05	3.25	n.a.
Carleton (b)	2	2	0	0	4	21
Mount Sinai Hosp. (b)	1	1	.25	.25	2.5	102
Concordia (b)	1	0	1	0	2	15
U.S. Universities (exchange rate 1:1.25)						
Stanford (b)	10	9	13	12	44	1640
MIT (b)	10	8	8	7	33	3040
California U. System (b)	32	32	26	16	106	6056
Median, 98 U.S. Respondents	2	1.1	1.6	0.8	n.a.	180

Notes:
(a) Data for 1992-1993 fiscal year, from "Program Proposal: Accelerating Utilisation of University Research by Canadian Industry," CUIPG, 6 June 1993, Table 1.
(b) Data for FY 1992, *The AUTM Licensing Survey, Fiscal Years 1991 and 1992*, AUTM, October 1993, various tables.

A 1994 report on the issue states that, ". . . as a general rule, university administrators must understand that a new technology transfer office will be in the `red' in years 1-5 and alternate between `red' and `black' in years 6-10."[217] To help ILO managers, the Association of University Technology Managers has produced a manual of "best practices" which will soon have a Canadian addendum,[218] and benchmark studies have been proposed.[219]

ILOs have noted a "commercialization gap"[220] in the innovation process at universities. This commercialization gap refers to a lack of finance from either public or private sources for the development work required to scale up research generated at the lab bench (often with NSERC or MRC funding) to a level where the technology is sufficiently developed and tested to attract industrial funding and IRAP support. Whether this "gap" is the result of insufficient marketing by the inventor or the ILO, is due to the less-developed receptor capacity of Canadian firms or to a combination of these and other factors has been the subject of recent policy discussions.[221]

Several academic entrepreneurs have, in fact, were forced to start spinoffs to develop and commercialize their own inventions when these were not yet at the stage to attract the interest of established firms.[222] Some recent initiatives are intended to reduce the effect of the commercialization gap. For example, UBC's Prototype Development Program, created in 1988, is financed partly by the British Columbia government to support further research and development to demonstrate the commercial potential of selected invention disclosures. Since 1989, 48 projects have been supported: 24 are licensed or ready to be licensed (to existing firms or new start-ups), 10 are still in progress, and 14 have been abandoned.[223] UBC's technology-transfer activities and its Prototype Development Program benefit from the Science Council of

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[217] R. Armit, reporting on a presentation by Brian Gurney (Colorado Institute for Technology Transfer and Implementation) at the 1994 annual meeting of the Association of University Technology Managers, op. cit.

[218] *AUTM Technology Transfer Practice Manual,* distributed by AUTM, Norwalk, Connecticut; Canadian addendum under preparation by Helen Becker (B.C.) with contributions by several ILO directors.

[219] L.G. Tornatzky, "Benchmarking University-Industry Technology Transfer in the South, a Proposal . . . ," Southern Technology Council: Research Triangle Park, NC, July 1994.

[220] See Chapter 2 of this paper, discussions on "Intellectual Property Management Initiatives" at NSERC.

[221] NSERC Task Force on Intellectual Property, Minutes, Meeting # 1, 1 February 1993, pp. 4-5.

[222] J. Doutriaux and G. Dew, "Motivation of Academic Entrepreneurs and Spin-Off Development: Analysis of Regional and University Effect through Case Studies," Frontiers of Entrepreneurship Research Conference, Babson College and INSEAD, June 1992.

[223] D. Jones, draft copy of "UBC UILO Prototype Development Report," received by electronic mail on 25 July 1994, p. 7, of electronic copy.

British Columbia's Market Assessment of Research Technology (MART) Program[224] which provides funds to hire consultants to perform market assessments of new technologies, and from UBC Research Enterprises Inc, a fully owned for-profit company created by the university to "attract and develop the necessary resources . . . for commercialization of UBC technologies."[225]

The new federal Technology Partnerships Program, managed as a Tri-Council-Industry Canada initiative, and discussed earlier in Chapter 2, will provide additional resources to ILOs for the commercialization process. Trans-Forum, the electronic network also discussed in Chapter 2, has the potential to deliver on-line information critical for identifying and locating partners, to market university inventions to Canadian firms. A Technology Transfer Opportunities program, announced at the time of writing, is a joint initiative between NSERC and IRAP to promote university technologies to Canadian firms by relying on the IRAP-ITA network.

More information on ILO operations comes from other results of the summer 1994 survey. All institutions interviewed, whether large or small, have several industrial research chairs and participate in or manage federal or provincial Centres of Excellence. Globally, all the universities report the same type of U–I links, from individual consulting by professors (generally encouraged as long as it has no negative impact on teaching and research duties), to research contracts, joint seminars and workshops, professional exchanges and student summer employment. All but one of the universities interviewed have co-op programs. Intellectual property rules are mixed, with inventions entirely owned by the university in some cases, or entirely by the professor in others, but typically, arrangements are such that the net result is a 50:50 split. Five of the universities surveyed are affiliated with a research park. Linkages with the local business community are considered important: in most cases, the director of the ILO or a representative sits on the board of the regional economic development organization and participates actively in the activities of other regional or local development groups and networks.

When reflecting on the most important factors which contribute to the U–I knowledge-transfer process, many respondents insisted on research excellence. Professors, their research programs, their personal communication networks, as well as the research centres and government programs supporting basic research and collaborative research programs are all important. The need for continuous encouragement of U–I communications at all stages of the R&D process, for assistance with commercialization, for work with client firms (SMEs in

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[224] See Chapter 2 of this paper.

[225] Jones, op. cit., p. 12.

particular) to develop their receptor capacity,[226] was also mentioned. This underlies, again, the critical role of ILOs as catalysts of successful U–I technology transfer.

Individuals interviewed reported that the negative attitude of academics toward industrial research, and of small firms toward the relevance of university research, are still a factor limiting exchange, but understanding seems to be increasing. The lack of financial resources to offer effective industry liaison services was also noted as a major problem for universities. In particular, it was suggested by one respondent that ILO funding should not come from the education budget (university budget), but from budgets set aside for economic development and job creation. Another limiting factor was the lack of time on the part of university and industry researchers, for networking and personal communications. It was felt that access to data bases and electronic communications was very useful, but that it cannot be a substitute for personal networks.

Colleges

In many ways, colleges and technical institutes are uniquely positioned to respond to the major challenge facing Canadian industry in its bid to compete in international markets, namely, to retrain or upgrade its employees' skills to match the new technologies.[227]

They are receiving attention as technology-transfer vehicles in a number of provinces. A recent report on technology transfer in British Columbia,[228] for example, focuses on the role of colleges and technical institutes in technology transfer, and on how that role could be enhanced. While the British Columbia Technical Institute, through its Technology Centre, has been active in various technology-transfer activities, most of the province's college community has played a passive role in technology transfer for a variety of historically valid reasons. There is, however, a determination to alter course and to capitalize on the dispersion of these institutions across the province, and their accessibility to the local communities they serve.

A report commissioned by Industry Canada indicated that technology-transfer activity is increasing at colleges in other provinces, including Alberta, Ontario, Quebec and Newfoundland.[229]

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[226] The development of SME receptor capacity often results from joint work by a university or college ILO and a regional development organization.

[227] C-HEF, *Brief to the Minister*, op. cit., p. 10

[228] Ference Weicker & Company, op. cit., Table 2.4, p. 10a.

[229] Burnside Development, op. cit.

The idea that colleges and institutes have a significant role to play in technology transfer is beginning to generate practical consequences. Across North America, the trend is to acknowledge colleges and technical institutes as important assets in economic development policy. They are expected to play a role in working with industry to support technology-based growth.[230] Colleges play a more prominent role in technology diffusion than in technology development. Diffusion activities include the provision of specialized, short courses on technological applications, sponsoring seminars and the like, faculty consulting, student industrial projects, responding to industry requests for information and improving access of local industry to information about new technologies.[231] Where technological development occurs, it is often based at a technology resource centre which focuses on a specific technological area and has close ties with a university. Certain centres are dedicated to applied research and development related to new products and processes, the building of prototypes and the testing of new products. There are approximately 70 such centres in the United States.[232] Quebec has a unique set of Specialized Technology Centres attached to some of its CEGEPS, serving the technologies corresponding to the local industrial base.[233] Other examples include the participation of Ottawa's Algonquin College in the Ottawa Carleton Research Institute and similar university-college-industry partnerships in other regions.

Industrial firms

In 1984, the OECD proposed a typology of firms[234] which provides a useful framework for the analysis of U–I linkages. The four elements suggested were large firms in high technology, large firms in traditional sectors, SMEs in high technology and SMEs in traditional sectors.

Large firms in high technology sectors and in traditional sectors do not seem to have much problem in gaining access to university technology. As noted in Chapter 1, surveys by the Conference Board of Canada and by the Canadian Research Management Association showed that these firms generally identify universities as their first source of externally purchased R&D. Many large Canadian firms are involved in Centres of Excellence, research chairs and other joint U–I activities. Such firms seem to have the capability, expertise and human and financial resources needed to work with universities. Many are planning to expand their collaboration

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[230] Ference Weicker & Company, op. cit., p. 28.

[231] Ibid., pp. 30-32.

[232] Ibid., p. 30.

[233] Burnside Development, op. cit.

[234] OECD, *Industry and University* op. cit., pp. 26-33.

with universities. For example, Dr. Alexander MacLachlan, former vice-president and chief executive officer of the DuPont Company, reported at a recent symposium that large research-oriented companies are currently reducing their in-house research activities: "The company is expanding its reach for outside sources of . . . [new knowledge and technology]. At present the favoured way to acquire new technologies is from other companies . . . Other sources are universities . . . ."[235] At the 1994 Colloquium on Science and Technology Policy sponsored by the American Association for the Advancement of Science (AAAS), Charles Larson, executive director of the Industrial Research Institute (IRI), stated that "Industrial R&D spending in the U.S. has been virtually flat since 1986 . . . . As industry diminishes the role of its central research laboratory, it is turning more to universities to provide basic research."[236] However, intellectual property rights and industry's need for secrecy still create concerns for industrial links with universities.[237]

In Canada, industrial support of R&D at universities seems to be on the rise. As already noted in Chapter 1, a jump in funding due to PMAC inflows occured in 1992-1993. Informal interviews with four large Canadian R&D-intensive firms in the sample during the summer of 1994 confirmed this trend. These firms, in four different industrial sectors, have very active U–I links involving many universities with research contracts, consulting by academics (particularly during sabbaticals), funding of research chairs and co-op programs. Joint workshops and seminars are held, and the firms are represented on certain university committees. In three firms, the management of U–I linkages is centralized, under the control of a senior vice-president or senior technology manager. Survey responses are consistent with the findings of Potworowski who interviewed 30 senior industry executives from 14 large firms in 1989.[238] The responses underline the utility of university research as an extension of "a company's own internal R & D capability."[239]

The interviews also showed differences in the perceived usefulness of various types of linkages. A telecommunications-microelectronics firm stressed the benefits of a university–industry consortium acting "like a halfway house between university and industry," funded by industry and government, and staffed by academics and graduate students. A

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[235] Comments made at a symposium on "Reinventing the Research University," at the University of California in Los Angeles, 22-23 June 1994, cited by Abelson, op. cit., p. 299.

[236] Cited by Hanson, op. cit., p. 38.

[237] Ibid.

[238] J. André Potworowski, *Accessing University Research: The Experience of Canadian Industry*, IDRC Manuscript Report 210e. Ottawa: March 1989; see Appendix 2 for excerpts.

[239] Ibid., p. 49.

pharmaceutical firm also valued the services of an intermediary, in this case, university ILOs and innovation centres. In contrast, a resource-based company liked direct contacts with university professors for well-defined research contracts, without interference from intermediaries, liaison offices or consortia, a reaction which may indicate sectoral differences. Finally, a public utility company sponsoring a number of industrial chairs also preferred direct contacts between its technical units and university research groups for basic research activities, applied research being done in company laboratories.

From Potworowski's 1989 project, and from our interviews, it is clear that large R&D-intensive firms look positively at U–I research collaboration, and that while still frustrated by secrecy, time and intellectual property issues, they find benefit in tapping into a university's technological know-how, directly or through facilitating organizations. The importance of maintaining world-class basic research activities at Canadian universities, directly, through Centres of Excellence or networks of centres, has also been noted.

Small- and medium-sized enterprises (SMEs) in high-technology industries are generally led by entrepreneurs with good technical backgrounds and connections in universities. They tend to have a positive inclination toward university research. Lack of resources, time and market pressures, and strong cultural differences between the worlds of the academic and small business, however, limit access to university resources.

The situation is very different for SMEs in traditional sectors which generally have few relationships with universities. As noted in Chapter 1, in a survey of 224 SMEs (100 employees or less) representing most of Canada's manufacturing sectors, the CRMA found only 15 percent carried out some of their R&D through contractual arrangements with universities or government laboratories: "There is a substantial sector that appears to be unaware of the opportunity provided by contracting; that is, the small and medium-size enterprises."[240]

This problem is not unique to Canada: "It seems clear that `building out' from the university has to involve something more than the grafting of a liaison officer(s) onto a university structure . . . it must involve a combination of educational and research activity . . . directed principally at SMEs within the region of the university."[241] To take one example, firms may be invited to suggest topics for master's degree dissertations (as at Chalmers University in Sweden or in British Columbia). Levels of practical training at different stages of the educational process may be arranged within local SMEs (as in Canada, France, Germany, Ireland and the United Kingdom), or adult education may be expanded to fields of industrial interest. It is through these types of initiatives, of an educational nature, that firm managers gain confidence

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[240] Canadian Research Management Association, op. cit., p. 12, 13.

[241] OECD, *Industry and University*, op. cit., pp. 26-33.

in the academic environment. Ideally, graduating students should feel they can return to former professors for advice and help in areas of mutual interest and expertise. Research on SMEs has shown that their managers spend 25 percent of their time looking for external information, a percentage significantly larger than for managers of large firms.[242] Some of the information sought by SME managers can be obtained through electronic communications, by accessing the increasing number of bulletin boards and data banks available through Internet. However, as shown by small business research, most of the information used by small business managers still comes from their personal networks of friends and acquaintances, suppliers and customers, professionals and other sources within the community. Most SMEs are therefore dependent on the personal contacts and professional and technical resources available in their region.

As discussed earlier, some provinces, such as British Columbia and Quebec, have mounted quite comprehensive programming to encourage more U–I interaction at the level of SMEs. Whether or not such programming has contributed to more innovation among SMEs is not clear, however.

University Spinoff Corporations

One group of SMEs with special links to the university is the university spinoff corporation. Academic researchers and inventors,[243] and other U–I actors,[244] assert that these arise as a result of a lack of receptor capacity of local firms. However, creating a company is generally considered riskier than licensing,[245] and academic entrepreneurship does have its problems, as inventive academics do not always have the time, the motivation or the skills needed to create and run a spinoff company.[246] Their involvement in a university spinoff may also reduce their effectiveness as researchers. In addition, academic entrepreneurs face a number of cultural, institutional, organizational and financial barriers because of the separate roles of university and business.[247]

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242 J.L. Johnson and R. Kuehr, "The Small Business Owner/Manager Search for External Information," *Journal of Small Business Management*, 25, 3, 1987, p. 53-60.

243 Doutriaux and Dew, op. cit.

244 ARA Consulting Group, "NCE Interim Evaluation," final report, op. cit., p. iv; Jones, op. cit., p. 6.

245 Science Council of Canada, "University Spin-off Firms," op. cit., p. 9.

246 E. McMulan and K. Melnyck, "University Innovation Centres and Academic Venture Formation," *R&D Management*, 18, 1, 1988, p. 5-12.

247 F. Van Dierdonck and K. Debackere, "Academic Entrepreneurship at Belgian Universities," *R&D Management*, 1988, 18, p. 341-353.

It is estimated that there are, currently, about 300 university spinoff companies in Canada. As noted in Appendix III, statistics collected recently by Denys Cooper of NRC's IRAP suggest that these spinoff companies have a significant effect in terms of economic activity and job creation. Recent research has shown that spinoffs with the highest initial rate of growth come from research-oriented, externally oriented faculties located in universities with a well-established ILO,[248] and were created by a founding team led by an academic entrepreneur with good industrial experience and including non-academic members (Appendix III). Of course, not all university professors make good high-growth, high economic-impact entrepreneurs: some firms created by "hobbyists" as a side interest or a retirement hobby tend to be low growth whereas firms started by genuine entrepreneurs or by reluctant academic entrepreneurs who started their firm to exploit an invention that nobody wanted to buy show a higher potential for growth and for economic benefits.[249]

Regional Development Organizations

As noted in Chapter 1, regional development, particularly in high-technology, can profit from the joint efforts of industry, the local business sector, the universities, governments and local economic development organizations.

Some economic development corporations take a very proactive approach, as illustrated by a private, non-profit facilitator of regional development interviewed during the summer of 1994. This organization operates a convention centre and a research park; it prospects for companies interested in local technologies, assists in the funding of local R&D projects and is part of a network of local educational institutions, research laboratories, industrial firms and other institutions. The representative stressed the importance of developing, across the region, a proper balance between the sources of highly trained, highly skilled personnel, a good research base (university, public and private laboratories), an adequate infrastructure (communications, research park, incubation facilities) and a good mix of complementary industrial firms. The greatest barrier to effective development, in the view of this respondent, was the persistent dependence of universities, colleges and some firms on government support and government funding.

In other cases, regional development corporations are mainly involved in planning activities, delegating action items to others. For example, a corporation which was interviewed is dealing with all aspects of economic development, including manpower planning and education, regional infrastructure and analyses of all sectors of economic activity. However, it is also working closely with a local consortium of high-tech corporations and institutes of higher

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[248] Doutriaux "Intéraction" op. cit.

[249] Doutriaux and Dew, op. cit.

education which are very proactive in nurturing regional high-tech growth.

Research Parks Related to a University

As noted by Bell and Sadlack, university-related research parks differ from business and industrial parks because of "the existence of a formal and operational link with one or several universities, research organizations, or other higher educational institutions."[250] In December 1990, there were 12 such parks in Canada, all members of the Association of University Related Research Parks (AURRP), hosting between one and 65 companies, and from 40 to 1200 employees.[251] Several new parks have opened since 1990, the newest, in biotechnology, located in Ottawa. Canadian research parks are significantly smaller than their U.S. counterparts. This is due partly to their relative newness, and partly to the lack of diffusion of R&D activities among Canadian firms. A major share of the country's industrial R&D is being done by a small number of very large firms.

Most research parks have incubator facilities or enterprise centres which facilitate the start-up of entrepreneurial companies with access to space, business services and professional and technical support. "The evidence of congruity between incubators and successful technology transfer in research parks is illustrated by the number of `mature companies' which are technologically strong enough to undertake upscale production and to move their operations into the unprotected environment . . . . Overall, it seems that successful research parks have a `critical mass' of academic, public organizations and industrial interests . . . which even if it is not a guarantee of success, gives an indication of community-wide involvement."[252]

Industrial and Academic Consortia

U–I consortia take a number of forms and orientations. Rather than going into detailed descriptions or typologies,[253] four current examples will be described. Information was obtained through telephone interviews during the summer of 1994.

A research institute which participated in the survey is directly associated with a university and a hospital, and has strong ties with many other universities and over 60

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[250] Bell and Sadlak, op. cit., p. 231.

[251] Ibid., p. 232.

[252] Ibid., pp. 236, 241.

[253] As noted in the Introduction, a review of U–I linkages was done in 1986 by the Science Council of Canada and published as a series of background papers. For U–I consortia, see, for example, Science Council of Canada, "University-Industry Research Centres," op. cit.

companies worldwide. It acts as a one-stop communication node between industry and university researchers, informing industry about institute activities, organizing seminars and visits of research facilities, and circulating industry requests for research and information. Its greatest achievement is its ability to conduct multidisciplinary group research involving up to 10 to 15 experts in a single project. Activities are restricted by reduced funding from large granting agencies. Fortunately, examples of successful U–I joint research tend to attract more industrial funding. One of the barriers to technology transfer remains the attitude of some university researchers who feel that industrially funded projects are not appropriate in a university.

Two other organizations, one Ontario Centre of Excellence and one "centre de liaison et de transfert" in Quebec, stressed their achievements as communication facilitators with networks spanning across Canada, forging links that otherwise would not have occurred due to distance. They also believed that they contributed to a significant increase in university research funding and made possible many research projects which would not have been carried out otherwise. The lack of receptor capacity of industry, as well as industry's lack of interest and resources to fund longer-term projects, was noted by the Centre de liaison et de transfert. The Centre of Excellence, operating in a different sector of the economy, cited the resistance of the academic community to applied work and its lack of information on industrial needs as problems it is striving to overcome. Nevertheless, both organizations feel that attitudes and capabilities are changing, and that university–industry communications and collaboration are increasing significantly. Remaining barriers to knowledge transfer noted by the Centre of Excellence include insufficient concern by universities and provincial departments of education for real excellence in our graduate programs (i.e., there is more concern about "time to degree" rather than excellence, in contrast to many of our Pacific Rim competitors) and the difficulty experienced by financial institutions and intellectual property managers in understanding the needs and characteristics of small high-tech firms. While large firms have the legal capacity to deal with intellectual property issues, this is not the case for smaller firms.

A fourth organization is a proactive consortium of institutions of higher education and high-technology enterprises. Its level of activities, visibility and recognition illustrate once more the feasibility of co-operation, both within the sector and at the regional level. Some of the activities of this consortium include:

- work with the local regional development corporation to ensure that high-tech growth and local infrastructure, communications, services and support industries, and trained manpower resources are kept in balance;
- outreach activities, particularly for SMEs, including breakfast meetings, press communiqués, local seminars, contact with companies to inform them of local resources and to facilitate networking; and
- training and research seminars, newsletters and other communication activities among consortium members.

Its visibility and level of activity may be attributed in great part to the personality and networking capability of its leading staff, which points to the critical importance of professional competence for technology-transfer personnel.

Conclusions

Industrial sponsorship of university-sponsored R&D may be increasing in Canada, and understanding between the two sectors is also beginning to improve. Some universities, through their ILOs or the equivalent, have experienced considerable success in forging U–I linkages, negotiating licences and collecting royalties. What evidence exists points to the important role of a competent university ILO. The number of spinoff companies based on university technology is not insubstantial. There are signs that colleges are also increasingly involved in technology-diffusion activities in Canada. Likewise, intermediary organizations, such as research consortia and regional development organizations, are having an impact on the communities they serve. Although rigorous evidence is not available, existing data and anecdotal evidence from interviews, point to the importance of having professional technology-transfer personnel with adequate resources to do the job. New federal and provincial programs to bridge the commercialization gap seem to be positively regarded, and the provision of electronic information services to improve marketing efforts of university ILOs may well serve as an important strategic tool.

Nevertheless, weaknesses persist in the system. Differences in local socio-economic characteristics and receptor capacity, in regional culture, in attitudes or needs, and a continuing lack of time, financial resources or expertise, despite the many programs, have all been cited as limiting the opportunities for transfer. U–I relationships face the ongoing challenge of increasing each partner's familiarity with the other's culture and of adapting the knowledge-transfer mechanism to the target population.

Large firms and high-tech SMEs are able to take advantage of the existing channels of collaboration and communications. However, these channels do not seem to serve SMEs in traditional sectors very well. Colleges seem to have had more success in this regard according to the limited literature available. For SMEs in traditional sectors, intermediary organizations are almost always necessary to provide technical and business assistance, and to develop networks. Regional support, regional role models, local outreach activities and increased access to local expertise are especially important. Colleges may be more appropriate as partners than universities for this particular industrial sector because of their applied orientation, their flexibility in designing locally suited training activities and their mandate to serve their local communities.

Surveys of organizations, approached in the context of this and other studies, have stated their priority concerns, summarized as follows:

- that adequate public support for basic research in universities be continued to ensure both its excellence and the continuing supply of highly trained personnel;
- that university faculty become familiar with the dynamics and culture of large and small

firms, and that entrepreneurs become equally perceptive about university capability;

- that university ILOs receive increased external funding from regional development budgets;
- that more development or support of other intermediary organizations working at the regional level occurs to permit personalized assistance for SMEs (high-tech and traditional sectors); and
- that there be an increased flow of technical information through electronic networks for the large corporations, the high-tech SMEs, and all the research and intermediary organizations that know how to use them.

4. CONCLUSIONS AND RECOMMENDATIONS

The aim of this background paper on the U–I relationship in science and technology in Canada was to enhance and renew our knowledge of this issue to provide better information for the academic and policy preoccupations of the 1990s. The paper was based on the literature concerning this and related topics, on interviews with relevant government officials, on published academic and other surveys and, finally, on anecdotal information collected from a small sample in 1993. Areas covered included the profile and socio-economic impact of academic research, a description of Canadian and foreign government programs designed to promote U–I collaboration and an investigation of the main organizations active in the U–I technology-transfer process.

From this study, we draw the following general conclusions:

- University R&D and U–I linkages generate a high social rate of return.
- Basic research should continue to be adequately supported at universities. By firms and ILOs alike, research excellence was reported to be one of the primary factors underlying technology transfer and the supply of personnel to industry.
- Because Canadian universities perform a high share of domestic R&D, and Canadian firms are not, on the whole, highly innovative, the efficient transfer of technology to the domestic market is important.
- University and college ILOs, when professionally staffed and allocated sufficient resources, are an important asset for U–I links and technology transfer. A well-run office appears to have a significant impact on the commercial activity generated by a given university.
- Other intermediary organizations, such as networks, consortia and regional economic development organizations also have critical roles to play in local U–I linkages and technology transfer or diffusion, and they tend to be more approachable by SMEs. Local economic development, including the forming of U–I links, appears to operate effectively when the different organizations, including ILOs, co-ordinate their activities and complement one another. The most effective technology-transfer and -diffusion activity seems to take place where the initiative arises locally.
- Industrial sponsorship of university-based R&D is on the rise in Canada. It is critical that sufficient resources are available to improve statistics and analyze this phenomenon, and that the policy implications of this trend, such as the impact on the free exchange of knowledge, are thoroughly explored.

Many of the interesting findings emerging from this report are based on literature and surveys in other countries, and they point to the need, in Canada, for comparable research and the development of standard, reliable data sets. Specifically, research is recommended to provide six specific factors.

- Estimations of the social rate of return of U–I links in Canada, giving attention to the probable differences among industrial sectors and geographical regions, should verify the degree to which foreign results apply to Canada. Ideally, work of this nature would not only take account of the knowledge creation and assimilation in U–I links, but would also evaluate the broader impact of knowledge creation for other domestic social entities (e.g., government) and the economic effects of supplying highly trained personnel.
- Analyses of the role of the higher-education sector in regional economic growth in Canada would involve case studies on university and college links with local industry and intermediary organizations and would assess their influence on the economic growth of high- and low-technology regions and, when appropriate, development of regional receptor capacity. Existing information on this topic should be compiled, and new studies undertaken where there are gaps, to create a meaningful sample of regional economic studies to address U–I links. On the basis of such case studies, some models could be generated.
- Assistance to organizations which normally collect basic data, including the Canadian Association of University Business Offices (CAUBO) and Statistics Canada, would be helpful. Research projects which would distinguish among different modes of industrial sponsorship, that is, in U–I centres as opposed to individuals or faculties, should be encouraged to determine the differing degrees of leverage which exist, depending on the source of public sector funds. A related research area deserving of more study is a comparison between the Networks of Centres of Excellence and ILOs to determine if these organizations differ in the extent to which they lever industrial funds, and to analyze differences in approach for the commercialization of academic research. Finally, investigation of the extent to which firms, especially SMEs, rely on external sources, such as universities and colleges, for research and development, technology and technology training is an area of research which should be pursued with more vigour.
- An analysis of the relationship between university training activities (traditional, continuing and distance education) and the cultivation of U–I linkages, including both large firms and SMEs in the region would determine the best methods to encourage U–I co-operation in the design and delivery of academic and professional development programs at the undergraduate and graduate levels. It would also point out the most effective means of raising industry awareness of university expertise and capabilities. It might also investigate the feasibility of developing a framework for joint U–I continuing-education activities in science and technology, to ensure minimum standards and portability of the training obtained.
- Comprehensive and accurate information on the commercialization activities of Canadian ILOs at universities, related research institutes (including university hospitals), technical

institutes and colleges would involve developing standardized measures acceptable to the institutions sampled and undertaking a comprehensive survey which would embrace the wider Canadian population of research-intensive universities and institutes. Some organizations with expertise in these areas, such as the Association of University Technology Managers (AUTM) and the Canadian University Intellectual Property Group (CUIPG), have already made headway in investigations of this nature, but lack the resources to carry out more detailed surveys and analysis. Results could be used as a benchmark study of ILOs comparable to the one currently being conducted across the southern states of the United States, with the aim of creating "models" of ILOs for use by various types of Canadian higher-education organizations. Results could also be used to evaluate the appropriateness of creating regional technology-transfer centres to act as a liaison between smaller universities, local colleges and SMEs in traditional sectors.

- Preliminary estimates of the economic benefits generated by university spinoff companies have already been carried out, and indications are that spinoff companies have a non-negligible economic effect in terms of employment generated and revenues earned. More work should be conducted to determine how spinoff companies compare in their economic effects with Canadian SMEs in general. Ideally, the analysis of spinoff companies would be designed to test the notion that such companies build technological receptor-capacity in Canada.

APPENDIX 1
RECENT STUDIES OF CANADIAN UNIVERSITY–INDUSTRY LIAISON OFFICES

The first technology transfer offices at Canadian universities were created in Canada in the late 1970s. In 1986, Enros and Farley visited 26 universities in Canada and identified 15 offices for technology transfer.[254] They noted the heterogeneity of the population, explained by the newness of the concept and by differing characteristics and cultures of the various universities.

- Most offices were located at large research-intensive universities, a few at smaller universities. Not all large universities had created liaison offices.
- All but one of the offices operated within the organizational structure of the university, often within its office of research services. For the exceptional case, U–I liaison was handled by a separate, fully owned, non-profit corporation.
- Services offered generally included liaison activities within the university (informing university researchers on technology-transfer opportunities and describing the process) and with industry (marketing the university's research capability and its research resources). Activities included:

    - industrial contract management;
    - assistance to inventors to find funding, industrial partners and clients to further develop or commercialize their inventions;
    - management of the university's intellectual property;
    - patenting and licensing inventions; and
    - support for creation of spinoff companies or other forms of commercialization.

There were, however, significant differences of scope and capability between them.[255]

A number of additional Industry Liaison Offices (ILOs) were created in the late 1980s. In 1990, in the course of a survey for the study of university spinoffs, Doutriaux obtained data from ILOs at 32 universities, with seven other universities returning blank questionnaires because

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[254] Science Council of Canada *University Offices for Technology Transfer*, op. cit., p. 10.

[255] Ibid., pp. 20, 21.

they were mainly teaching institutions with limited research activities.[256] The characteristics of the ILOs had not changed dramatically from those described by Enros and Farley in their 1986 study.

- Ten percent of the ILOs existed as sections of schools of graduate studies, 80 percent were independent divisions reporting directly to the top administration (often within university research services) and 10 percent were external university-owned corporations.
- Only 13 percent of the ILOs (at both smaller and larger, research-intensive universities) were responsible for the administration of research grants *and* research contracts. In all other cases, ILOs focused exclusively on research contracts, intellectual property management, identification of opportunities and marketing of inventions.
- The average year of creation was 1984 (1971 to 1990 in that survey).
- The average number of employees (technical and support staff) was 3.9, with a range of one to 14.
- The average budget (1990) was $340 000. The average funding source breakdown was 70 percent from the university budget, eight percent from the federal government, five percent from provincial governments, 11 percent from internal sources and five percent from other sources.
- Forty-seven percent of the ILOs had an advisory board, whose membership averaged 35 percent professors, 35 percent industry and 18 percent university administration and staff.
- Half the ILOs had a newsletter with research and office news published about four times a year and sent to professors (47 percent of the cases), or professors and external companies; only in a very few cases were these newsletters sent to venture capitalists.
- Most of the technology-transfer initiatives came from the professors,[257] making the ILO a facilitator rather than initiator: 54 percent of research contracts resulted from requests from faculty members, 27 percent were signed in response to requests by companies, 13 percent resulted from systematic canvassing of industry to identify its needs or advertise the research expertise of faculty members, and the rest resulted from informal contacts with the business community. The ILO negotiated and signed only an average of 42 percent of university research contracts, the balance being signed directly by the faculties (16 percent) and by other offices in the university (42 percent). Again, the ILO became aware of research activities with interesting commercial potential following visits by faculty members (67 percent of the time) or visits by ILO employees to academic labs (21 percent of the cases). The rest were due to informal exchanges between staff, deans and professors.
- With the exception of industrial research contracts with pre-arranged rules, official intellectual property rules were mixed. Sometimes 100 percent ownership by the faculty

[256] J. Doutriaux, unpublished data collected for studies on university spinoff firms.

[257] This is consistent with the findings and recommendations made by Gerwin et al., op. cit. p. 40.

was the rule, in others 100 percent ownership was assumed by the university. However, it is significant that, after adjustments for university assistance in the commercialization process, actual ownership almost always came up to half to the inventor and half to the university, with sometimes a small share for the ILO or the inventor's faculty.

- The success of the ILO in developing U–I linkages, commercializing university research, spurring industry's interest for university research, seemed to be more a function of the personality of the ILO officers and of their networking skills than of the policies and structures developed by the university.

APPENDIX 2
RECENT STUDIES OF RELATIONSHIPS BETWEEN UNIVERSITY RESEARCH AND LARGE FIRMS

U–I research linkages in science and technology between large firms and universities have been described in several recent studies.

- In 1987, Hutchison et al. analyzed the R&D links between six Canadian firms of various sizes and universities. A number of tangible and intangible benefits were identified.[258] Tangible benefits included increased university research funding and increased industrial competitiveness. No specific data were provided. Intangible benefits included technical "cross-pollination" between the firms and the universities, resulting in improved teaching and increased research activities on both sides and, in some cases, leading to the creation of Centres of Excellence. Regional development benefits were also observed when the projects were in regions with a good match between university expertise and industrial strengths. Among the most useful findings were the need for a "champion" to support the U–I link, the importance of good and unrestricted communications between the partners, the need to understand each other's corporate culture and the flexibility to facilitate co-ordination.
- In 1989, Potworowski focused his analysis on the measures taken by selected Canadian firms to transfer and receive technology from universities.[259] Interviews were conducted with 30 senior industry executives from 14 large firms, all of whom are users of university research. Eleven of these firms have a significant in-house R&D capability, with 130 or more employees engaged in research in 1989. All firms are dependent on research, with R&D budgets ranging from $400 000 up to $660 million. The sample included Bell Northern Research, Alcan Aluminium, Pulp and Paper Research Institute (PAPRICAN), SEMEX Canada, CAE Electronics, AECL, Ontario Hydro, GM Canada, Institute for Chemical Science and Technology, Stelco Inc., Allelix Inc., Polysar Ltd., Connaught Laboratories and Noranda. No tangible measures of the business impact of these links were provided, but the durability of the links analyzed indicates that they were considered good investments by the companies involved. Specific projects would be terminated and new projects started, but the overall collaboration would continue. "`We

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[258] Science Council of Canada, *R&D Links* op. cit., pp. 34, 35.

[259] Potworowski, op. cit.

are not a charitable organization,' emphasizes one senior executive."[260] The major conclusion drawn was that extent of benefit to industry from its links with universities is positively correlated with the depth of the relationship between the relevant industry scientists and academic researchers, the monitoring of the links between partners and the long-term outlook taken when establishing these links.[261] It was also determined that firms from different sectors approach university–industry links in diverse ways. Highly knowledge-intensive firms, such as biotechnology firms, actively promote university–industry linkages in appropriate areas. Companies in more traditional manufacturing areas seek to develop expertise among a core of interested academics or to generate research projects which have potential for enhancing competitiveness.

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[260] Ibid., p. 10.

[261] Ibid., pp. 3-5.

APPENDIX III

RECENT STUDIES OF UNIVERSITY SPINOFF CORPORATIONS

Statistics collected recently on university start-ups and on their economic impact have been collected by Denys Cooper of NRC's IRAP.[262]

- Two hundred and fifty firms formed to transfer university-researcher technology have been found; 120 received IRAP support in their early days.
- Of these firms, 110 employed a total of 5500 people in 1992.
- Of these firms, 92 had combined 1992 sales of over $550 million.
- About 50 new spinoffs are formed each year (average of last four years); numbers decreased in 1993, probably due to economic conditions.
- Eleven firms are quoted on the stock exchange.
- Relatively few firms have been taken over by foreign companies.
- Star performers include Connaught Laboratories, MacDonald Dettwiler, Develcon and SED Systems.

These data suggest that university spinoffs have a non-negligible economic effect. It is estimated that there are currently about 300 university spinoff firms in Canada.[263] Even if they could all be found, estimating their total economic benefits and comparing them with those of independently created companies to evaluate the appropriateness of federal government spinoff programs would require much more data than currently available.[264] Economic impact analyses would also have to consider the incremental effect of spinoff activity: whether the university technology licensed to the spinoff would have been licensed — albeit with some delay — to an existing company, whether an existing company would have made more efficient use of the technology, whether the research productivity of the inventor-entrepreneur is enhanced or reduced by the spinoff, whether the regional impact of spinoffs justifies their risks, a number of questions with no easy answers.

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[262] Denys Cooper, private communication, 12 July 1994, and data presented at the Conference on Small Universities, Cooper, op. cit.

[263] Denys Cooper, private communication, 12 July 1994.

[264] R. Sweeting, "The Commercialization of Academic Research: Subproject on University Spin-off Companies," report prepared for Industry Canada, March 1994, p. 18.

Recent research[265] has shown that academic entrepreneurs seem to be of three types:

- the hobbyist, starting a firm as a side interest or a retirement hobby;
- the genuine entrepreneur, often with past industrial experience, who would have started a firm whether in a university or not; and
- the reluctant entrepreneur, generally a very active researcher, who started a firm because no existing firm willing to buy his or her licence could be found.

Whereas firms created by hobbyists tend to be low growth "lifestyle firms," firms created by the two other types of entrepreneurs have a high potential for growth and for economic benefits. And if their creation contributed to the successful commercialization of an invention which did not interest existing firms, it made good economic sense.

An analysis of 58 spinoffs created between 1971 and 1990 by science and engineering professors has shown that they are "fairly typical," similar to other (non-university) high-tech start-ups in terms of sales level and rate of growth.[266] It has also shown some characteristics of spinoffs with the highest rate of growth during their first five years of operations.

- They come from research-oriented faculties having an external orientation (co-op programs, external linkages, participation in external networks, institutes) and are located in universities with well-established ILOs.
- They had a founding team led by an academic entrepreneur with good industrial experience (the main founder, not necessarily the manager of the spinoff) and including non-academic members, had planned well before start-up and were striving for technological excellence.

The academic entrepreneurs most productive in research were able to raise the most external capital for their start-ups, an initial strategy conducive to good product development and sales growth; they also came from universities with the most proactive ILO.[267] Contrary to expectations, the research productivity of the academic entrepreneurs did not suffer from their start-ups. No noticeable effect was observed in terms of self-reported publications (10.1 on the average, two to three years before start-up compared with 11.9 for the second and third years after start-up), and a strong, statistically significant, positive effect on research funding ($169 000 on the average, two to three years before start-up compared with $265 000 for the

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[265] Doutriaux and Dew, op. cit.

[266] Doutriaux, "Intéraction" op. cit., p. 7-39.

[267] Ibid., p. 31.

second and third years after start-up).[268] There was however a negative correlation between the post-start-up academic productivity of entrepreneurs, the initial "marketing" orientation of their firm and their *early* sales, initial research orientation and objectives of technological excellence for the start-up (and continuing academic productivity for the entrepreneur) being generally associated with slower initial growth of sales but higher later growth.[269]

As for large successful corporations, research orientation and external orientation seem, therefore, to be two characteristics of universities spinning off high-growth firms. For these universities, spinoffs may be a good U–I technology-transfer mechanism, with the advantage of contributing to local job creation and industrial activity.

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[268] J. Doutriaux, unpublished data, 1990 survey of academic entrepreneurs; these results were confirmed during a series of 26 interviews: the R&D activities and market-pull of their spinoff gave them new ideas for academic research and opened new opportunities for their university research.

[269] Ibid., p.31. The delayed effect (by six to seven years) of sales growth is especially clear for "reluctant entrepreneurs" (Dew and Doutriaux, op. cit.) and for biotechnology firms (as shown by preliminary data on IRAP-supported spinoffs prepared by Denys Cooper, private communication, 12 July 1994).

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