deans of research facilities, was made available for the author's use, as well as access to other data and survey results. It was mutually agreed that the statistical comparisons of results for each university would be kept confidential.

At this point, the magnitude of pursuing the original research objective became apparent. External funding was unavailable, and at that time (spring 1990) the response rate to Doutriaux's survey was weak. A reorientation in the survey focus was in order. It was decided that a limited survey of the research linkages of seven Ontario universities, situated in regionally distinct settings, would be appropriate. It was hoped that the survey results would verify whether Canadian universities conform to regional and economic characteristics found in studies of their counterparts in the United States and Europe, and provide adequate results to analyze regional contracts. Selected from Doutriaux' mailing list, only four of the seven universities provided any information on their research connections with industry. Hence the practice of industry R&D cooperation prevalent at four Ontario universities became the scope of the investigation undertaken for this thesis.

The survey, although restricted to a limited number of institutions, attempts to add credence to the argument supported from the literature, that university-industry ties

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service

Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

**Development of The High-Technology Sector Through
University-Industry Linkages**

by

Ingrid Pongratz

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of**

Master of Arts

**Department of Geography
Carleton University
Ottawa, Ontario**

December, 1991

(c) copyright

1991, Ingrid Pongratz

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-75942-9

Canada

The undersigned recommend to
The Faculty of Graduate Studies and Research
acceptance of the thesis
**Development of The High-Technology Sector Through
University-Industry Linkages**

submitted by
Ingrid Pongratz
in partial fulfilment of the requirements for
the degree of Master of Arts

Thesis Supervisor

Chair, Department of Geography

Carleton University

January 8, 1992

ABSTRACT

Research and development (R&D) activities have been identified as critical inputs to the performance of the high-technology sector, which is found to be a key stimulant of economic growth in industrialized societies. Compared to other industrialized countries, Canada's standing in this sector has been lower than anticipated. The thesis analyzes the inter-reliance of variables contributing to a viable high-technology sector, paying particular attention to the Canadian context. Various initiatives have been promoted to encourage greater university-industry interaction than has been the case in the past. The thesis points out that collaborative research links between universities and the industrial community will be beneficial for the Canadian economy. An exploratory survey of 4 Ontario universities examines the extent of collaboration these institutions undertake with industry. The survey substantiates that cooperative links are established and are on the increase. The establishment of on-campus technology transfer offices has been accredited for promoting university-industry interaction. However, survey results also suggest a need for more comprehensive data availability in order to fully assess the direction university-industry interaction is heading in Canada.

PREFACE

The thesis was initiated as a consequence of the author being introduced to research related environments in which leading-edge technology was employed or was being registered. Literature indicates that during the last few decades science and technology have assisted in the transformation of society on a scale never seen before, creating a new landscape of industrial economy.

While numerous forms of cooperation in R&D exist, the form chosen for closer inspection in this thesis is the cooperation between university and industry. The author believes that this type of cooperation is particularly suitable to encourage in the Canadian context. The literature demonstrates that small scale developments entertain many beneficial consequences for their regional and national economic environment. Indeed, some of these university-industry relationships, once established, cultivated, and having found a specialized niche within a market, may expand their operations to international clients.

Although the particular university-industry programs referred to in this thesis pertain only to Canada, literature draws comparisons with universities in other nations. The increasing role played by science and

technology in society, and the national concern for economic well-being, brings this complex issue to the forefront of concern for many nations. Examples illustrate the differing forms of cooperation in R&D between universities and industry as a means of adapting to national concerns.

During the growth and development stage of this thesis the author would like to extend her thanks for encouragement received from thesis supervisor, Dr. Iain Wallace; for comments and suggestions provided by Dr. T.P. Wilkinson; and direction received from Dr. Robert Armit of the Office of Commercialization at Carleton University. I would also like to give special regards to Dr. J. Doutriaux, University of Ottawa, for his enthusiasm on this topic and for providing access to his survey database on university spin-off companies and institutional culture.

The author wishes to express thanks to her parents for providing the opportunity of 'free-time' to undertake the writing of this thesis and to the Demers' for exhibiting patience and perseverance during the technical production of this paper. Finally, this report is dedicated to my three children, Sonya, Rosemarie and Kyla. They are a perpetual fountain of motivation and inspiration. They are the generation growing up in the new age of science and technology.

TABLE OF CONTENTS

	PAGE
Acceptance Sheet	i
Abstract	ii
Preface	iii-iv
Table of contents	v
Glossary of terms	vi
List of tables	vii
List of figures	viii
CHAPTER I: Introduction to High-Technology and Economic Development	1
1.1 Economic Theory and High-Technology	5
CHAPTER II: Canada's Industrial Profile in the High-Technology Sector and its Contribution to Regional Economic Development	16
2.1 Canada's High-Technology Profile	16
2.2 Industry's Reliance on Higher Education	26
2.3 Regional Economic Development	30
CHAPTER III: University-Industry Interaction	42
3.1 University R&D	51
3.2 Survey of R&D Interaction at Four Ontario Universities	61
CHAPTER IV: Summary and Conclusion	74
BIBLIOGRAPHY	79
APPENDIX 1: Major Science and Technology Initiatives Promoting the Innovation Cycle	90
APPENDIX 2: Definition of High Technology Products	96

GLOSSARY OF TERMS

GDP - Gross Domestic Product. GDP is the GNP minus the income from abroad.

GERD - Gross National Expenditure for Research and Development. In Canada, GERD is the sum of the intramural R&D expenditures of the following sectors: industry, federal and provincial governments, universities, provincial research organizations, private non-profit research organizations. The ratio of GERD to GNP provides an indication of the proportion of a country's economic output that is allocated to R&D activities (Chand, R. 1980).

GNP - Gross National Product represents the sum of expenditures for final products and services at market prices. This is the sum of personal consumption expenditures, plus net export, plus gross private domestic investments and government purchase of goods and services. (Gauvin, W. 1981).

HIGH-TECHNOLOGY - For an extended definition of "high-technology" see Appendix 2.

INDUSTRIAL COMPETITIVENESS - Is a measure of the immediate and future ability of industrialists to design, produce and market goods whose price and non-price qualities form a more attractive package than those of competitors abroad or in domestic markets (Canadian Manufacturers' Association 1982:6).

INNOVATION - This term covers the whole sequence of research, development, pilot plant test and commercialization in a full-scale plant. An invention which is not commercialized is not an innovation. In this report 'innovation' entails the whole process, from original conception to acceptance in use.

STRATEGIC TECHNOLOGIES - Describes technologies that will be fundamental to an industry in the future, such as artificial intelligence. These are new technologies in which industry places long-term R&D investment to gain a monopoly in a particular market (Whelan, B. 1988).

SOCIAL RATE OF RETURN - Is the return on the investment to a broader group than the initial investor alone. The social rate of return from performing R&D is higher than the private rate of return for the firm performing the initial research.

LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
1)	Research Intensity of Manufacturing Firms	27
2)	Erosion of the Financial Capacity of Universities	54
3)	Percent of Faculty in Each Science and Engineering Field who Report Consulting Activity	56
4)	Distribution by Client of Science and Engineering Faculty Who Were Consultants in 1983-85	57
5)	Selected Vehicles of Technology Transfer	58

LIST OF FIGURES

<u>FIGURES</u>	<u>PAGE</u>
1) The Technology Transfer Continuum	14
2) Total R&D by Performing Sector	17
3) Total R&D Expenditures by Canadian Industry and Federal Government	23
4) University Research Oriented Towards Industrial Innovation	44

DEVELOPMENT OF THE HIGH-TECHNOLOGY SECTOR THROUGH UNIVERSITY-INDUSTRY LINKAGES

CHAPTER 1: INTRODUCTION TO HIGH-TECHNOLOGY AND ECONOMIC DEVELOPMENT

Over the past thirty years or so, internal and external influences have been causing the Canadian pattern of production and trade to change. Increasingly the focus is directed away from primary commodities towards the production of high-technology ('high-tech') products for domestic consumption and foreign exports.

Characteristics of the high-tech industry necessitate a high research component. Greater collaboration between higher education and industry has been promoted in Canada, as in other industrialized countries, as a means to conserve R&D resources. It is hoped that by stimulating the interaction between those sectors of society which engage in differing poles of the research spectrum, product innovation in the high-tech sector will be enhanced.

The importance of promoting university-industry collaboration is that it provides a functional link between the nation's ongoing basic scientific research activities and those active in applied research. It provides a functional link whereby research information is disseminated and, it is hoped, directed towards a competitive marketable

product, providing economic benefits. It is only in the interaction between university and industry in the area of high-tech R&D that this thesis concerns itself.

In Canada, the public sector has encouraged the private sector to invest in performing indigenous R&D by means of a host of fiscal incentives, references to some of which appear in Appendix 1. Although there is a great variety of linkage mechanisms, the thesis concerns itself only with those involving the building of linkage mechanisms between universities and industry. Programs to promote links encouraging awareness of activities in each sector and the use of available fiscal resources have been strengthened in the 1980's through the services provided on campuses at technology transfer offices (Derikx, 1988; Millington, 1986; Enros, 1986; MacAulay, 1984).

The thesis emphasizes the role of the development programs in fostering university-industry interaction in R&D. It attempts to verify to what extent this development strategy is working and whether the development of linkage mechanisms is being promoted. Results of an exploratory survey of four Ontario universities, covering the existing R&D links they hold with industry, are presented.

At the outset, undertaking a survey of Canadian universities and the regional, national, international links they hold with partners in industry was contemplated.

Detailed project data, similar to that of Carleton University's, Research and Studies (1988-89) was assumed to be available for each university. It was expected that the data could thereby be quantified and a statistical analysis performed. The data would provide for an analysis of such factors as the faculties which are most active in undertaking research with an industrial partner, the number of faculty active, the identity of industrial partners, and sources and amount of funding, whether public or private. These criteria would have been ideal for performing a statistical analysis similar to that undertaken by Lawton-Smith (1990 a;1990 b).

Local sources for this sort of data were assessed, but none comparable to Carleton University's were found to be available. However, in the course of the research, an officer at Carleton University's Office of Commercialization indicated that a survey similar to the author's proposal was already being undertaken by Professor J. Doutriaux at the University of Ottawa.

Professor Doutriaux was contacted and found to be undertaking two national surveys of university spin-off firms and university culture. The present proposal, emphasizing university-industry contacts in a regional context, was seen to provide an interesting adjunct to his survey. A survey mailing list, with appropriate contacts at the various technology transfer offices, or alternatively

deans of research facilities, was made available for the author's use, as well as access to other data and survey results. It was mutually agreed that the statistical comparisons of results for each university would be kept confidential.

At this point, the magnitude of pursuing the original research objective became apparent. External funding was unavailable, and at that time (spring 1990) the response rate to Doutriaux's survey was weak. A reorientation in the survey focus was in order. It was decided that a limited survey of the research linkages of seven Ontario universities, situated in regionally distinct settings, would be appropriate. It was hoped that the survey results would verify whether Canadian universities conform to regional and economic characteristics found in studies of their counterparts in the United States and Europe, and provide adequate results to analyze regional contracts. Selected from Doutriaux' mailing list, only four of the seven universities provided any information on their research connections with industry. Hence the practice of industry R&D cooperation prevalent at four Ontario universities became the scope of the investigation undertaken for this thesis.

The survey, although restricted to a limited number of institutions, attempts to add credence to the argument supported from the literature, that university-industry ties

in Canada are indeed established, are prospering, and do foster economic development locally and regionally.

The thesis also considers the role of these links in regional economic development. Research in the U.S.A. and Britain has indicated that well established university-industry ties bring important economic benefits for the region and for the nation (Malecki 1983, 1981 b, c; Steed 1989, 1983; Lawton-Smith, 1990 a,b). The question is whether this is also the case for Canada? A comparison of the survey results to studies produced in other industrialized countries, in Europe, Britain and the U.S.A., attempts to confirm this relationship.

1.1 Economic Theory and High-Technology

Monk (1988), Rottenberg (1981) and MacAulay (1984) document the early historical development and present symbiotic relationship between science and technology. Essentially, science, usually referred to as basic research, entails the accumulation of a body of knowledge, including the embodiment of this knowledge in a set of theoretical principles by its practitioners. On the other hand, technology, also known as applied research, is the body of knowledge concerned with the solution to practical problems, embodied in the tools utilized to achieve these solutions.

Generally, basic research seeks fundamental scientific knowledge of a phenomenon but is not immediately concerned

about its practical application, which may not even be apparent. This type of research is mostly carried out in universities. Frequently called 'pure' research, its primary concern is with explanation or the development of a new body of knowledge. Applied research is generally undertaken in corporations. Here the concern is primarily with new technological products and processes developed from a body of science that can be exploited commercially, such as the production of useful materials, devices, systems or methods.

Since the turn of the twentieth century, particularly within the last thirty years, the resulting products of increased interdependence of science and technology have become paramount. Increased commercial value placed upon these creative, high value-added commodities has increased the competition within and between nations. The ensuing market competition has played a key role in changing the nature of traded commodities away from natural resources towards, for example, electronic products. New commodities have opened opportunities for the emergence of new trading nations, illustrated by Japan's rise to preeminence in world trade and affairs. At an OECD sponsored conference (OECD 1991), many explanations for the new pattern of corporate financial investment flows and industrial activities were given. Most experts, however, stressed that modern technological development was a driving force. Increasingly sophisticated markets and higher R&D costs are found to be

inducing firms to conclude more co-operative agreements of all kinds. There is a progressive trend for global integration of corporate financial and industrial activities.

The generic term for these creative, knowledge-intensive commodities is 'high-technology products'. Definitions as to what constitutes a high-tech product varies, involving a great deal of flexibility in the comparison of statistics (Matthews, 1984; Dermer, 1983; Le, 1986; MOSST, 1984). The common thread throughout these definitions of 'high-tech' products is that they are "state of the art" in terms of their technological function and design, as well as employment of leading edge science. This definition implies the necessity of close interaction between science and technology in the 'high-technology' sector. R. Nelson (in Dosi, G. 1989) distinguishes between two different aspects of a technology. On the one hand, a technology consists of a body of generic knowledge, in the form of generalizations about how things work. On the other hand a technology also comprises a collection of specific ways of doing things which are known to be effective in achieving their end if performed or used with reasonable skill in an appropriate context. He claims that much, if not all, of the generic knowledge tends to have properties destined for public good, (R. Nelson, in Dosi, G. 1989:315).

A public good may be seen as technology which is

invented via available knowledge which may be used by anyone seeing the potential to apply that knowledge to a particular problem at hand. Leiss (1988), as will be discussed later, defines public good in terms of being a social investment in knowledge which, although not necessarily utilized immediately, can be stored until required retrieval, giving the initial investment a long-term payback.

For the synthesis of statistics on high-tech in Canada, a widely utilized commodity-based definition is adapted from that of the United States. It is based on prevalent technologies and the research intensity (R&D expenditure/output) of the industries in question (see Appendix 2, C.Le, 1986).

R. Nelson (in Dosi, G. 1989) rated the relevance of certain fields of science according to the research needs of industry. Computer science and materials science were found to head the list, followed by metallurgy and chemistry. Those industries for which these sciences are important tend to look to universities for new knowledge and techniques, as well as training (in Dosi, G. 1989:321). Also, industries where technological advance is being fed significantly by academic science look for links with university scientists and laboratories where that work is going on. They are the pharmaceutical, computer and semiconductor industries. Indeed, these fields of science were demonstrated to be the fields of science with the most R&D activity in the survey

of four Ontario universities.

Contemporary economic theory on high-technology products asserts that in market economies, in which there is freedom for a firm to enter or depart the market, and in which a choice among product alternatives may be made, the market produces efficient outcomes. Consequently, many industrialized countries, including Canada, are increasingly looking to the private sector to support the efforts of research, as it is assumed that the private sector is aware of research priorities. Historically, industry has been more concerned with applied, short-term, results-oriented research, than with basic research. The state, which has previously been the leading source of research support in Canada, in addition to its traditional role of providing funding for basic research, has provided a broader spectrum of support, embracing both applied and basic research. Increasingly, however, the state is withdrawing funding support from basic research. This is unfortunate. Millington (1986) noted Bernstein's research indicating that R&D performed by firms in one sector of the Canadian economy has significant benefits (spill-overs) for other sectors. It was suggested that it may be desirable to give preferential treatment to certain more technologically intensive sectors, which in turn will benefit other sectors (Millington, A. 1986) (Palda, 1982; Rodgers, 1987; Chand, 1980; Economic Council of Canada, 1983; Rottenberg, 1981).

(MOSST) Task Force's 1984 report on the Canadian government's effort in promoting technological development states that research which is 'demand-driven' i.e. applied, generated by market pull and is undertaken in response to a clearly-defined market need, is more effective than research which is 'supply-driven' i.e. basic; that is, research which is pushed (R. Coombs, in Dosi, R. 1989:295) by intellectual curiosity: for example via research institutions conducting research for which a limited or no market may exist.

" We think it's helpful to picture this innovation process as a chain which stretches from pure research to the introduction of new products. Like a real chain, it responds better if it's 'pulled' by market demand than if it's 'pushed' by research and technology development" (MOSST, 1984:2).

Although it may be useful to picture the innovation chain as such, in actuality the model espoused by MOSST represents a rather narrow, linear model of the innovation process. The model entertains no concept of potential feedback mechanisms which may potentially arise while interaction between the push and pull factors occurs. The concept leaves little room for adjustment effects experienced along the innovation chain. Also, in reference to Bernstein's previously referred to comments, such a policy minimizes possible spill-over effects for other sectors.

The assumption is that basic research in where market forces fail state intervention by means of government funded programs is intended to bring about a socially appropriate allocation of resources.

" Market failure can be expected most clearly in the case of basic research, and this is the field in which it is clearly right for government support to be engaged" (Rottenberg, S. 1981:43).

According to R. Nelson (in Dosi, G. 1989), three different kinds of government R & D support have been identified. One is concerned with the support of basic research, the second is tied to government procurement needs, and the third kind, which was stated as having modest importance in the U.S.A., is aimed to advance the commercial competitiveness of a particular industry or a group of firms. The latter category appears to hold much greater importance for Canada. In particular, many government programs appear to target certain 'key technologies' for support. It would make an interesting study to determine whether this is, in fact, the case.

W. Leiss (1988), paraphrasing a report by Harvey Averch, provides an excellent historical summary of the foundations for policies leading to sustained government support for research in science and technology. Emerging in the U.S. after the Second World War, the following

propositions were advanced in a series of reports: 1) new knowledge is a necessary condition for economic growth; 2) new knowledge originates in basic research; 3) the supply of new knowledge is unlimited and is not subject to diminishing returns; 4) the government should support basic research directly due to its interests in national security, the economy, health, and so forth; 5) industry lacks sufficient economic incentive to do more than a small part of the required basic research.

The key idea is that research is a very good social investment, providing a good social rate of return on the initial outlays. Millington (1986) notes that a variety of studies have shown that while private returns on R&D investments may be of the order of 20 to 30%, the social benefits are at least double these returns. A nation's investment in research will have a large long-term payback in terms of economic prosperity. However, firms left to themselves, making private decisions, will tend to under-invest in basic research to a significant degree.

" This provides the primary rationale for government intervention in the area of science and technology policy...Preferential tax treatment of R&D expenditures will result in increased R&D activity, which in turn will occasion a greater number of successful technical innovation(s), thus more commercially successful products, finally

resulting in a higher standard of living" (Leiss, W. 1988:59).

This is the assumption upon which the argument is built, namely that market failure operates with respect to basic research only. It does not include what is called the innovation process - the 'D' for development. It was assumed that given optimum levels of basic research as assured by government intervention, industry would then make the appropriate business decisions on applying this research to technical innovation and product and process development. This, however, necessitates the existence of adequate lines of information, or links between the two sectors, communicating each sectors' needs or accomplishments.

Feller (1990) notes that "university-industry cooperative research is heavily oriented to technology transfer, the movement of ideas and innovations from university laboratories and research centres to industry and on to the market place" (Feller, 1990:317). Figure 1 depicts the stage of the corporate R&D process and the way university-based knowledge enters into the process. University and industry technology-transfer may overlap at differing stages of the project. Hence, the transfer of knowledge occurs at whatever stages of the process of technological innovation universities and industry care to cooperate. This model more accurately stylizes the dynamics of an ongoing 'high-tech' cycle from the concept, to the

FIGURE 1

Technology transfer continuum. Source: D. M. Amidon Rogers. "Building the technology transfer infrastructure: contrast with Japan," 1987 International Symposium of the Technology Transfer Society, June.

(Feller, 1990:317)

innovation, to development through to marketing.

The performance of R&D, however, is not an end in itself. Countries invest in R&D to obtain significant private and social returns associated with industrial competitiveness and the creation of a higher standard of living. Millington (1986) found that the spin-off benefits accruing from R&D are greater than those for other areas of national expenditure. Mansfield (in Council of Science and Technology Ministers, 1987) suggests that these returns are not guaranteed, but R&D must be tied effectively to the overall science and technology policy and the economic system of a nation. According to Mansfield, financial returns for the initial R&D investor are at a median of about 25% per annum and 70% per annum for social returns, that is, benefits including spin-off effects to other firms. This would imply that governments should give adequate leadership via a national science policy, and consider the principles of economic theory before large sums of money are invested in possibly inappropriate R&D.

CHAPTER 2: CANADA'S INDUSTRIAL PROFILE IN THE HIGH-TECHNOLOGY SECTOR AND ITS CONTRIBUTION TO REGIONAL ECONOMIC DEVELOPMENT

2.1 Canada's High-Technology Profile

In 1990, Canada spent 1.32% of its GDP on R&D, of which universities reported 0.32% (Statistics Canada, 1990). Here Canada compared reasonably with France (0.37%) and Australia (0.30%), but lower than countries such as Japan, Sweden, the Netherlands, West Germany and the U.S.A.. Government R&D, at 0.32% of GDP, is on a par with that spent in government laboratories in West Germany (0.33%), Japan (0.28%) and the U.S.A. (0.34%) (MOSST, 1985; Millington, 1986). It is however, in the area of industrial R&D that Canada rates significantly lower in comparison to other industrialized countries. While the industrial R&D intensities of most industrialized countries have risen over the long term, Canada's has not risen significantly since the 1960's. Canada spends about 0.68% of its GDP on industrial R&D. This proportion is less than half of what industry spends in almost any other industrialized country (Peterson, D. 1987).

Figure 2 depicts the total R&D funding by performing sectors, as well as their projected targets as identified by the former premier of Ontario. Canada's low GERD/GDP in industry can be attributed to three principal aspects:

Firstly and, one might add, foremost, the high degree

FIGURE 2

TOTAL R&D BY PERFORMING SECTOR

Constant 1986 Dollars

Figure 2

Source: Statistics Canada (1977-87)

Note: PNP is the private non-profit sector.

(Peterson, D., 18, 1987)

of foreign ownership in the Canadian manufacturing sector has militated against the promotion of research in Canada. As indicated in Le's study (1986), due to the sensitive nature of the ongoing research to the future welfare of the firm, foreign firms prefer to undertake strategic research at its head office. In the majority of cases the head office is situated in the firm's home-country. Secondly, Canada possesses a comparatively limited number of firms in R&D intensive sectors, such as aerospace, pharmaceuticals, electronics, and petro-chemicals. It is these industries for which a high R&D component is especially mandated. These are usually large, invariably multinational firms, for which being the market leader in a certain product is vital for survival. Hence, these are the firms which tend to devote a large part of their budget to R&D. Thirdly, Canada has firms for which comparatively low levels of R&D are required such as chemicals and non-ferrous metals. Although these may constitute leading exports, they may require little to no processing and little to no R&D, (Study Team Report to the Task Force on Program Review, 1985:405).

Empirical evidence from Statistics Canada analyzed by C. Le (1986), attempts to establish the relationship between the level of R&D activities of a country and its trade performance in high-technology products. The paper shows that, in general, the higher the level of R&D activities of a particular high-technology industry of a country, the better its export performance with regard to the products of

that industry. It follows that if a country does not carry out sufficient indigenous R&D to secure and maintain a leading edge for its high-tech industries, as well increasingly for 'low-tech' industries too, such as wood products and minerals, eventually it will lose its international competitiveness and its export performance will suffer.

Le's study (1986), suggests that host nations such as Canada should not attempt to rely on multinational branch plant firms to further their indigenous R&D. Although it varies with the type of R&D carried out, it is evident that R&D for strategic technologies is more apt to be conducted at, or close to, the firm's head office in its native country. Therefore, Canada's science policy should not depend on foreign branch plant firms as an instrument in the creation of R&D capacity. Instead, it is recommended that an indigenous capacity, built on a greater self-reliance in domestic research capacity in Canadian firms is required to boost Canada's scientific and technological skills (Le, C. 1986; Drucker, P. 1986; MOSST, 1987). This can be achieved via the promotion of domestic policies such as that of university-industry programs.

A focus on building stronger university-industry ties, either through a) the building of R&D links between Canadian universities and small sized Canadian firms, or b) through spin-off firms established as a result of a university

entrepreneur, has been identified by the Canadian government as a type of arrangement by which to strengthen indigenous R&D. These two categories of university-industry interactions will be more closely reviewed as these are the activities which are found to be the most prominent at the universities under review in the survey reported herein.

The first formal Canadian National Science and Technology Policy (1987) redirected an implicit science policy which was based on the principle of society's need to support basic research, towards a more market oriented science policy. The new 1987 policy called for the promotion of partnership with business, universities and labour to make a commitment to promote Canada's industrial research base, entrepreneurial activity and address impediments to research, development and innovation in Canada (MOSST, 1987 d). One might suggest however, that this policy presented an attack on science funding in general. The initiative can be viewed as an opportunity for budget-balancing for a federal government heavily in debt. By reducing federal-provincial transfer payments for R&D throughout the 1980's and cutting university R&D funding, the federal government had lessened its responsibility for R&D. Consequently, the provinces and universities are increasingly responsible for R&D funding and increasingly financially squeezed themselves. This may benefit 'commercially' oriented faculties, e.g. computer science, to the detriment of others. The policy attempted to bring R&D

policy through a state of transition from heavy reliance on government R&D funding towards a more market-driven, private sector investment approach.

In 1990, about \$9 billion was spent on R&D in Canada (Statistics Canada, 1990:10). Business enterprises account for more than one third of Canada's GERD. Figure 3 reflects the growth in R&D expenditures by industry compared to government expenditures. It verifies that although government expenditures have increased since 1978, the expenditures peaked around 1984. In the same period expenditures by industry have also increased, with the gap in expenditure levels widening, as government funding experiences a slight decrease. Figure 3 indicates that industry is slowly increasing spending on R&D in order to be internationally competitive and by taking advantage of government funding initiatives. Government R&D funding is, on the other hand, decreasing as a result of contracting out, cost recovery and privatization initiatives.

In spite of the recent increase in R&D investment by firms, the fact that only 970 out of a total of more than 35,500 Canadian manufacturing firms conduct R&D indicates the narrowness of Canada's industrial base and the target population for government development programs (Statistics Canada, in Council of Science and Technology Ministers, 1987). It is smaller Canadian performers who are responsible for a growing share of industrial

R&D (Monk, 1988; Science Council, 1988; Galbraith, 1987).

Potworowski's (1989) survey reviews measures taken by 14 large Canadian firms, such as Bell Northern, Atomic Energy of Canada, General Motors and Ontario Hydro to transfer and receive technology from universities. All the firms have a significant in-house research and development capability and all benefited from university research. Each company approached the university relationship differently, depending on the nature of its business and the role that technology played in its strategy. Eight principles for successful R&D links with major Canadian universities were identified, from clearly defining industry's objectives to managing the university-industry relationship, to developing longer term strategic links (Potworoski, A., 1989:3). The survey summarized why each company pursued R&D links with its designated university. For example, closer links with universities were seen as a critical component of strengthening Alcan's capability to potentially useful technologies.

In almost all industries, the smaller companies, which tend to be mostly Canadian owned, spend proportionately more on R&D than the larger ones. They are also found to utilize a higher ratio of R&D personnel to total firm employment and tend to have lower sales per employee, but higher R&D to sales ratios. Smaller firms also depend more heavily on government R&D funding programs and interaction in R&D with

FIGURE 3**TOTAL R&D EXPENDITURES BY CANADIAN
INDUSTRY AND FEDERAL GOVERNMENT**

SOURCE: Statistics Canada and MOSST estimates.

(MOSST, 1987:18)

other companies. Nevertheless, almost 70% of government R&D program funding went to the larger companies in the mining and manufacturing sectors in support of activities such as process development (Statistics Canada, 1987:6).

Since the 1970's, smaller and middle-sized businesses have done remarkably better than larger sized firms in respect to market standing, exports, and profitability. This reversal of the dynamics of size is occurring in Canada, the U.S.A. and in other developed countries.

" In part, especially in the United States, this is a result of a resurgence of entrepreneurship. But perhaps equally important, we have learned in the last 30 years how to manage small and medium-sized enterprise to the point where the advantages of smaller size, e.g., ease of communications and nearness to market and customer, increasingly outweigh what had been forbidding management limitations. Thus, in the United States, but increasingly in the other leading manufacturing nations such as Japan and West Germany as well, the dynamism in the economy has shifted from the very big companies that dominated the world's industrial economy for 30 years after World War II to companies that, while much smaller are professionally managed and largely publicly financed" (Drucker, P., 1986:10).

This phenomenon can also be seen occurring in Canada, but only to a limited extent, because of the generally small regional and national market size. Technology, particularly strategic technology, creates opportunities for the originator. According to Feller (1990), changes in technology are initiated for their conventional effects, such as lower production costs, but also because they strengthen the ability of a firm to shape its competitive environment. He notes that technological change may diversify the working R&D environment, by such things as elevating barriers to entry through changed capital requirements, enhance or eliminate opportunities for product differentiation or alter a firm's relationship with its suppliers or distributors.

2.2 Industry's Reliance on Higher-Education

Galbraith's (1987) survey of Canadian corporations indicated that 40 percent of technology-intensive manufacturing companies are highly concerned about the lack of skilled R&D personnel, and two-thirds of all corporations reported that they purchase R&D from external sources. Universities and other companies are the most common sources, cited by 50 percent and 45 percent of respondents, respectively. Current shortages of qualified R&D personnel were reported by half of the technology-intensive manufacturers. Among the large size firms, only a quarter were experiencing shortages of qualified R&D personnel (Galbraith, W., 1987:1). These statistics indicate the

reliance of the high-tech sector on a high R&D component and the concern expressed by firms for present and future skilled labour shortages. The potential applicability of the capabilities of universities to industry is in terms of the development of skilled human resources in addition to the traditional basic research capabilities.

Botkin (in Matthews, 1984) found that one requirement of high-tech industries in the U.S.A. is that:

"one-third of the work force requires college degrees, about half of which are technical degrees. Another third requires [associate] university degrees. These figures indicate that a high-tech work force has 10 to 12 times more R&D, 5 times more scientists and engineers in non-R&D functions, and 70 percent more skilled workers than traditional manufacturing companies" (from Botkin, in Matthews, J. 1984:28).

The research intensity required in high-technology manufacturing industries is reflected in Table 1.

TABLE I

Industries	Research Intensity (%)
<hr/>	
High-Technology	7.89
Other Manufacturing	1.02
Total Manufacturing	2.22

1. Defined as R & D Expenditures/Value Added

SOURCE: R & D Expenditures: Statistics Canada,
Science Statistics (Cat. No. 88-001)
Value Added: Statistics Canada,
Manufacturing Industries of Canada:
National and Provincial Areas (Cat. No. 31-203)

(Le, C. 1986:4)

These statistics suggest important consequences for the partnership between industry and higher education. Whether conceived of as a research partnership or as a partnership in education and training, it is the emphasis on R&D and a suitably trained work force to carry out the R&D which distinguishes high-tech firms from other forms of manufacturing enterprises.

Data collected by the Corporate-Higher Education Forum (1985), formed in 1983 to further cooperation between firms and post-secondary institutions, indicates the pace of industry-university interaction within the past few years. The Forum's 1986 survey, Update: Spending Smarter, documents 113 collaborative projects undertaken by 30 of its member corporations and universities. These numbers are markedly above the 29 collaborative initiatives undertaken by 10 Forum members cited in Spending Smarter, one year earlier (CMA, 1987:34).

The Canadian Manufacturers' Association (CMA) has been furthering collaboration between its members and universities.

" The universities are strategically important in the Canadian research infrastructure. Research and development strategies must promote linkages between institutions and industries to ensure the rapid transfer of technologies and research advances"

(CMA, 1987:39).

There are two major modes of university research collaboration for Canadian industry. Contract research is the most common way for companies to make use of university capabilities. The low cost factor aside, companies benefit through the use of graduate students for much of the routine work. In this way cooperation provides a firm with access to talent. Such projects provide cost savings while providing financial support and experience to students who may be good prospects for recruitment in the future. The benefits accruing to the university from contract research offset part of the decrease in government funding. Contract research also assists in maintaining research facilities and retraining faculty.

Technology-transfer arrangements are another avenue for cooperation. These are agreements to commercialize and market the research and technology that has been developed in the universities. Secondments from industry to university and vice-versa are increasingly seen as being a beneficial form of cooperation (CMA, 1987).

Interviews with senior industrial officials conducted by the Industrial Research Institute (1991) noted that without university research there would be a considerable lack of depth in the level of basic scientific understanding. The interviews recognized the role of

universities in providing understanding and techniques that enable companies to solve problems, invent and design effectively. They also recognized the important role universities maintain as the "retainers of knowledge" and the role they play in the dissemination of this knowledge by means of cooperative training and education of the workforce.

2.3 Regional Economic Development

Discussion of technological change has become increasingly important as an explanation of the dynamics of regional economic change. It has been documented in studies from the U.K. (Segal Quince, 1985), the U.S.A. (Malecki, 1981a), and to a lesser extent Canada (DeGenova, 1985), that the regional effects of technological change are among the most important long-run influences on a regional economy. These studies illustrate an industrial life cycle whereby older 'resource-based' regional economies are rejuvenated or economic hinterlands can be developed to achieve regional economic prosperity. Each region develops a specialized niche in response to some market demand or develops market demand because of a unique commodity.

Within an industrial sector, firms that actively conduct R&D to develop leading-edge products, for which there is high market demand, are in a position to reap higher profits and to hold on to larger markets than firms that have more static, conventional, product mixes. This

gives rise to manufacturing regions in the U.S.A. which reflect a patchwork landscape dotted with a matrix of emerging (sunrise) and aging (sunset) industries. Though as much U.S. R&D is defence related, the prosperity of 'high-tech' regions does tend to fluctuate with the level of defence expenditures. The newer industries, for which one finds widespread product innovation in the high-tech sector, are able to capitalize on innovative technologies and high degree of inter-firm competition. This results in economically prosperous regions, Silicon Valley for example, as opposed to depressed regions, as for example the region known as the American rust belt (Malecki, 1981).

Regional aspects of small firm development are of interest, as studies in the U.K., Canada, and U.S.A. have tied the performance of R&D to small firm development to national employment demographics. In the U.K., Segal Quince (1985) and Lawton-Smith (1990, a,b) emphasized the importance of indigenous R&D, small firm development and the generation of employment in a regional and sub-regional context. Similar observations have been made in Canada by Steed (1982) and De Genova (1985) and in the U.S.A. by Oakey and Rothwell (1986).

Surveys conducted on small firms have drawn comparisons of the firms' growth and development within the region over several years. Data from these studies point toward the high potential for employment growth for firms in the high-

tech sector. A minority of firms, in the Cambridge Phenomena study, exceeded performance expectations created in any given year. A different interpretation of the phenomenon has been presented by Crang and Martin (1991). The authors dispute the official view, held by many in political and academic circles, which implicitly assumes that high technology means high skills, high wages, job creation, and prosperity. They claim that high-technology growth has brought its own problems to Cambridge and it is misleading to view the local economy as a whole in these terms, as it is to assume that the Cambridge phenomenon can or should be replicated elsewhere.

Crang and Martins's perspective is based on recent survey findings that about one-third of high-technology firms are experiencing financial problems, some of the city's technologies are now looking dated and that development of the high-technology sector has not led to high remuneration for all that live in the region. In fact, widening social disparities are emerging.

While these claims might be substantiated in the context of Crang & Martin's survey, the present author believes that the observations noted are equally valid for many sectors and regions in many nations. This author submits that financial problems, dated technology and widening of social disparities between the employed and unemployed are phenomena evident since the late 1980's and

not unique to Cambridge. And while growth in the region has brought problems such as congestion, environmental concerns, etc., development does not come without cost. Development is a factor for which variables may be planned and for which each region must determine its 'development comfort' zone. The author also submits that although a development scenario identical to the Cambridge phenomenon might be difficult to replicate, various papers within this thesis and references supplied by Crang & Martin adequately indicate that similar phenomena do exist elsewhere for different reasons in different regions. Whether or not the high-technology sector should be supported at a particular location is a different question for analysis.

What these studies suggest is that most high-technology firms are in the small firm category of 25 employees or less, sustaining a proportionately high employment to sales ratio to that of large firms.

"Indirectly, they are therefore suggesting that spatial variation in small firm growth and new firm formation is one of the most significant factors accounting for the changing geography of employment in the U.K." (Mason, 1985:3).

Not only were the sectors of employment experiencing a change, but also the locations of employment potential. Since the 1970's, the most prominent regional development

implication in the U.S.A. (less so in Canada) is the trend toward decentralization of R&D away from major urban areas. Studies by Malecki (1981, 1982, 1983) on corporate regional organization identify four location types which are significant for high-technology industry development in the United States. Of these types, although the least numerous of the four found in the U.S.A., two are the most pertinent to this study. Firstly, that of the federal government laboratories, which include scientists and engineers employed by the federal government; secondly, that of the location of research universities. These criteria are characteristics of the growth of innovation centres characterized by having a relatively large university and federal government components with low levels of manufacturing. Canadian examples would be the National Capital region and the industrial park associated with U.B.C. around Vancouver.

Similar to Malecki, Steed (1983) identified four models of technology oriented complexes: 1) technology centres, from locally initiated firms and spin-off's e.g. Boston's Route 128 and Silicon Valley; 2) research oriented centres, restricted to park sites, such as Toronto's Sheridan Park and North Carolina's Research Triangle; 3) attraction to existing manufacturing facilities of high-tech companies; 4) result of large expenditures of government funds at development facilities, such as U.S. defence research at Houston, Texas and Huntsville, Alabama (Steed, 1983:265).

The Ottawa complex represents one such technology oriented model. In 1980, 85 high-tech firms were listed, representing 15,000 employees, in the sectors of electronics, telecommunications, avionics, scientific equipment and medical instruments. Typically representing the high-tech industry, these products have a high value to weight ratio, with the competitive basis being placed on product performance rather than on price; many of these products were destined for large industrial, government or institutional markets. A conducive social environment amenable to a highly skilled labour force, and such factors as closeness to universities, culture, and sports facilities, were also cited as important factors of location (DeGenova, 1985; Christy, 1986).

Although the recent trend is toward decentralization of R&D away from major urban areas, in the U.S.A., as with Canada, urban agglomeration was found to be the most dominant existing locational factor, around federal government research facilities, research universities or research manufacturing sites featured as the sites for major R&D centres. Manufacturing sites frequently require some product-oriented R&D nearby, as new products which are developed enter commercial production. For basic and applied R&D, research universities can provide important personnel, consulting, and direct and indirect research results. As such, urban areas with a great deal of university research often serve as major attractions to

innovative activity.

"The deconcentration among large urban areas [of the U.S.A.] can be largely attributed to an increase in the number of sites utilized for industrial R&D by large R&D performers. R&D is being located in a greater number of locations, both smaller metropolitan areas but non-metropolitan areas as well" (Malecki, 1981:227).

The regional development context of R&D is highly dependent on the fact that technological activities, such as private R&D, are strongly influenced by agglomeration economies and existing locations of research. Within industry, firms tend to maintain their relative position because small firms can generally reap the benefits of an innovation only on a small scale. Once the product has been market tested, large firms are able to imitate, produce more at lower cost, and thereby tend to grow larger. Also, greater capital resources of large firms have been shown to be really decisive. Small firms often run out of cash as they move from innovation to commercialisation. They are often taken over by a large firm at that point. Lumonics is, to some extent, a local Ottawa example. Therefore, it has been found that new products and other radical innovations tend to come out of new small firms which compete on product innovation alone. This firm size-profit phenomenon has been called the spatial division of labour

between large and small firms by Malecki (1981).

Thus, relatively few regions actually benefit from the location of large R&D firms. However, it was found that the ability to generate new innovative enterprises, such as through spin-off firms, is limited to major R&D complexes, especially to those nodes where industrial research is located, in addition to government or university complexes.

"A regional technology base is generated by a regional comparative advantage in scientific and technological capability, represented particularly by large skilled-labour forces... the creation of significant new centres of technological activity may also require efforts by industry rather than only by government or university science" (Malecki, 1980:232).

Malecki's studies for the U.S.A. indicate that development activities by government run R & D agencies are among the policies rarely assessed for their regional impact. Yet the regional effects are considerable, more so in Canada, given the greater proportional role of government R&D.

"The distribution of government R&D provides one of the few opportunities to alter the regional structure of technological capability... the

concentration of federal funds in a few large firms in a small number of industries necessarily has effects on regional growth. Any shift in funding, federal or private, towards development and away from basic research would only serve to further concentrate R&D potential in very few urban areas; basic research at universities was one of the few dispersing categories of funding found in this study" (Malecki, 1982:33).

This suggests that initiatives by the Canadian government to distribute government R&D to designated regions throughout Canada was beneficial for the regions concerned. However, recent policy to curtail government funding for basic research-performing institutes and universities may curtail regional development effects.

Rugman (1981) and studies by Malecki (1982), and British studies from which he quoted, suggest important consequences for Canada. In their opinion, branch plants are of little consequence in corporate innovative R&D activities. Studies present that mature product manufacture includes little or no innovation because it incorporates products & processes which require little improvement. Firms that operate in several countries tend to concentrate innovative R&D activity near the head office in the home country. British findings, cited in Malecki (1982), noted the backward nature of regions in which branch plants

reside. It may be surmised that Canada, known for its branch plant economy, will be ineffectual in eliciting R&D activities for major innovations within its borders from large multinational firms. One viable domestic alternative, as has been previously mentioned, is to stimulate indigenous innovative research undertaken at small firms through university-industry interaction.

Malecki's implications about R&D activities in large and small scale firms may be affected through government policy in Canada. He makes suggestions which may be beneficial to Canadian enterprise, such as the reduction of risks to firms, mandating of regulations for specific purposes, and ensuring adequate direction in government funding of R&D. He advocates that the uncertain effects of technological change should not be left to chance, but that choices must be made at the national level regarding which industries can be supported in the long run, and that high-priority industries should receive federal funding for process R&D which would direct future production in the industry toward high-productivity and internationally competitive processes. However well intentioned the latter two suggestions may be regarding the effective and efficient expenditure of R&D funds, a strong element in Canadian government R&D funding is that of regional development, which results as an indirect outcome of national policy. Both aspects of funding and decisions on location of R&D facilities are determined by government policy, be they

based on natural regional specialization or upon other criteria of government priority. Malecki sees regional policy issues as complicated and political, with the long-term implications of any regional policy not well understood. Unfortunately, regional development policy issues, along with decentralization, are priority concerns for the Canadian federal government. If Malecki's observations are supported, Canadian policy may be counterproductive to R&D development for the nation. As Malecki espouses the need for a critical mass for effective R&D establishment, in the Canadian context, government policy advising decentralization or establishment of R&D facilities for 'political balancing' is inappropriate for the nurturing of a particular basic R&D. However the promotion of the provincial and federal centres of excellence can be seen as an attempt to establish a critical mass via the networking of R&D.

Steed (1982) draws similar conclusions for the Canadian context. He notes that innovation theory is unable to identify a few key global determinants of technological innovation. Citing Freeman, on the limitations of policy research for the stimulation of industrial innovation, "although we must not expect too much of policy research in the sense of providing unequivocal answers, we should expect it to reduce our ignorance and at least slightly to increase the probability of being able to make good decisions" (Steed, G. 1982:141).

In order to stimulate Canadian industrial innovation, in addition to all the criteria alluded to above, it is important to ensure that there are sufficient facts on the Canadian context on which to base policy research in order to make adequate policy decisions on industrial innovation. This thesis attempts to expand the relevant information base for such activity.

CHAPTER 3: EXISTING UNIVERSITY-INDUSTRY INTERACTION

The CMA's report, Keeping Canada Competitive, (1987) recommended that Canada strengthen the technical capacity of its universities, as well as the interaction between universities and industry. By strengthening the technical capacity of a university, industry's demand for skilled human resources could be satisfied. An increase in the technical capacity could also result in an increase in research capacity. For example, a study by Feller (1990) on biotechnology firms in the U.S.A., found that research performed at universities produced more than four times as many patent applications per industry dollar invested in R&D projects than did in-house research in industry.

In the CMA's view, Canada's educational and training institutions do not yet fulfil this role. They claim that scarce university funds, inadequate facilities and equipment and shortage of well-trained faculty in key fields such as engineering are all factors which make it difficult for universities to contribute to their full potential (CMA, 1987 a).

It is felt that although Canadian universities are hampered by an increasing shortage of funds, cramped science facilities and shortage of support staff in science faculties, an increase in outside consulting activities may somewhat alleviate these conditions.

The Science Council's has recommended a 'new' university, one which possesses a culture conducive to a knowledge-intensive technical economy, in which the interests and concerns of the marketplace are prominent. It is one in which a university is more actively engaged in technology transfer than has been typical to date and pursues exploratory research relevant to its specialization. The Science Council's view of such a university is depicted in Figure 4.

" Although many universities perform some form of interaction with industry, there is not yet a university such as we propose. In the 'new' university that is needed for Canada's emerging knowledge-intensive society, the present ways of teaching and performing research would not be displaced so much as reoriented". (Science Council, 1988:18).

Wide variations of this model university are already in existence throughout Europe and the United States. All have formed an integral relationship with their surrounding communities in order to answer or build upon the communities' immediate needs. Most of these model universities have prospered, as have the surrounding communities.

FIGURE 4

UNIVERSITY RESEARCH ORIENTED TOWARDS INDUSTRIAL INNOVATION.

(Science Council, 1981:287)

According to Tomlin (1988), European universities are attempting to adapt their expertise appropriate to their unique circumstances. The following case histories are some of the several universities he references. Imperial College, in London, is one example of a university which has set up a company, Impel, bringing together the college and two companies to handle its technology transfer services. The existence of a company within the college is seen as being advantageous in preparing proposals and contracts for collaborative research.

At Leuven in Belgium, by imbedding a company within the university, academic staff are encouraged to think about the commercial potential of their work. This company handles projects for the exploitation of innovations. The company, called KU R&D, contracts to university staff to carry out projects. They work within the university, supervised by academics, but are accountable to the company and paid at market rates. The personnel bring an industrial perspective with them. The university promotes KU R&D as being central to its role as a source of economic opportunity for the Flanders region.

At the University of Calabria, Italy, the strongest commercial sector has moved from the university to form a separate consortium, called CRAI - Consortium for Research and Application of Information Technology. This consortium recruits trainees from among the university's students to

work on research contracts in the division of applied research. CRAI makes its consultancy expertise available throughout the geographic region. The aim is to promote advanced technology in Italy's least developed region while at the same time undertaking the training of a highly skilled work force.

The Institute National Polytechnique de Grenoble (INPG) in France, presents yet another structure for managing innovative ideas. The recession in the late 1970's, and early 80's led to a large number of failures among small high-technology firms, due to heavy dependence on research contracts from government and large companies. The goal for this region was to make these companies more self-sufficient. The role of INPG, therefore, is to undertake R&D for small firms that have already developed and tested their ideas in a limited market. The companies have at their disposal access to all the resources, both equipment and people, as well as professional support of INPG. At the end of two years the firm should have a product that will enable it to compete commercially.

The Cambridge Phenomenon (1985), an outstanding case study, measures the effect university R&D has on regional and national economic growth from a central node, Cambridge University. The study complements the debate in Britain in the 1970's over the correct balance between basic R&D, the fostering of a university R&D culture and applied R&D.

The scale and nature of growth around Cambridge of a large number of high technology companies was demonstrated by a total of 322 high-tech firms in the Cambridge area by the end of 1984. Of these, three-quarters were indigenous and independent. The study indicates the growth pattern over twenty-five years. Fully 60% of the population was established after 1978, or about 190 firms were set up in the decade 1974-1984. In the 20 years since 1964, the number of companies that established operations in the Cambridge area has averaged nearly one per month; over the period 1975-1985 the average monthly rate of growth was 1.5 (Segal Quince Ed., 1985).

The Cambridge based study emphasized the importance of freedom of academics to do with their intellectual property as they please without reference to the university. In this respect Cambridge academics are in a similar position to academics in West Germany, where the constitution prohibits universities from interfering with the rights of their staff to ownership of their inventions (Tomlin, R., 1988:7). However, in West Germany, universities are now beginning to establish units for technology transfer to promote links with industry. This suggests that entrepreneurial liberalism may not always be successful, and that at times more of a structured approach is necessary to encourage link building.

Canadian universities are increasingly becoming aware

of their role in affecting regional and national economic development. Canadian studies are beginning to document examples of the extent to which the university acts as a catalyst to stimulate the development of R&D intensive small firms.

The Survey of UBC Spin-Off Companies, in Giles (1989), documents the development of over 70 spin-off firms within the last two decades from the largest research university in Western Canada. Here commercialization of publicly-funded research takes place through the formation of spin-off companies or through licensing technology to existing companies. These companies directly employ over 2,800 people and, in 1988, had sales in excess of \$300.6 million (Giles, V. 1989).

The Edmonton Research Park, having the University of Alberta as a major contributor, has grown from the establishment of one high-tech facility in 1983, to 35 such firms in 1990 (Edmonton Research Park fact sheet, 1990).

Christy's (1986) study of the development of the high-technology sector in the province of Alberta is generally in agreement that the high-tech sector, although still in its infancy, is providing the promise of regional economic diversification and providing an alternative to Alberta's resource based economy, though this hi-tech cluster has also had its casualties in the late 1980s/early 1990s.

DeGenova's (1985) study documents the development of the high-tech sector around the National Capital region. Although the region's proximity to the federal government, cited as a strong locational incentive, is unique within Canada, it was found that approximately 90 percent of the firms' founders indicated a strong local association with the area. Besides the advantage of locating near the federal government, nearness to the region's universities and colleges is indicated as providing a strong benefit, as these institutions provide facilities and skilled human resources.

However, Bathelt's (1991) survey comparing the industrial structure of five high-tech regions (Boston, Atlanta, the N. Carolina Research Triangle, the Canadian Technology Triangle (Waterloo area) and Ottawa noted that Ottawa ranked the lowest (36%, compared to a high of 48% for Atlanta and Boston) for firms linked with local universities. The Ottawa region's spin-offs from universities was considered to be weak, but ranked the highest (25%, to a low of 8% in the Carolina Research Triangle), for firms having strong government linkages.

Bathelt's study found that of firms in the Ottawa region, 61% specialized in the telecommunication industry. This is characteristic of a young technology centre having a firm structure of 60% small (less than 100 employees); 15% medium sized (101-500 employees); and 25% large firms (500 + employees). During 8 years, between 1980-88, Ottawa

experienced the second highest (80%) growth performance in employment. It should be noted that all regions proved successful in terms of employment growth.

The conclusion which may be drawn from the above studies is that participation in high-technology R&D activities is emerging as the basis for a regional economic development strategy in certain regions in Canada, as elsewhere. Most university case studies indicated giving a high priority to assisting business to undertake innovation, either through science parks, spin-off companies, companies indigenous to the university, or other forms of 'formalizing' the commercialization of university R&D. The exploitation of potentially applicable university technology has been promoted from the status of merely a university by-product to a goal, providing economic benefits for the community.

"In analogy with the big industrial research laboratories which have produced so many spin-off dynamic companies, the university so oriented provides a stimulating incubator environment where bright new ideas are nurtured and experimentally tested both from a technological and commercial point of view. Importantly, faculty and students are not only motivated towards acquisition of new knowledge but also the socio-economic exploitation of that knowledge" (R. Blais, in the Science

Council, 1981:248).

Conklin (1989), however, felt that the most important aspect of university-industry cooperation is that there should be open dialogue on the university research agenda between university and industry personnel. The participation from both sectors would prove beneficial to ensure research relevance, research needs and future direction. A brain-storming session could come up with much innovative potential.

CHAPTER 3.1: CANADIAN UNIVERSITY R&D

The Science Council of Canada (1987) estimated that university R&D is concentrated in a small number of institutions, with 15 percent carrying out 75 percent of the R&D. Participation in sponsored research has experienced one of the highest rates of increase of any of the sources of university income. Sponsored research, as defined by the Canadian Association of University Business Offices, is funds paid to the university in the form of grants or by means of a contract from sources external to the university. Funding from this source increased by 166 percent between 1975-83 to reach \$665 million (current dollars). Universities in Ontario and Quebec perform the bulk of sponsored research with 41.8 percent and 24.7 percent respectively (Science Council, 1988:19).

Until the late 1980's, the federal government was been the chief source of higher education basic research funds. Due to budget constraints, it was stated that it would no longer be continuing its present level of financial support. By 1990-91, grants for higher-education will no longer match rises in inflation, increasing the shortage of funding which has been devastating to research on campuses. This deficit in funding is intended to encourage funding from other sources, targeting industry as a primary source of funding. A variety of government sponsored program initiatives have been implemented to encourage various forms of university-industry partnerships (see Appendix 1). The National Science & Engineering Research Council's (NSERC) programs, particularly the University-Industry Program, have received government priority as a funding dispersal mechanism.

If the federal government's objective with the deficit funding policy is to encourage funding from sources outside the federal government, indeed, this objective is achieved. However the dangers of continuing a deficit funding policy are multi-fold. Lack of funds may compromise promising research, larger amounts of funding will be accrued by the larger universities, consequently the smaller universities are the ones which may suffer, or even have to discontinue their research programs altogether. Also, concern has been raised by the Granting Councils, such as NSERC, that the demands for funding placed on some programs, such as the University-Industry Program, exceed the money available.

Consequently many worthwhile projects go unfunded. Concerns are raised that should low sponsorship continue into the future, many future applicants will be discouraged from applying.

Because of rising student enrolments, the effect of government underfunding on universities has grown steadily worse during the past decade. Consequently the universities' capacity to support their teaching and R&D has declined significantly (see Table 2). Government outlays in constant dollars rose by merely 2.5 percent between 1977-85, while the number of students attending universities increased by 27 percent, and community colleges experienced a 36 percent increase (CMA, 1987:17).

TABLE 2**EROSION OF THE FINANCIAL CAPACITY OF UNIVERSITIES**

Total	Total	Total	University	Capacity to
			Sponsor:	
University	University	Sponsored	Teaching	Sponsored
Expenditures	Enrolments	R & D		R & D
(1)	(2)	(3)	(4)	(5)
(as measured % against 1970-71 [Index: 1970 = 100])				
(1)	(2)	(3)	(4)	(5)
1970-71	100	100	100	100
1975-76	92.5	119.7	101.2	91.4
1980-81	98.3	124.2	124.0	79.2
1983-84	108.5	144.2	158.6	68.4

(DE LA MOTHE, 1986)

A 1985 report published by the Carnegie Foundation for the Advancement of Teaching in the United States brought to light the need for universities to uphold their traditional role of education, with modification to take the concerns of industry into consideration (Neil Eurich, 1985, Corporate Classrooms, The Learning Business, in the Science Council, 1985). The Foundation's report noted the extent to which industry had developed a parallel educational system to that of the universities and colleges. It estimated that the total annual expenditures of corporations in the United States on training was fast approaching the total annual expenditures of all of America's four-year graduate colleges and universities. Also, a single corporation, IBM, estimated that it had invested more than \$700 million on employee training in 1984.

In order to adapt to changing circumstances, several Canadian universities have been undergoing curricula change since 1982. Some have developed or begun to develop engineering management programs (University of Alberta, the University of Ottawa, the Technical University of Nova Scotia, and Simon Fraser University). Twenty of the 42 Canadian universities surveyed by Clarke (1987) had courses on either technical innovation or technical entrepreneurship.

A workshop sponsored by the Science Council in 1985 addressed the issue of university spin-off firms (the

creation of new business ventures by university staff and/or students). The Council addressed the need to build a more supportive environment for entrepreneurs within Canadian universities. Workshop participants felt that university policy must take into account the growing trend among faculty and students to take up various forms of consulting activity or that of setting up in business for themselves. An impression of the degree of consulting activity undertaken by faculty, and with whom, may be gained from Tables 3 and 4.

TABLE 3
PERCENT OF FACULTY IN EACH SCIENCE AND ENGINEERING FIELD WHO
REPORT CONSULTING ACTIVITY

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

(Science Council, 1988:25)

TABLE 4
DISTRIBUTION, BY CLIENT, OF SCIENCE AND ENGINEERING FACULTY
WHO WERE CONSULTANTS IN 1983-1985

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

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

Frequently persons inside university laboratories see the economic potential of their discoveries but often have no way of capitalizing on them. The university environment is not set up to bring a prototype or process to commercial standards. The recent setting up of Offices of Technology Transfer in most university campuses across Canada has aided greatly in facilitating the movement of knowledge between university and industry. Table 5 provides a listing of various modes of technology transfer.

TABLE 5

Selected Vehicles of Technology Transfer

1. Publications
2. Consulting
3. Conferences and Seminars
4. Institutes, Centres and Groups
5. Affiliate Programs
6. Research Consortia
7. Patents and Licences
8. Contracts
9. Facility and Equipment Arrangements
10. Research Parks
11. Spin-off Companies
12. Joint Ventures
13. Guest Companies On-Campus
14. Personnel Exchanges
15. Students & Continuing Education

The lack of industrial laboratories in Canada accentuates the importance of the university spin-off phenomenon. S. Smith, of the Science Council, stated:

"We must look to our universities, even more than other countries need to, as a resource for this spin-off phenomenon... It would be easier and better for spin-offs to occur from other industries since people there have marketing experience and business knowledge.

Universities struggle to establish their public identity without having burdens of commercialism thrust upon them. Nonetheless, it is essential for Canada that we have more commercial activity arising from our universities"

(Science Council, 1987:8).

In the United States, spin-off companies are more common than in Canada. Malecki (1981(a)) and the British study by Segal Quince (1985) trace the locational characteristics which are opportune for spin-off development. Geiger (1986) documents the initial impetus for the establishment of research universities in the U.S.A. Academic centres such as Stanford and Massachusetts Institute of Technology produce intellectual and geographical focal points for the development of high-technology companies. Examples such as Silicon Valley and Route 128 near Boston have been noted. Liberal university patent and conflict of interest policies, beneficial federal tax laws, generous industry funding practices, supportive corporate attitudes toward the university community, all enhance the setting up of spin-off

companies.

In Canada, a University of Ottawa study by Doutriaux (1986) notes that university spin-offs are increasingly being promoted by university-based technology transfer offices. Doutriaux studied the evolution of 38 young firms, from 1980 to 1985, originally created by entrepreneurs at various universities in several Canadian provinces. Results indicated that for firms offering technical services, one of the main determinants of growth and success is the entrepreneur as a driving force. Other factors led to the conclusion that for a university professor interested in the successful transposition of an idea, licensing out the invention may be the wisest course; or if a company is created to exploit it, it should be as independent as possible from the university. For the universities, the part-time business person/part-time professor may provide for an efficient use of academic resources and increase contacts with the business world for the benefit of students and applied research (Doutriaux, 1986).

Several valuable aspects of the spin-off firm are that: it is a mechanism for developing specific inventions and innovations; it provides independence for the university by avoiding the tendency to regard research contracts as grants; it benefits the long-term exploratory research provided by the university and its own short-term targeted research; it can attract contract research chairs for the university for a particular specialization; it provides employment in the

community; and provides a model for future entrepreneurs working in university labs elsewhere (Science Council, 1987:10).

The current status of university-industry links for several selected Ontario universities is documented in the following section.

3.2 SURVEY OF R&D INTERACTION AT FOUR ONTARIO UNIVERSITIES

Characteristics by which to gauge university-industry interaction include formal linkage mechanisms with industry, involvement in basic research with the high-technology sector, university spin-off companies, interaction with the surrounding local and regional community, and establishment of industrial contacts.

Taking all the variables into consideration, it was decided that a telephone interview of several Ontario university technology transfer offices was the most efficacious technique to verify the quality, and hopefully frequency of interaction with industry. The intent was to demonstrate the extent of the university's geographical influence in R&D in a local, regional or broader setting.

Ideal parameters on R&D linkages the university holds with its industrial research community, and specific data with which to gauge a university's influence within its regional community, were difficult to acquire. Much of the information requested

was considered to be confidential. While some universities, such as Carleton (Carleton University, 1988), were forthcoming in their identification of contract research, publishing each active faculty member, by project, noting with which contracting party, specific financial data, duration, etc., such data was not as easily accessible for other universities. Although most university personnel were quite willing to give an overall indication of the nature and size of projects, few were willing to identify specific projects. Hence difficulties in the collection, acquisition and standardization of data for comparison purposes were encountered.

Following the report by Van Dierendock and Debackere (1988), only the 'formal' linkage arrangements between university and industry, that is those transfer mechanisms requiring the involvement of the university technology transfer office, were gathered. Their study indicated that the disciplines of Agriculture, Engineering, Computer Science and Medicine were the disciplines inclined to demonstrate the highest contract interaction with industry in the high-tech sector

An analysis of Carleton University's Research and Studies (1988-89) verified that the disciplines of Engineering, Natural Sciences and Computer Science were indeed undertaking the most numerous research contracts with both public and private parties. Hence, it was these disciplines, including Agriculture, with which this survey concerned itself.

Wherever possible, an in-depth comment on exemplary projects and established links with industry for each university was requested. For example, any information regarding the nature of the industrial partner, the specific university faculty active in cooperation, the duration and financial interaction with industry, and in which sector it took place was requested. Published data on research, although requested, was available for only two of the universities, Carleton and, to a limited extent, Queen's University.

Eventually, the universities selected were chosen because of their contrasting regional environments, their distinctive profiles of specialization, and the availability of data. The universities surveyed are Laurentian University (Sudbury), the University of Guelph (Guelph), Queen's University (Kingston), and Carleton University (Ottawa). The survey responses originated from either personnel of the respective technology transfer office or a faculty dean as specified in Professor Doutriaux's survey. University personnel were contacted over the phone during the months of May to June 1990 and their responses recorded accordingly. However, only those personnel which responded to Dr. Doutriaux's survey on behalf of the university were contacted. Personnel from several other universities were contacted, they noted however that no interaction with industry was undertaken.

Laurentian University

Within the past ten years Laurentian University has come under what was termed as a 'new outward looking' university management structure supportive of faculty interaction with outside companies. It is estimated that 50% of the faculty in surveyed disciplines are active in accepting contracts, and 90% of the relevant university academic staff receive research funds. A strategic development plan for the university to specialize in the earth sciences was developed and is presently being followed. University staff are encouraged to accept contracts with private firms, and these interactions are experiencing an annual increase.

In 1990 the university had established its mandate to build its reputation in the field of mining and mineral expertise. There are two Academic Research networks in which faculty participate. The Geomechanics Research Centre specializes in ground control, particularly the biology of industrial barrens. It operates from the university and interacts with all sizes of firms. The Centre in Mining and Mineral Exploration and Research emphasizes mining and extractive metallurgical techniques. These specializations have attracted the interest of both small exploratory companies and large international resource companies such as INCO and Noranda.

Large international mining companies, represented locally by INCO and Noranda, consider the university to be an economical

source of skilled resources and utilize the university services for both short and long term projects. Participation in research projects geared towards the development of automatic ground control process mechanisms is worth several hundreds of thousands of dollars. As an example, a local geological company has on a shared cost basis spent \$150,000 on ground control and backfill research. Another example is a mega land backfill project sponsored by the Premier's Technology Fund of Ontario. Funding will develop a pilot plant to supply the infrastructure to conduct basic research on this issue.

The biggest push towards interaction with industry has been attributed to the introduction of two technology transfer resource officers working on campus as a filter establishing outside contacts and contracts. The National Research Council's on-campus representative specializes in acquiring funding from government sources, particularly to provide assistance to small business. The other technology transfer officer, working at the Innovation North Office, specializes in mining technology and matching private business research projects. Research funding is equally spread between federal granting councils and contracts from industry.

Satisfaction was noted with recent Ontario government R&D promotion incentives. The opinion was expressed that research resources should not be mandated to be divided equally across the country, but preference should be given to the development of a concentration of research resources in a critical mass,

specializing in a certain field of expertise unique to that university. This would prove beneficial for smaller universities, such as Laurentian, to attract research funding and develop national prominence in their own field of expertise.

Queen's University

A representative at Queen's University noted that the university is actively involved with large international pharmaceutical companies in medical and health care research projects. In this faculty the university has jointly taken out a number of licences with Ontario and Canadian companies. The pharmaceutical industry by nature performs long-term, expensive research. This funding source is being reflected in Queen's University research statistics. From 1981 to 1986 source funding for sponsored research has increased by about 113 percent from federal granting councils, whereas sources from industry have increased by about 288 percent in the same time period (Queen's University, 1987).

Over the past several years Queen's has spun-off several new companies exclusively in the Toronto-Kingston-Ottawa region two of which relate to conducting R&D for the high-tech sector. Although no figures were given to provide information on firm size, these companies were established largely through the acquisition of private sector funding. As was the case with fledgling companies in the Segal-Quince study (1985), funding was initially difficult to come by, but was more easily accessed once

the expertise and technology were established. Now most faculty inventions are developed at the new companies. One company that originated from the University is Q-Life Systems, actively involved in the production of medical research instruments. The Microwave Chemistry Corp., located in Stittsville, conducts research in chemical processes. It was noted that in one or two instances the transfer of technology over the past few years was successful in that the product and market demand were established, but commercial activity was not continued for reasons of economic competitiveness.

The survey results for Queen's University only document case studies for which comment was received, hence the full range of university-industry interaction for Queen's is not covered in this thesis.

What has proven to be helpful to the university in negotiating research contracts and contacting new companies is the on-campus location of a National Research Council's industry advisor. The advisor keeps on top of small companies (under 200 employees) in the eastern Ontario region and provides small business assistance such as location of expertise, clarification of mode of interaction, and establishment of written contracts. It was estimated that about 15% of the research contracts are negotiated through the technology transfer office and 85% of the contracts were done directly through other university offices.

University of Guelph

The University of Guelph has gained a reputation in the agricultural sciences, locally, regionally, as well as internationally. With a 1989 research budget of \$24.4 million directed to the Faculty of Agriculture alone, the University ranks third or fourth in Canada in its amount of research funding. The Faculty of Agriculture received approximately one half of the university research budget. At Guelph, research funding sources are divided between an agreement with the Ontario Ministry of Agriculture and Food, constituting approximately \$11.6 million; an NSERC grant, for about \$7 million, towards 25 different crop commodity research programs involving crops such as corn; and another \$5.7 million originating from contracts with private Canadian sources such as the Canadian Association of Animal Breeders, the Pork Producers Association, and the chemical industry. Although a larger proportion of funding is beginning to come from private sources, the largest proportion of research funding has and continues to come from public funds (Government of Ontario and NSERC). Overall, 90% of funding is from regional sources to serve the regional needs of the Ontario agriculture and foods industry. Emphasis is placed on the short and long-term testing of cereals and crops. Participation in projects with the Canadian International Development Agency entails the initiation and maintenance in Third World development projects overseas.

It is estimated that 85% of the staff in the Faculty of

Agriculture hold contracts with off-campus sources. The majority of contracts are not elicited through the technology transfer office, instead they are initiated through personal contact between faculty and client.

Two agricultural companies, residing within the city of Guelph and on campus, have developed an international reputation in research and in product sales. These companies were an off-shoot from the University and, although now private, continue to maintain close liaisons with the university. Langford Incorp., specializing in veterinarian pharmaceuticals, has developed into a multimillion dollar international company. Originally started by faculty members, it now markets veterinary vaccine extensively in the U.S. and Europe, reaching \$10 million annually in sales. The company continues to contract primarily for basic research, tests the specific targeted vaccine, and develops it into a product to be licensed.

Semex, larger in size, is not a single company but a consortium of companies conducting long term research into artificial insemination and embryo transplants to a host. Endeavours on which the consortium is staking present research include the shipping of embryos in a frozen state to a selected host anywhere in the world. Attainment of this goal will make the consortium the leading edge supplier of this technology, charting a financially lucrative market for the consortium in the future. Semex is primarily the marketing arm of the consortium, developing markets worldwide. Basic research for the consortium

is undertaken with significant research funding received from NSERC in five year project intervals with the possibility of five year extensions. The consortium's heavy reliance on university resources and expertise is reflected by its choosing to have its newly completed research facility located directly on campus.

Carleton University

Between 1987 and 1989, grants for all university faculty research totalled approximately \$15 million (68%), plus approximately \$7 million (32%) in contracts. Of the total grant portion, approximately \$3.5 million (43%) was credited to the faculty of engineering, the contract portion was approximately \$4.5 million (57%). These figures confirm that many faculty members whose field of research is considered to be valuable expertise are in demand by the Canadian high-tech industry. The university's proximity to the regional high-tech community surrounding Ottawa and the research facilities of the federal government, as described in the literature of DeGenova (1985) and Bathelt (1991), encourage regional interaction with the industrial community (Carleton University, 1988). DeGenova's (1985) survey, although not specifically mentioning the number of high-tech spin-off companies formed due to local university connections, did indicate that approximately 90 percent of the firms' founders 'held a strong association with the area'.

Team research, occasionally in association with the University of Ottawa, was applied to basic and applied problems,

particularly in telecommunications, energy and transportation systems, industrial design, aerodynamics, computer-aided design and manufacturing, robotics and artificial intelligence.

Carleton university participates in two provincial Centres of Excellence, the Telecommunications Research Institute of Ontario and the Manufacturing Research Institute of Ontario. The Centre for Advanced Studies in Computer-Aided Design and Engineering promotes basic research on issues relating to the use of computers and design.

It is estimated that 85 percent of engineering faculty, and a lesser proportion of science faculty, participate in industry funded research projects. Contracts from local high-tech firms such as Gandalf are common: major funding is received from regional sources such as the Telecommunications Research Institute of Ontario, and from national/international companies such as AECL, Bell-Northern, Northern Telecom and Pratt and Whitney. Of about 160 of the contracts held by staff in the faculty of engineering, about 50 were directly in cooperation with private firms. The latter figure does not take into consideration the contracts held with NSERC's matching grants program, which manages research collaboration in conjunction with private firms. The funding from NSERC accounted for the smaller, but more numerous contracts. Funding from NSERC, particularly individual operating grants, provided for continuity and flexibility in research into new and perhaps unforeseen research opportunities.

Participation in off-campus research with private firms provides practical training experience for students. As an example, in 1988 the Department of Electronics had approximately 40 full-time Masters and Ph.D. students engaged in research projects, many of whom are associated with government and industrial laboratories in the Ottawa area.

'CONCLUSION'

The preceding survey of four universities illustrate that each one has developed a particular research niche interacting in cooperative R&D with industry in its region. Each university has developed community recognition, be it agricultural expertise on a regional and international level at the University of Guelph; developed links to clients around Queen's University to satisfy the demand for surgical instruments in the region and elsewhere; or Carleton's well developed local networks with computer firms in the national capital region.

All universities held contracts with multinational firms. Laurentian cooperatively participates with international firms on several of their large scale projects on ground control; Guelph continues to build its international reputation in agriculture and veterinary science.

The networks and spin-off firms at the various universities under review were established by addressing a need in the market,

either as a product demand locally or regionally; or these firms developed a unique leading-edge technology such as Semex, which attracts international recognition. All universities provided expertise to local entrepreneurs. Difficulties in satisfying a perceived local or international market niche were overcome provided that funding arrangements were accessible and the academic environment structured to encourage interaction with the private sector.

Development of a critical mass in a university's research specialization was identified by various university representatives as being a key to interaction with industry R&D. The author fully agrees that the building of a critical mass in a university's research capability in a specialized field not only increases resources over time in the way of expertise and research funding, but, if the term 'economy of scale' may be applied to research, a catalyst is established to attract further resources, expertise and economic benefits. As has been noted, it also develops skilled human resources while providing training and income opportunities for university faculty, students and employment potential for the surrounding community.

CHAPTER 4: SUMMARY AND CONCLUSION

Placed in an international context, Canada's performance in the high-technology sector is found to be lower than would be expected for a comparable industrialized country. The reason to focus on the development of a vibrant high-technology sector arises from the fact that products emerging from this sector are growing in importance as traded commodities. They are identified as bringing high economic returns to industrialized countries undertaking their production.

Within this context, the scope of the thesis focuses more narrowly on an examination of high-technology's dependence on a high R&D component. The status of the R&D performers, universities and industry in Canada was analyzed, with comparisons to other industrial countries. It was found that basic, long-term research is primarily performed in universities, whereas applied research of a short-term nature is primarily undertaken in industry. Closer interaction and cooperation between both basic and applied research performers is seen to be a viable approach to stimulating the high-technology sector, conserving resources and encouraging innovative product development. This closer interaction is being promoted by various federal and provincial program initiatives.

Constraints to the development of the high-tech sector

in the Canadian economy were analyzed. The difficulty the sector experiences in Canada stems from the industrial branch plant economy, which prevents adequate stimulation of indigenous R&D towards innovative product development. Incentive programs to encourage cooperation between university and industry are seen as a method of constructing links between performers of basic and applied R&D. It is hoped that a thriving R&D capacity for the high-technology sector in Canada can be sustained.

Small R&D-intensive firms were seen to perform an important role in Canada. They tend to be mostly Canadian owned, hold a high R&D to product sales ratio and develop innovative products. Studies such as those by Malecki and Bathelt indicated that an important role provided by small R&D-intensive firms in regional economic stability is through income generation and employment opportunities. The phenomenon of small firm establishment is reflected in the development of science parks surrounding some of Canada's universities, such as the University of British Columbia and the Edmonton Research Parks. In the survey of four Ontario universities, some spin-off firms were found to have been established. Overall, however, the rate of establishment of spin-off firms is still meagre in comparison with that of other industrialized countries. For Canada, these developments represent a growth sector but by U.S. standards, the rate of small firm and science park development and Canadian universities may still be

considered to be in its infancy. Also, contrary to studies from Europe and Britain, in most instances there are too few firms to provide a great amount of regional economic stability.

It should, however, be pointed out that an important observation is made in Bathelt's (1991) survey of five high-tech regions. He estimated that it took at least twenty-five years before a high-technology region became well established to be in a position to supply regional stability. Before that period of time a critical mass of key technology activities had to be put in place. Following this reasoning, the author believes that there is much merit in the viewpoints, expressed by university representatives in the survey herein, that it is crucial that universities are left to develop a critical mass in their field of specialized research and expertise.

An examination of the state of basic research in Canadian universities provides an overview of their adaption to the new demands placed on them by society by addressing the need to establish a closer relationship with the industrial community than has been the case in the past. Programs encouraging research cooperation are in place and are being taken advantage of. A survey of four Ontario universities, although limited, provided some evidence of the sectors of R&D specialization which each wishes to pursue. Specific examples noted the various linkage options

utilized to relate to the industrial community, be it consulting, cooperative grant or consortium. Opportunities for the university to expand its interaction with the surrounding community were established. Likewise, from the perspective of industry, the study undertaken by Potworoski (1989), indicated that industry was satisfied with cooperative links established with the universities. It verified industry's need for cooperation with universities on long-term research and the development of skilled human resources.

It is noteworthy that throughout the survey reported herein, university personnel commented on the value of having a technology transfer officer on campus. Personnel from these offices, whether employed by the university or government, were seen as providing a very useful function. Their role of networking, establishing contacts or negotiating contracts with industrial partners proved invaluable in providing a central communication hub to disseminate information. In essence the offices provide a window on who is doing what in the research field. They are particularly useful should the seeker of information come from outside the university environment. Another useful function provided by these offices is in making a larger resource base available to the university in the way of research funding for faculty and students and access to a wider sphere of research expertise. This suggests that research into the role and function of on-campus technology

transfer offices would be a worthwhile undertaking.

Throughout the thesis a paucity of research data on Canada has been noted. The results of D. McFetridge and P. Grady (1985) indicate that empirical analysis with which to validate and quantify studies indigenous to Canada are in many instances weak or entirely missing; a Science Council publication (1988) notes that very few studies of the relationship between universities and industry exist in Canada; and the Organization for Economic Cooperation and Development (OECD), in their study Review of Educational Policy of Canada (CMA, 1987:19) urged Canada to define broad goals for higher education and shape educational policy in accordance to national policy. The experience encountered by the author while attempting to access data on four Ontario universities reinforces this view. These results indicate to the author that there is still much to be researched on this topic in the Canadian context. It is useful to analyze R&D trends emerging from studies of other industrialized countries; they give an indication of the direction the high-technology sector is taking, and are useful for comparison. However, one becomes aware that Canada, with its small market, foreign ownership of firms, and large land mass, presents unique challenges. The author suggests that it is only by having a good understanding of the functioning of R&D along with the state of the high-technology sector in Canada that direction can be provided towards implementing a national science and industrial policy.

BIBLIOGRAPHY

Bathelt, D. "Employment Changes in Input-Output Linkages in Key Technological Industry: A Comparative Analysis", Regional Studies, vol. 25(1): 31-43. 1991.

Behrman, Jack and Fisher, William. Science and Technology for Development, Corporate and Government Policies and Practices, p.p. 145. Oebgeschlager, Gunn and Hain, Publishers, Inc. 1980.

Birch, D. Communication at the International Symposium on the Evolution of Small and Medium Sized Business in an Ever-changing World, Trois-Rivieres, Quebec, October 1984.

Black, J.T. A Future That Works, The Canadian Manufacturer's Association, p.p. 61 Toronto. 1984.

Bozeman, Barry and Lynk, Albert. Investment in Technology, Corporate Strategies and Public Policy Alternatives: p.p. 149. Praeger, 1983.

Canadian Advanced Technology Association (CATA). The National Technology Policy Roundtable, Discussion Draft, pp. 107. CATA, Ottawa. 1986.

Canadian Manufacturer's Association (CMA). Competing on Industrial Research and Development, Keeping Canada Competitive, pp. 21. Toronto. 1987.

_____. Keeping Canada competitive: The Importance of Post-Secondary Education, Report of the CMA Task Force on Business-Education Relations, Final Version, pp. 60. Toronto. 1987a.

_____. Improving our Industrial Competitiveness, a Science Policy for Canada, pp. 20, February 1986, Toronto. 1986.

_____. Competing in the Global Village. Toronto. 1982.

Carleton University. Research and Studies, Science and Engineering, Office of Research Administration, pp. 198. 1988-89.

Chand, Ragna. "Pressure on Research and Development", Canadian Business Review, vol. 7(4): 42-47. Conference Board of Canada, Ottawa. 1980.

Christy, C. High-Technology Development in Alberta, M.A. Thesis Dissertation, University of Alberta, Department of

Geography, pp. 244. 1986.

Clark, T.C. "Federal Government & University of Science & Research: A Comparison of Practices in the United States & Canada, 1970 - 1979", in Canadian Public Policy, vol.6 (2): 342-351. 1980.

Conklin, D. and Deschenes, L. Canada's Information Revolution, The Institute for Research on Public Policy and Canadian Workplace Automation Research Centre, Proceedings of a Conference on Information Technology: Globalization, Diffusion, Innovation and Retraining June 7-8, 1989. Toronto. 1989.

Corporate - Higher Education Forum, Spending Smarter Corporate University Cooperation in Research & Development, Montreal. 1985.

Council of Ministers of Education, Canada. Changing Economic Circumstances: The Challenges for Post-secondary Education & Manpower Training, (Oct.1985) pp. 15. Westprint. 1985.

_____. Principles for Interaction, Federal - Provincial Relations & Post-Secondary Education in Canada. pp. 1-6, Toronto. 1985.

Council of Science & Technology Ministers, Canada's Research & Development Effort, Annual Conference of First Ministers, Toronto, Ontario: November 26,27 1987. pp. 24, Department of Supply & Services, Ottawa. 1987.

Crang, P. and Martin. "Mrs. Thatcher's vision of the 'new Britain' and the other sides of the 'Cambridge phenomenon'", Environment and Planning D: Society and Space, vol. 9:91-116. 1991.

Crelinsten, Jeffrey. University Spin-off Firms, Helping the Ivory Tower Go To Market. Proceedings of a Workshop held November 21-22 1985, pp. 44, Science Council of Canada, Ottawa. 1987.

DeGenova, Don. Silicon Valley North: the development of High-Technology industrial base in the regional municipality of Ottawa-Carleton, M.A. dissertation, University of Ottawa, Department of Geography, pp. 84. 1985.

De Granpre, Jean and D'Cru, J. New Visions for Canadian Business, Strategies for Competing in the global economy, Kodak Canada Inc., Toronto p.p. 56. 1989-90.

Department of Secretary of State for Canada. Federal and

Provincial Support to Post-Secondary Education in Canada, a Report to Parliament 1984-85, p.p. 84, Department of Supply & Services, Ottawa. 1985.

Department of Supply and Services. Services & Subsidies to Business: "Giving with Both Hands", A Study Team Report to the Task Force on Program Review, p.p. 479. Ottawa. 1985.

Department of Supply and Services. Education & Research, A Study Team Report to the Task Force on Program Review, p: 77-88. Ottawa. 1985.

Derikx, L. "Government Industry and the University: Partners in Research & Development": p. A1-32. The Canadian Institute, Toronto. 1988.

Dermer, Jerry. "Technological Leverage: Benefits, Investments and Risks", Business Quarterly, vol:48(2): 124-129. University of Western Ontario, London, Ontario. 1983.

Dickson, David. "Basic Science's Skies Brighten in Britain", in Science, November 4, vol: 242: 664. 1988.

_____. The New Politics of Science; p.p. 393, Pantheon Books, N.Y.

Dosi, G. (ed). Technical change and Economic Theory, Pinter Publishers, London. pp. 646. 1988.

Doutriaux, Jerome. Growth Pattern of Academic Entrepreneurial Firms, University of Ottawa, Faculty of Administration, Working Paper 86-56. 1986.

Drucker, P. The Changed World Economy, National Conference on Technology & Innovation, January 13-15, 1988. Toronto. MOSST, Ottawa. 1986.

Economic Council of Canada. The Bottom Line, Technology, Trade & Income Growth: p.p. 171. Minister of Supply & Services, Ottawa. 1983.

Ellis, Robert. Post-Secondary Cooperative Education in Canada, Discussion paper, p.p. 70. Science Council of Canada, Ottawa. 1987.

Enros, Phillip & Farley, Micheal. University Offices for Technology Transfer: Toward the Service University.: pp. 68, Science Council of Canada, Ottawa. 1986.

Feller, I. "University-Industry R&D relationships," in Growth Policy in the Age of High Technology, the role of regions and states, J. Schmandt (ed.), pp. 313-338,

University Press, Cambridge. 1990.

Florida, R.L. and Kenney, M. "Venture Capital, High Technology and Regional Development", in Regional Studies, Vol. 22(1): 33-48. 1988.

Flowers, Edward. Forging the Links: A Technology Policy for Canada: p.p. 107. Science Council of Canada, Ottawa. 1979.

Freeman, Christopher. Quantitative & qualitative Factors in National Policies for Science & Technology, Paper prepared for OECD seminar on Science & Technology Policy & its Relation to the Economic Growth of Small Industrialized Member Countries, Helsinki (29-30 Jan. 1986). 1986.

Galbraith, J. William. Research & Development in the Canadian Corporate Sector, a Survey of Attitudes & Spending Intentions, 1987 edition: pp. 22, Conference Board of Canada, Ottawa. 1987.

Gauvin, W. H. "Contributions of Research & Development to Economic Growth", in Chemistry in Canada, vol. 33 (5):14-26, Chemcan Publishers Ltd. Ottawa. 1981.

Geiger, Roger. To Advance Knowledge: The Growth of American Research, 1900 - 1940, pp. 321. Oxford University Press, N.Y. 1986.

Giles, V. et al. Survey of UBC Spin-Off Companies, UBC Press, p.p. 20 1989.

Gordon, J. King. (ed). Canada's Role in Science & Technology for Development: Proceedings of a symposium Held at the Ontario Science Centre, Toronto, Canada, May 10-13, 1979. International Development Research Centre, Ottawa. 1979.

Gough, P. "Location Theory and the Multi-Plant Firm: A Framework for Empirical Studies", in Canadian Geographer, vol. 28(2) p.p. 127-141. 1984.

Gualtieri, R. "The Federal Strategy for Research & Development", in Research & Development, p. C1-10. The Canadian Institute, Toronto. 1988.

Grossman, Larry. "The Technological Revolution in Ontario : A Joint Venture for Industry and Government", in Business Quarterly, vol. 48 (4): 92-97. University of Western Ontario, London, Ont. 1983.

Industrial Research Institute. Industrial Perspectives on Innovation and Interactions with Universities, National

Academy Press, pp. 23, Washington, D.C. 1991.

Johnson, Lynn. The High-Technology Connection: Academic/Industrial Cooperation for Economic Growth, Asher-Eric Higher Education Research Report No.6, pp. 115. 1984.

Keeble, David. Entrepreneurship, High-Technology Industry and Regional Development in the United Kingdom: The Case of the Cambridge Phenomenon: Paper presented at a seminar on Technology and Territory: Innovation Diffusion, in the Regional Experience of Europe and the U.S.A. Institution University Oriental, University of Naples, 20-21, pp. 21. February 1987. 1987.

Lawton-Smith, Helen. "Innovation and Technical Links: The Case of Advanced Technology Industry in Oxfordshire", Area, 22.1, pp. 1-11. 1990.

Lepkowski, Wil. "The Making of a Conservative Science Policy", in Technology Review: pp. 39-46. 1984.

. The Case of Innovative Industry: The Case of Advanced Technology Industry in Oxfordshire, Research Paper 44, School of Geography, University of Oxford. 1990(b).

Le, Can. D. The Role of R & D in High-Technology Trade: An Empirical Analysis, Presented at the Twenty-Second International Atlantic Economic Conference, Boston, August 28-31, 1986, MOSST, Ottawa. 1986.

Leiss, William. "Policy Anarchy, Industry, Technology & the Political Agenda; the case of government support for R & D", in Science & Public Policy, vol.15 (1): 57-65, 1988.

. Government Support for R&D: An Assessment of the Canadian Experience: p. 31. Paper prepared for delivery at the International Telecommunication Union Sixth International Conference on Forecasting and Analysis for Business Planning the Information Age, Tokyo, Japan, Nov.30-Dec.3, 1986. 1986.

Lynn, Walter and Long, Franklin. "University-Industry Collaboration in Research", Technology in Society, vol. 4(3): pp. 199-212, 1982.

Lynton, Ernest and Elman, Sandra. New Priorities for the University. Meeting Society's needs for Applied Knowledge & Competent Individuals: pp. 187, Jossey-Bass, San Francisco. 1987.

MacAulay, James and Dufour, Paul. The Machine in the Garden, The Advent of Industrial Research Infrastructure in

the Academic Milieu: pp. 147, Science Council of Canada, Ottawa. 1984.

Malecki, E.J. "Government Funded R&D: some regional economic implications", in Professional Geographer, vol. 33(1): 72-82. 1981(c).

_____. "Corporate Organisation of R&D and the Location of Technological Activities", in Regional Studies, vol. 14: 219-234. Pergamon Press Ltd, Great Britain. 1980.

Malecki, E.J. "Towards a Model of Technical Change and Regional Economic Change", Regional Science Perspectives, vol. 13(2): 51-60. 1983.

_____. "Federal R&D Spending in the United States of America: some impacts on metropolitan economies", Regional Studies, vol. 16(1): 19-35. 1982.

_____. "Recent Trends in the Location of Industrial Research and Development: regional development implications for the United States", in Industrial Location and Regional Systems, Rees, J. (et al) (ed) pp. 217-237. Croom Helm. 1981(a).

_____. "Science, Technology, and Regional Economic Development: review and prospects", Research Policy, vol. 10, pp. 213-234. 1981(b).

Marcum, J. "Technology Leadership: Cooperation, Competition and Interdependency", Science & Public Policy, vol. 12. No.6, pp. 317-23. 1985.

Mason, C.M. and Harrison, R. "The Geography of Small Firms in the U.K.: towards a research agenda", in Progress in Human Geography, vol.9(1): p.p. 1-37. 1985.

Matthews, Jana and Norgaard, Rolf. Managing the Partnership between Higher Education and Industry: pp. 111. National Centre for Higher Education Management Systems, Boulder, Colorado. 1984.

May, A. "Government, Industry & The University: Partners in Research & Development", in Research & Development & Technology Transfer, Staying Competitive. NSERC, Ottawa. 1986.

McFetridge, Donald and Grady, Patrick. The Economics of Research & Development: A Review of the Literature, Executive Summary, by Grady Economics & Associates Ltd., July 3, 1985, Ottawa. 1985.

Millington, Alan. "Canada in the World of Research &

Development", in Insight, Beyond the Basics, Technology Transfer Agreements, in Conference held April 22, 1986, Toronto sponsored by MOSST, Ottawa. 1986.

Ministry of State for Science And Technology (MOSST). Science and Technology Resource Allocation Statistics. 1987/88, MOSST, S & T Data Intelligence Branch. pp. 32, Ottawa. 1987(c).

_____. Strengthening the Private Sector University Research Partnership: pp. 18, DSS, Ottawa. 1986(a).

Ministry of State for Science and Technology (MOSST). Canadian trade in High-Technology: An Analysis of Issues and Prospects, A Discussion Paper, pp. 87, MOSST, Ottawa. 1987(a).

_____. The Government of Canada's Support for Technology Development, A Summary of Federal Programs and Incentives, Minister of Supply and Services Canada, pp. 38, Ottawa. 1987(b).

_____. Building on Our Strengths, pp. 28, A Background Paper for the National Forum on the National Science & Technology Policy Winnipeg, June 1986, Ottawa. 1986(b).

_____. Science, Technology & Economic Development, pp. 60, Ottawa. 1985.

_____. Canada Tomorrow Conference, November, 6-9, 1983, Commissioned papers, pp. 81, DSS, Ottawa. 1984(a).

_____. Canada Tomorrow Conference, November, 6-9, 1983, Proceedings, pp. 111, DSS, Ottawa. 1984(b).

_____. Task Force on Federal Policies & Programs for Technology Development, pp. 69, Ottawa. 1984.

_____. Research and Development in Canada. Report of The Ad Hoc Advisory Committee to the Minister of State for Science & Technology, Ottawa. 1979.

Monk, C.S. et al. Science Parks and the Growth of High Technology Firms, pp. 270, Croom Helm, London. 1988.

Natural Sciences and Engineering Research Council (NSERC). 12 years to 2000; Draft Discussion Paper, Ottawa. 1988.

Natural Sciences and Engineering Research Council (NSERC). Completing the Bridge to the 90's: NSERC's Second Five-Year Plan, pp. 205, Ottawa. 1985.

Oakey, R.P. and Rothwell, R. "High-Technology Small Firms and Regional Industrial Growth", in Technological Change, Industrial Restructuring and Regional Development, pp. 258-284, in Amin, A. and Goddard, J. Allen Aunwin, London. 1986.

Oakey, R.P., Thwaites, A.T. and Nash, P.A. "The Regional Distribution of Innovative Manufacturing Establishments in Britain", in Regional Studies, vol. 14, p.p. 235-253. 1980.

OECD. The Technology/Economy Programme, International Conference Cycle. Paris. 1991.

Palda, Kristian & Pazderka, B. Approaches to an International Comparison of Canada's R & D Expenditures, pp. 1-52, Economic Council of Canada. 1982.

Peterson, D. A Commitment to Research and Development, an Action Plan Government of Ontario, November. 1987.

Potworowski, A. Assessing University Research, the Experience of Canadian Industry, Manuscript 210^e, International Development Research Centre, Ottawa, pp. 82. 1989.

Queen's University. The Changing External Environment for Research, Queen's University Press, pp. 12. 1987.

Ramo, Simon. "SMR Forum: America's Technology Slip, a New Political Issue", in Sloan Management Review, vol. 21 (4), pp. 77-85, MIT, Mass. 1980.

Rottenberg, Simon. "The Economy of Science: The Proper Role of Government in the Growth of Science", in Minerva, vol. 19(1), pp. 43-71, Spring. 1981.

Rosenzweig, Robert. The Research Universities & Their Patrons, pp. 143, University of California Press, Berkeley. 1982.

Rowe, Christopher. "Government & New Technology: The Quiet U-Turn", in Journal of General Management, vol. 9(1), pp. 5-20, Published by Henley, Management College, England. 1983.

Rugman, Alan. "Research and Development by Multinational & Domestic Firms in Canada", Canadian Public Policy, vol. 7(4), pp. 604-616. 1981.

Science Council of Canada. Local Initiatives to Promote Technological Innovation in Canada, eight case studies, Davis, C. (ed) pp. 147, Ottawa. 1991.

2

PLANT 3 IN METHYLENE BLUE TESTING SINCE 1974

Micro-P
A Division of Micro-P Corporation
10000 E. 15th Avenue, Suite 100
Denver, CO 80231
(303) 751-1000

19000 COUNTY ROAD 5 BURNSVILLE MN 55337 USA
TEL 612 446 1987 FAX 612 436 1987 TLE 612 436 1987

_____. Studies in University-Industry Interaction, pp. 17, Ottawa. 1987.

_____. Learning from Each Other: University-Industry Collaboration in the Continuing Education of Scientists and Engineers, Proceedings of a Workshop Held 24-25, November 1986, pp. 43, Ottawa. 1987.

Science Council of Canada. Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada, Report 39, pp. 84, Ottawa. 1988.

_____. University-Industry Research Centres: An Interface Between University and Industry, pp. 30, Ottawa. 1987.

_____. The National Science and Technology Policy Forum, pp. 41, Ottawa. 1986.

_____. Innovation in a Cold Climate: The Dilemma of Canadian Manufacturing. pp. 49. 1971.

Scott, W. "Growth in 'Big Science' Sparks New Industry-University Alliances", in Space Technology, June 18, pp. 67-72. 1990.

Secretary of State. Brain Power Our Neglected Resource, Ottawa. 1985.

Segal Quince and Partners. The Cambridge Phenomenon, the Growth of High Technology Industry in a University Town, pp. 102, Cambridge. 1985.

Simmonds, W. An Examination of the Industrial Research Assistance Program of the National Research Council of Canada, Final Report - Part-one "The Results of the Examination", National Research Council of Canada, Ottawa. 1983.

Skolnik, Michael and Rowen, Norman. "Please sir. I want some more": Canadian Universities and Financial Restraint, Ontario Institute for Studies in Education, Toronto. 1984.

_____. Federal Scientific Activities (1989 - 1990), pp. 62, Ottawa. 1990

_____. Indicators of Science and Technology, 1990, Resources for R&D in Canada 1988, pp. 45 Ottawa. 1991

Statistics Canada. Science Statistics, The Regional Distribution of R&D in Canada, 1979 to 1985, vol. 11(8), pp. 6. Science, Technology & Capital Stock Division, Ottawa. 1987.

Statistics Canada. Science Statistics, Regional Distribution of Federal Expenditures on Science and Technology, 1985-86. vol. 11(7), p.p. 6, Science, Technology & Capital Stock Division, Ottawa. 1987.

_____. Science Statistics, Federal Government Expenditure on Technology and Capital Stock Division, Ottawa. 1987.

Stead, Humphry. Industrial Research & Development & Company Size, pp. 18, Statistics Canada, Ottawa. 1987.

Steed, Guy P. Not a long Shot, Canadian-Industrial Science and Technology Policy, Background Study 55, Science Council pp. 146. 1989.

Steed, G.P. and Tiffin, S. et al. A National Consultation on Emerging Technology, Science Council, pp. 73. 1986.

_____. Threshold Firms: Backing Canada's Winner's, Science Council. 1982.

_____. "Policy in High-Technology Complexes: Ottawa's Silicon Valley North", in Industrial Change in Advanced Economies, F. Hamilton (ed), pp. 261-269. 1987.

_____. and DeGenova, D. "Ottawa's Technology-Oriented Complex", Canadian Geographer, vol. 27(3), pp. 263-278, 1983.

Tarasofsky, Abraham. The Subsidization of Innovation Prospects by the Government of Canada, pp. 106, Economic Council of Canada, Ottawa. 1984.

Thom, Gordon. Employer Interaction with Public Colleges and Institutes in Canada, pp. 53, Science Council of Canada, Ottawa. 1987.

Thomas, M.D.(ed). "Regional Economic Development and The Role of Innovation and Technological Change", in The Regional Economic Impact of Technological Change, pp. 13-35. 1985.

Tomlin, R. "How Far Can You Go On Your Own ?", in New Scientist, November 12, pp. 7-8. 1988.

Thompson, C. "Definitions of 'high-technology' used by state programs in the U.S.A.: a study of variation in industrial policy under a federal system", Environment and Planning C: Government and Policy, vol. 5(4), pp. 417-431. 1987.

Van Dierdonck, Rand and Debackere, K. "Academic

Entrepreneurship at Belgian Universities", R&D Management, vol 18(4), pp. 341-353. 1988.

Walker, Gord. "Ontario Plan's to Aid Manufacturers Through High-Technology Centres", in Business Quarterly, vol. 47(3), p.p. 91-94, University of Western Ontario, London, Ont. 1982.

Whelan, B. "Answering to the Market", New Scientist, November 12. 1988.

Wright, Vincent (ed). "Even With Definition, High-Tech. Trade Deficit is Growing at 9%", Research Money, vol. 1(4), March 11, Gordon Hutchinson Publishers, Ottawa. 1987.

_____. "Early Matching Policy Data Surprises NSERC about Private Sectors Largesse", Research Money, vol. 1(20), pp. 1-2, Gordon Hutchinson Publishers, Ottawa. 1987.

APPENDIX 1

Initiatives to Encourage
University-Industry Cooperation in R&D

APPENDIX 1

Initiatives to Encourage University-Industry Cooperation in R&D

Millington (1986) identifies the major federal science and technology programs directed at the different stages of the innovation cycle which foster the interaction between universities and industry. Other summaries are referenced to publications such as Enros, (1986); Rodgers, Bereskin and Parr, (1987), Government of Canada's Support for Technology Development, (1984); MOSST, (1987(a)); the Science Council of Canada, (1988).

Although not an exhaustive listing, some of the major initiatives to encourage the development of university-industry research are as follows:

a) University Offices for Technology Transfer

University offices for Technology Transfer were set up to improve flow of the scientific and technological knowledge from university to industry. A 1986 study by MOSST was able to identify over 250 such centres; of this amount 100 were attached to universities; 33 were operated by provincial organizations; 18 by industry; and 99 federal government laboratories. The federal government contributes

approximately \$40 million annually to these offices (MOSST, 1986:37).

As university faculty have become more alert to the commercial potential of their work, the demands placed on these offices on campus have increased. Achievements of the offices in transferring technology can be measured by evidence of increased commercialization such as patents registered, benefits to the economy, and financial returns for the faculty and university and the degree to which these offices have shaped attitudes in the university. At present the Offices for Technology Transfer almost always serve the needs of faculty in science and engineering and do so only at the research level.

b) Natural Sciences and Engineering Research Council (NSERC)

NSERC is the primary federal agency responsible for the direct support of university-based R&D. A number of special programs exist to promote university-industry cooperative research of which the University-Industry Program has particularly been in demand.

The University-Industry Program, reflected in the number of submitted applications, is one of NSERC's most successful programs in sponsoring university-industry interaction. The program funds a range of activities in

order to help companies locate university-based expertise and makes contributions to the cost of industrially-relevant research conducted by universities. It also provides financial support to enable companies to hire undergraduates and recent PhD graduates.

c) Provincial Support

Since the federal government cut-backs in university funding in the mid 1980's, several provinces have increased their share of research support to post-secondary institutions. Various provincial initiatives exist, some reflecting research specialization for a region.

Provincial Research Organizations are non-profit organizations, established by their respective provincial governments (eight in all) to provide technical support to primary and secondary industry. They assist in the exploitation of provincial natural resources and enhance the economy of the Province.

Some of Ontario's initiatives are the establishment of Centres of Excellence, such as the two in which Carleton University participates (see Chapter 5.2). The goals of these centres are to encourage world class research, promote the transfer and diffusion of technology, and training.

Some of Ontario's University Research Incentive Fund, Ontario Innovation Centres Program, and the IDEA Corporation were set up primarily to advance the process of commercializing technology by assisting Ontario universities to identify and commercialize early-stage research. Under the Ontario University Research Incentive Fund, every two dollars invested by a private corporation in an approved research project will be matched by one dollar from the Incentive Fund (Council of Ministers of Education, 1985:11).

d) The Federal Networks of Excellence

The centres establish program funding to promote university-industry partnerships to encourage Canada's long-term international competitiveness. Researchers in a variety of different institutions, including universities, industry and government laboratories are networked according to field expertise in order to maximize resources.

e) University-Industry Research Centres

There are 90 university-industry research centres throughout Canada. These institutions have formal links with both industry and university. Their funding originates from a number of different sources, from government, industry and university. The centres were set up to service small and medium-sized companies which might have difficulty

in acquiring or adapting new technology for their own use. Many of these centres established in the 1960's are now self-sufficient. In most cases federal government funding was terminated after a five or six years of support.

APPENDIX 2

Definition of High Technology Products

APPENDIX 2:

High-Technology goods were defined by the U.S. Department of Commerce (DOC-2 List) as products receiving an above-average level of R&D. Thus, the following commodities are defined as being of a high-technology nature:

- . aircraft and parts;
- . computers and office equipment;
- . electrical equipment and components;
- . optical and medical equipment;
- . drugs and medicines;
- . plastics and synthetic materials;
- . engines and turbines;
- . agricultural chemicals;
- . professional and scientific instruments;
- . industrial chemicals;
- . radio and TV receiving equipment.

The above commodities can be grouped together in six categories as follows:

- . chemicals
- . office machinery
- . other machinery
- . aircraft and parts
- . electrical products

. scientific instruments

This definition suffers from a shortcoming in that R&D expenditure data in Canada, as in many countries, are not collected on the basis of commodities.

The U.S. DOC-2 List has been widely used for international comparisons. Statistics Canada (Science and Technology and Capital Stock Division) uses a slightly modified version of the U.S. definition to produce data on high-technology trade.

END

22.12.92

FIN