INDUSTRY AND ACADEMIC LINKS IN LOCAL ECONOMIC DEVELOPMENT: A TALE OF TWO CITIES

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A TALE OF TWO CITIES

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Abstract. In both the U.K. and Canada it has been identified that collaboration between industry and academia is a critical factor in technological growth. Using the locations of Oxford and Ottawa, both being major sites of Higher Education and Technological Enterprise, the factors which facilitate successful linkages between firms and universities are investigated. The results are based on surveys and interviews of parties on both sides of the divide and in both regions. They show that local factors are of paramount importance to the success of such linkages.

Industry and Academic Links in Local Economic Development: A Tale of Two Cities

1. Introduction

It is apparent that universities and industries need each other. This need reflects society's current valuation of the role of the universities as providers of industrially significant research. For industry, the need is based on the potential for competitive advantage derived from the acquisition of externally generated inputs at a time of rapid technological change. Industrial organisations have evolved to include organisational flexibility to accommodate different forms of university interaction. At the same time, pressure on universities to undertake research of relevance to industry, to gain financial support for research, and attract good students, has increased the overall willingness of Higher Education Institutes (HEIs) to work with industry. The measures taken to create interaction have a spatial context and spatial outcomes.

This paper reports preliminary findings from a study funded by "Canadian Studies in Britain" on the form, scale, scope and outcomes of links between industry and academia in two disciplines: electronic engineering and computer science. The study focuses on Carleton and Ottawa Universities in Canada, and Oxford University and Oxford Polytechnic in the UK; and their links with companies in the Ottawa-Carleton region and in Oxfordshire. The focus is at the local level though the context is national. The study examines the role of universities in local economic development through the creation of "knowledge complexes", and their role as a spur to innovation and expansion derived from networks of research interaction and contact through students, (the latter particularly by means of the Co-operative Education Programs in Ottawa).

The paper examines how the factors which initially led to the development of the high technology complexes and their local peculiarities in the two areas now affect the incidence and outcomes of links between companies and universities. Comparisons between Ottawa and Oxfordshire highlight differences in modes by which technology is transferred, how productive personal links are developed, and what limiting and facilitating factors are involved. It investigates the outcomes of strategies designed to create links between commercial concerns which often are reluctant to divulge their secrets, and higher education institutes which have traditionally been the source of public domain information.

The measures instituted to overcome Canada's weakness in innovation are in contrast to those operating in the UK (where there is a strong technological base that it has however failed to exploit). The infrastructural mechanisms in Ottawa are designed to compensate for the failures in the national systems of production, which in Canada are associated with a lack of an industrial base and "underdevelopment" of links between universities and industry; while in the UK, government allocates resources to the science base at arm's length. We argue that what is emerging is a clear distinction between a laissez-faire model of interaction in the UK and at the local level Oxfordshire, with the strongly directed approach through the Ontario government in Ottawa. In Ontario both provincial, local and national initiatives are important mediators of interaction, while in Oxfordshire although national and regional institutional mechanisms exist there is little coordinated local intervention.

The remainder of the paper is in seven sections. Section 2 introduces the background to the study, and Section 3 summarises the methodology. The next three sections discuss issues important to the study: the characteristics of the two regions, the local mechanisms which foster joint R&D, and the university mechanisms to set up such projects. The final section itemises the findings of the research in 4 subsections. It describes the response of the educational institutes to working with industry, the reactions by the companies to such joint work, the impact on the local labour market, and finally provides some conclusions.

2. Background

Universities have undergone changes in function and image in the last ten years. The role of the University now, we are told, is to manage (innovation and entrepreneurship) by encouragement, facilitation, and participation; it is to set the climate and the culture (Palfreyman 1989,218). This implies a strategic coherence on the part of universities but, according to Howells (1986), industry/academic links in the UK have been haphazard, "ad hoc and maintained on a largely random nationwide basis". This would appear to be the case in Canada also. The Science Council of Canada Report "Winning in a World Economy" (1988,ix) argues that

> *"The most urgently needed linkages are those between the research community within the universities and the private sector."*

However, interaction between industry and universities is constrained by a series of personal, economic, geographical, institutional, organisational, cultural and political factors. These include the "information" and "competence" gaps (Dosi and Orsingo, 1988) which restrict "economic agents" abilities to identify and adopt limited available information. In addition, take up and adoption of innovations and other forms of interaction can be expensive. Hence information and economic barriers limit industries' ability to take advantage of the potential benefits of cooperation with HEI departments. Hidden barriers also exist through the mutual preference by large industrial units and universities for contact via training placements, academic contacts, and large and attractive research programmes (Howells 1986).

Considerable differences exist in the expectations within industry, academia and government about possible interactions between industry and university. This is partially because of a historically evolved internal structure and culture (Segal Quince 1988). This affects academics' actual and perceived bargaining positions, which are determining factors in their response to pressures and the terms of trade negotiated. This varies according to institutions and industry within different countries with regard to the valuation of the role of universities. In the UK, Bodrophy, Jervis and Montague (1985) point to industry's concern that pressures on universities for relevance and the need to earn money to relieve financial hardship has dangerously eroded the amount of basic research, and that universities are seen as the correct location of basic not applied research.

It seems clear that the image and self image of academics has undergone transformation. Academic entrepreneurship and the ability to attract research money are now prized as an indicator of dynamic and vibrant research virility. Indeed an academic existence, promotion, and departmental status very often depends on the track record of industrial money brought in.

2.1 National policies towards industry and academic links

Amable (1990,1) argues that the institutional environment is strongly country-specific, which contradicts the basic assumption of the large majority of neo-classical models - the universality of technology. The institutional framework within which industry and HEIs operate (the national and state systems of support for innovation within industry and the way HEIs are funded) are important in shaping the modes of interaction. Government policies are responses to identified strategic needs based on existing strengths and weaknesses, and shaped by political ideology.

Like other advanced industrialised countries, both the UK and Canada have identified that industry and academic links provide the means for maximising output from a major source of technical resources for the economic health of their industrial infrastructure (ACARD, 1983; Peters and Fusfeld, 1983; Schwarz et al 1982).

Canada

A number of official and academic studies have highlighted failures in the Canadian system of innovation and have suggested that industry and academic links are a factor in economic competitiveness. It should be remembered that Universities are funded provincially in Canada (and the Province of Ontario's funding of universities has been cutback in the last few years, though the problems are not as severe as those faced by UK universities).

It is well attested that Canadian industry has under-invested in R&D. The 1988 Premier's Council Report "Competing in the New Global Economy" found that the lack of industrial competitiveness in Canada, except in a few sectors, has been identified as "inadequate industrial R&D" (p.197).

Overall, Canada spends a low percentage of GDP on R&D (1.3%) compared with other advanced industrialised countries (UK 2.3%). In few high tech sectors do Can[illegible] invest more in R&D than firms in other countries except in the case of Northe[illegible] "aggressive pursuit of international leadership in telecommunications technology [illegible] fact that a large part of its R&D spending is in Canada while its sales are spread around the world." (Premier's Council 1988). Support for increased interaction in Canada operates at both the Federal and Provincial levels with initiatives from both tiers of governments.

Britton (1987) identifies two underlying problems: firstly, that Canada has failed to develop coherent, consistent, and effective policies for the technological development of the industrial sector, and secondly, that foreign ownership arising out of a history of tariff protection in Canada is a significant factor in the low level of R&D in high technology sectors. An Ontario Government official suggested that this has had a negative effect on the economy because companies have failed to develop types of managers who are entrepreneurial and have the kind of skills which should be present in large corporate structures. Instead, branch plant economies have developed accountants and sales managers, not product orientated engineers with financial and marketing skills, nor general managers who have a grasp of different disciplines. This point will be returned to as it influences the scope and kind of interaction with universities.

Hence the problem of the lack of links between Canadian firms and universities is a function of their low level of internal R&D. This in turn leads to a lack of the resources to invest in universities, the inability to appropriate results, and a lack of mutual interest in interaction.

UK

National policy toward increasing interaction between universities and industry and hence the value of universities in economic development is articulated in Chapter 8 of the January 1988 White Paper "DTI - the Department for Enterprise" . The White Paper emphasised the importance of innovation to sustain businesses' competitive edge but expressed concern that, in 1985, UK industry funded R&D was a lower proportion of GDP than in other major industrial countries (8.1). Despite this it offered no increase in the level of DTI funding.

The DTI's current philosophy is to disseminate, not to intervene. The UK's overall weakness in industrial innovation performance is identified as arising out of its inability to bring its scientific capability into commercial application.

The White Paper states

> *"We will encourage the transfer of technologies and cooperative research".*

The DTI proposes to

1. give greater emphasis in collaborative programmes to longer term research between companies, and to encourage collaboration between HEIs and companies (at the pre-competitive stage). One of the mechanisms is LINK - which encourages companies to undertake joint research with HEIs and Research councils.
2. give greater emphasis to encouraging and facilitating many different aspects of technology transfer.

UK Universities are facing acute financial hardship. They have been consistently cutback on funding since the early 1970s (Palfreyman 1989,207). Universities are expected to reduce their dependence on the state and diversify their sources of income (CVCP 1985;1986). Cutbacks to research councils have meant less research is funded in universities, and it is industry which is expected to make up this gap.

2.2 Role of Universities in Regional Economic development

Universities perform different functions in local and national economies because of specific historical circumstances. Furthermore, specialisations within university departments have widely differing hinterlands of networks. Hence links with the local communities inevitably will be qualitatively and quantitatively different. These points will be discussed later in the paper.

Geographical inequalities exist in the adoption of externally developed technology at regional, national and international scales (see Dosi 1984,42; Goddard, Thwaites and Gibbs 1987, 147; Howells 1989). Lundvall (1988) argues that when technology changes radically and rapidly, the need for proximity may become more important. Generally, experience in the UK and Canada has shown that proximity to universities seems not, in general, to be a causal factor in the incidence of technical links and the location of research orientated high technology firms (Oakey 1984; Howells 1986; Breheny and McQuaid 1987; Lawton Smith 1989; Steed and de Genova 1983; Steed 1987). Nevertheless there are exceptions: Segal Quince (1985) argue that these have been an important locational influence in Cambridge.

The availability of labour, its quality and price is now arguably the single most important determinant of regional competitiveness (Reich 1991). Therefore a region's capacity to attract, produce and retain an appropriately skilled labour force is critical (Clark 1991, 1). Clark also argues that educational agendas can be tuned to local agendas while also addressing international competitiveness, and thus can be a potent instrument for economic development. This point is particularly germane to the present study.

3. Methodology

This paper draws on interviews conducted with the staff of university departments of computer science and engineering, firms, centres of excellence, local government agencies and university agencies in Ottawa between June and September 1991; and from research in Oxfordshire undertaken in 1985-87 and supplemented by interviews conducted with several firms and academics in computer science and electronic engineering in Oxford University and Oxford Polytechnic from May to November 1991. These included the Japanese electronics firm Sharp, and a US manufacturer of electronic components. The activities and size of the high tech firms in Oxfordshire are shown in Table 1.

The site size of the ten interviewed firms in Ottawa ranged from 30 to 6,700, and their business functions included developing software tools, manufacturing telecommunication equipment, and fulfilling the function of systems integrators, and military and aerospace integrators. The largest company interviewed, and which has particular local significance, is Bell Northern Research (BNR).

In a study of this kind anecdotal evidence is useful as a barometer of prevailing opinion. We have therefore included some unattributed quotations and have thereby spared embarrassment to their authors.

4. Characteristics of Ottawa and Oxfordshire

It may seem an arbitrary choice to compare Oxfordshire and Ottawa but there are a number of common characteristics. The populations of Oxfordshire and the Ottawa metropolitan area are of similar size (563,000 and 623,000 respectively), and both regions are major centres of private and public sector research, and are important centres of high technology industry. However, Ottawa's appellation of "Silicon Valley North" is rather better known than Oxfordshire's "Cryogenics Valley". Both have major universities and a concentration of research establishments, in the public and private sectors.

Ottawa is the main Canadian location for research and development (Figure 1), although Toronto has more high tech activity in terms of number of firms particularly in manufacturing. It is the centre for both government and industrial R&D, a reflection of its core position as national capital leading to a corporate hierarchic effect in location of activities.

Oxfordshire has a concentration, unique in Europe, of seven national laboratories, including two belonging to the Atomic Energy Authority one of which is Harwell. The location of Harwell was made as a strategic decision after the war and was related to the availability of ex-airfield land and proximity to a major university. However, like Ottawa, it is still relatively under-developed as a centre of high technology industry within the national context.

In the late 1980s it was estimated that both regions had 200 firms. At that time in Oxfordshire these firms had around 11,000 employees, while the Ottawa firms employed more than double (23,000) indicating a much larger average size. Nearly two thirds employ fewer than 20 people. A more recent figure for Metropolitan Ottawa (August 1991) from the Ottawa-Carleton Development Corporation (OCEDCO) was 500 firms with 31000 employees with an average size of 62.3 employees per firm. A similar degree of foreign ownership exists - about 30% of firms. Although Oxfordshire has started to show more signs of entrepreneurial life it is not on the scale of Ottawa.

The composition of the firms' activities is very different. Over half of the high tech firms in Ottawa undertake service or software activities (Table 2). The over-riding specialisation is telecommunications - Ottawa's major sectoral specialisation, with the "Holy Trinity" of BNR, NT and Bell. Figure 2 shows high technology specialisations in the Ottawa area.

Medicine is the largest sector in Oxfordshire: 37 firms produce specialist software or undertake commercial R&D. Overall, manufacturing is the major activity - for nearly 70% of firms (Lawton Smith 1989). These differences reflect the different function and different industrial history of the two areas. These are also key variables in the explanation of different patterns of interaction.

However, the causal factors in the development of Technology Oriented Complexes (TOCs) (Steed and De Genova, 1983) around the major academic centres of Ottawa-Carleton and Oxford have only some features in common. In "Silicon Valley North", Federal Government Research agencies such as the National Research Council's Laboratories were important locational influences - not the universities of Ottawa-Carleton (Christy and Ironside, 1987). On the other hand, Oxford University has been the source of at least 35 high technology firms - formed by academics/technicians, with another 18 formed by graduates who were not also the former. Oxford Polytechnic has neither been a major source of founders of advanced technology companies nor technical linkages (Lawton Smith 1990).

The Federal government has played a crucial role in Ottawa's high tech development. Its major contribution is through procurement patterns, but not only in defence (Doutriaux 1988).

The research agencies in Oxfordshire such as the UKAEA establishments, and the SERC Rutherford Appleton Laboratories have not had the same effect; and defence spending has not been a major factor in the growth of firms. Moreover, in both countries and in both areas, there is evidence to show that industry and academic links are limited in scale and scope (Steed 1987; Lawton Smith 1990).

5. Activities to support R&D in Industry and Universities

Ontario

The Premier's Council on Ontario was founded in 1986. It is composed of representatives from labour, industry, government and education. Its mandate is to "steer Ontario into the forefront of economic leadership and technological innovation". It is involved in advising on the principles governing the administration of the Ontario Technology Fund. This fund will devote $1 billion over 10 years to increase the competitiveness of the Ontario economy through the development, diffusion, and application of scientific activity.

The Premier's council supports nine schemes targeted at innovation. We will focus on the three which directly apply to the creation of industry and academic links.

The first is the Ontario Centres of Excellence. These seven centres were set up in 1987 as part of the Premier's Council Technology Fund. Their common objectives are to encourage advanced research, develop world-class researchers, and transfer technological discoveries from academic laboratories to industry. In early 1987, the Premier's Council had received 28 proposals for centres involving 28 colleges, universities and hospitals, 160 firms, six industry associations, and three government departments. The seven selected range from laser and light research to groundwater research. The institutes have no physical entity other than a very small administrative centre. The centres co-exist with 14 Federally funded Networks of Centres of Excellence, distributed throughout Canada; the commitment to these $240 million centres was announced in January 1988 and the 14 selected ones were announced in October 1989. The UK has equivalent centres of excellence, located in universities, but not in Oxford, in these disciplines.

The Ontario Centre of Excellence on which this study will focus is the Telecommunications Research Institute of Ontario (TRIO) based at Kanata, some 20 miles outside Ottawa.

TRIO operates with a five-year $26-million grant from the province. It conducts research in six areas and involves 73 professors at the universities of Ottawa, Carleton, Queens' and McMaster. In 1989, TRIO raised c$460,000 from 14 companies, which work with the Institute's researchers and have access to IPR in such areas as software engineering and network architecture. TRIO will retain IPR while the province will receive 25% of any royalties.

The recent Panel Evaluation Report on TRIO (June 1990) concluded that the overall quality of the TRIO programme was excellent; that it has had a substantial impact upon graduate programmes and research activities in all four universities; and that it has attracted more graduate students and, for the most part, has provided them with a broader research experience. It recommended that TRIO should focus upon augmenting the higher-level research staff with new faculty staff to reduce the burden on existing staff.

On IPR, it was recommended that a positive effect on productivity would be the institution of some award policy for patents on inventions. It reported that

> *"Universities are not sufficiently aggressive in this matter. The award would provide recognition and encouragement for engineers involved in more applied or entrepreneurial aspects of the work. It might also encourage the more theoretical of the researchers, accustomed mainly to publication of journal papers, to broaden the scope of their technology transfer activities as well as to find a new set of problems (4/5)"*

The second is the University Research Incentive Programme (URIF) a successor to the Board of Industrial Leadership Development (BILD) research grants programme which commenced in 1984 (Bell 1990, 59). In its current form universities can apply to the fund for a dollar to match every dollar invested by industry in a university research programme. Bell (1990, 68) found that there was little evidence that the BILD programme had had a negative impact on universities seeking new industrial research contracts, but that had the matching level been 1 for 1, as is now the case, Ontario universities would probably have behaved differently. He found that, for firms, the availability or possibility of a matching grant was not a significant factor in their decision to undertake research in a university environment.

One of the problems with URIF is that the university must make the application for the funding - which makes it research orientated. When the project comes to an end, an academic will often want to continue but the companies do not.

The third is the Industry Research Programme of Ontario. Its goal is to establish collaborative projects between industrial research sectors and universities and develop links between companies. It must have two partners, one of which must be in industry, and one in a university or centre of excellence. These programmes tend to be long-term state of the art type of activities but normally based on industrial/commercial requirements. The programme ran out of money this summer and the next two years money has already been allocated. Projects range in value from $200 - 5 million.

An important local initiative is the Ottawa-Carleton Research Institute (OCRI). OCRI is funded through subscription from industry, local authorities, and NSERC (the Canadian equivalent of SERC in the UK). It has as its mission statement

> *"To accelerate the growth of a world class technology infrastructure within the Ottawa-Carleton Region and its environs by enhancing collaborative research and development activities among industry, government laboratories, and the participating universities and colleges. The Institute focuses on micro-electronics, communications and computer technologies, and bioscience. Other areas of technology of interest to the region will be added ...."*

Among its activities are organising workshops and conferences, working with schools, and its Industrial Chairs Programme. The Chairs Programme was established to draw additional "world class" research talent to the region's universities in specific technological areas selected by an OCRI industry/university committee. Each chair is expected to provide $1.2 million in support to the University over a five year period. The funding breakdown of a typical chair would be NSERC (60%), OCRI (7%) and OCRI partners (33%). As at December 1990, 6 had been proposed or approved, three each to Carleton and Ottawa Universities (OCRI 1990).

Table 3 shows the membership of OCRI and the membership fees, and reveals the pattern of investment from the high tech community in Ottawa. The size of the membership fee reflects the size of the firm. Six of the affiliate members together with BNR were interviewed for this project.

6. University Mechanisms

The organisations which look after the contractual side of research grants and have a public function in publicising and dealing with links from industry will not play a major part in this discussion. This is not because they are unimportant in shaping the development of interaction. Indeed they have a precise and important role in handling the formalities of the contractual side of the interface, negotiating and defining the terms of interaction, and protecting the academics and the university from exploitation as much as possible. The problems of IPR and publication which arise out of the practicalities of those contracts will be discussed in the section on issues arising out of the interface. However, the paper will concentrate on specific initiatives designed to create and facilitate interaction between universities and industry.

At Carleton University in Ottawa the Technology Development and Commercialisation Office is heavily involved in creating links between industry and universities. Two recent developments at Carleton are anticipated as being important to the way it becomes more involved with industry in the immediate future. The first is the formation of the Carleton University Development Corporation (CUDC) which will be active in the area of lands, technology and training. The second is the plan to construct a building on campus dedicated principally to industry-university related enterprise and projects. The university is hosting a series of roundtable discussions to assist industry and the university in moving forward. These have been well supported by industry and academics.

Oxfordshire does not have the same local strategic resources to call upon since research funds are administered centrally through research councils, charitable trusts etc. What technology transfer activities exist are organised by the University and Polytechnic or by a local charitable Trust. The Oxford Trust was formed in 1985 by the founder of Oxford Instruments the stated aim being "The encouragement of study and application of science and technology enterprise in Oxfordshire". The Trust has starter premises in the centre of Oxford and runs programmes of seminars and forums of topics related to the needs of high technology industry. It also seeks to bring together informally academics, industrialists, and the providers of commercial services with the objective of creating a synergy - which we hear so much about existing in Cambridge.

The difference between Oxford University and the two Canadian universities is its collegiate system, with its autonomous departments (100+ institutions and departments) and 35 colleges, 6 private halls and 1 college for management studies. This effectively precludes a coherent strategy. Even the Oxford Science Park is owned by Magdalen college on land it owns on the edge of the City.

7. Findings

We now discuss the findings of the research. The HEI's responses to working with industry are first itemised. Then the reactions from the interviewed companies are summarised. Next, the impact on the local labour markets are discussed and, finally, there are some conclusions.

7.1 The HEI's

7.1.1 The HEIs in Ottawa

The departments

The level of academic activity is far higher than might be expected in a city of its population size. Carleton University has one of the highest intakes in Canada, while Ottawa University, a bilingual university, is a little smaller.

The two universities collaborate in offering graduate programs. Over the last 10 years they have been able to integrate all their Master's and Doctoral programs in Science and Engineering most of which are now run by joint institutes. Thus, the Ottawa-Carleton Institute of Computer Science and the Ottawa-Carleton Institute of Engineering are the bodies which administer the graduate programs in Computer Science and Engineering. Students are encouraged to take courses offered at either of the Universities and are encouraged to be involved with faculty members at both institutions. This produces a climate that encourages inter-university cooperation between faculty on research projects.

Carleton University's School of Computer Science has four areas of specialisation: Theory, Parallel and distributive systems, Intelligent systems, and Object Oriented Programming. The School has 18 faculty, about half of whom work in one of the latter two groups, the ones most likely to be involved in work with industry. The Computer Science department at Ottawa University has a higher industrial profile with areas of specialisation in communication protocols, artificial intelligence, and distributive computing.

The electronics departments have strengths in different areas. The Electronic Engineering department at Carleton operates in four areas: silicon processing, CAD, VSLI, and microwave MMIC. The areas of specialisation at Ottawa University in Electrical Engineering include electromagnetics, systems and control and robotics, computer engineering, electro-communications - radio and optical.

Scale of Links

The links which the School of Computer Science at Carleton has with industry are mostly with local software firms, both large and small. Larger firms are more likely to pay for contracted research, while smaller firms are often involved in special purpose software development which furthers a faculty member's research program.

The Ottawa University computer science department is more telecommunications orientated than that at Carleton: 80% of its industrial work comes from BNR. However, many companies which are not strong enough to finance research directly fund it through TRIO.

The Carleton University electronic engineering department has three dominant companies with which it interacts: Northern Telecom, BNR and a small local company, CDC, but has contacts with many firms in Canada and USA. The Ottawa University Engineering School mostly has links with local industry, although this has not arisen from any policy.

Changes in the last 10 years

In Ottawa as elsewhere in the developed world, industry and universities have moved much closer. At the same time the quality of and forms of interaction have changed. The main changes over the last ten years are firstly that industry is increasingly realising the importance of software research, and is now more asked to provide expertise. BNR, for example, ten years ago devoted 75% of its research activity to hardware, and 25% to software; now those proportions are reversed.

The Chairman of Computer Science at Ottawa University reported that

> *"...there has been an incredible increase in contract funded research over the last ten years. This has completely changed the character of research. Academics have bitten the bullet and want prestige which comes from industry money."*

He believes that although industry gets work done cheaply, there are fringe benefits to students. Promotion still depends on publications and would be impossible without them (the lack of a research grant from NSERC would be another negative reflection). However, as in the UK, promotion is affected by industrial activity.

Secondly, academics' attitudes have changed, although some people still don't want to work with industry. Over the last ten years the Ottawa University department of computer science has become more outgoing in attitude. Industry links have been more recognised as a valid activity. One academic said,

> *"Many academics have come out of the ivory tower and are now liking to do practical research".*

Thirdly, academics have become more "street-wise" in their dealings with industry. As one academic in the Carleton University School of Engineering said:

> *"Ottawa grew up. Ten years ago the only funding was from NSERC. Now we know how to deal with industry without being abused. Still most problems with industry are over IPR".*

In spite of these changes, one academic thought that Canada as a whole was parochial and not international in thinking, and that this was reflected in the limited scale of research links.

Initiation

In both localities, personal contact was the main means of establishing contact, with conferences playing an important role. In Ottawa TRIO and OCRI have helped extend the network of contacts. It takes time for young academics to make contacts, and TRIO provides a systemic way of making contacts and acts as a screening process for contacts within companies. It was generally felt that sufficient mechanisms for creating links exist. Computer engineering's reputation means that the active academics will turn some industry work away. This is both work that the academics would find interesting and work that they would not - software development particularly is turned away.

Criteria

Academics in the universities in Ottawa seem happy about the control they have over the work they undertake from industry. At Carleton official responsibility has been taken for the IPR issues. There have been difficulties over IPR in the past but they have now been resolved. Publication is not usually a problem as agreement on any period of delay is made at the outset. Typically there might be a clause which allows research to be submitted for consideration for publication after 6 months.

At Ottawa University agreements are negotiated on a case by case basis, but the principles are the same. The form of the agreement depends on who is approaching who on the development of the technology. If the company is approaching the university with a problem which they would like worked on, and they have put in quite a lot of directional input the university's claim is less. If it is the academics who are going to the company with a good idea and asking them to invest, then the academics' case is stronger. Terms are worked out on what the respective positions are on technology development. The best deal is not always possible to arrange but, so far, no contract has fallen through because of disagreement over IPR.

Academics have freedom in the arrangements they make with industry. The directors of the departments are informed of the work, what resources will be used and whether graduate students are to be involved - a practice which is also encouraged. In practice individual researchers decide whether the projects are of scientific merit. It is an unwritten policy that academics should not engage in activities which do not produce work of scientific significance. But some purely development work is carried out by a few academics, who take the attitude (supported by the Head of Engineering at Ottawa University) that local industries have to be helped.

Scope and Form of Links

(i) funding

Although the Ontario government is cutting back on the funding of universities generally, the amount of funding for industrially relevant research is increasing and is focussed through the mechanisms already mentioned. The amount industry spends on research has increased over the last ten years, although recently it has been decreasing as many Canadian firms have been hard hit by the recession and have cut back on R&D. These factors combined are changing the form of interaction between universities and industry.

Typical examples of research funding by industry are furnished by the Ottawa University Electrical Engineering department which gets nearly $4 million a year from industry including OCRI and TRIO, and CITR (the remainder of its research income coming from NSERC) and the Ottawa University Computer Science department which now has 3 industrial chairs: in communications, multimedia databases, and in high-speed networks.

(ii) Licenses

The Ottawa professors have a higher propensity to license their research than their UK equivalents. A number of licences have been sold to industry and licensed to a variety of different organisations.

(iii) secondments

Secondment is unknown in Ottawa as in Oxfordshire, industry cannot afford it, and the academics don't have the time. What is much more common is that Ottawa academics spend their sabbaticals in industry - very often in BNR.

(iv) Each of the four departments are associated with OCRI which can act as a broker in finding firms who might wish to be involved with university research. The departments are represented on the management board of OCRI by the directors of the two institutes which run the graduate programs in computer science and engineering.

Barriers to interaction

The academics identified two particular barriers to interaction with industry. The main barrier is that people in industry do not know what departments can offer. One of the reasons is that departments do not market their expertise.

A second constraint is that companies do not understand universities. They do not realise that they have to "grow students" and get involved in the production of them. Industry often feels that universities are not engaged in industrially relevant activities. A suggested solution to this would be a system of technical listeners from industry and academia.

What academics think

The Centres of Excellence have been generally welcomed by the academics. They have created an atmosphere of close collaboration and, in Ottawa, the TRIO director personally has been a strong catalyst. TRIO seems to have no major drawbacks, runs with a minimum of red tape, and maximises encouragement. A particular benefit is that departments get a large chunk of money from TRIO. The research is shorter term than normal in a university, but longer term for industry.

However one academic suggested that although the Centres of Excellence were "islands of excellence" they were not linked into the international research culture. The funds through the Centres of Excellence can be matched with URIF funds. The system seems to give academics more research funding and relative freedom in the direction of research.

Academics were united in their attitude that the best industrial contacts are those where they give industry a statement of work which industry accepts and then doesn't interfere. Nevertheless, industry grants are more constraining than NSERC grants.

Not surprisingly, given the nature of academia and the timescale of links with industry, there is not a unity in the attitude towards links with industry. Conflict exists between those who think that anything not profitable is not real work and those who don't want contacts with industry at all. Only a relatively few are involved in links - they are the ones who like it and who are active. It was thought that more freedom should be given to individuals from whom breakthroughs come.

One department pointed out that links with industry can have a divisive effect. Few people are good at writing proposals and creating a positive public image. This divides them from other people who do not want to spend their time writing reports and convincing politicians. Success in this regard requires some political acumen. This takes time from active research, and brings about a politicisation of the innovation process.

Teaching versus research is a major issue: more research means less teaching. The potential to buy-out from teaching because of research activities has created two classes of professors: those who buy out and those who cannot. This creates resentment, and has become a big contention between those for and those against teaching relief. The official policy in the Ottawa University Computer Science department is to disallow any buy out from teaching but directors of TRIO projects are given teaching relief.

At both Carleton and Ottawa Universities it has become necessary to stress the importance of teaching and the notion that scholarship encompasses teaching and research. This indicates a considerable shift in the perceptions of some academics of the role of university professors.

It is understood that industry is getting research done on the cheap in the universities in Ottawa, but other benefits are felt to outweigh this. It is also recognised that universities are supported by the government to do things cheaply. For those involved in industrial research, the gains from interaction were the same in all departments. They include resources, equipment, money, ideas for problems, more awareness of problems in industry and knowledge which can be applied in teaching, and research. Industry grants often allow feedback and cross fertilisation.

One academic at Ottawa University in the department of Computer Science reported that he got first hand exposure to a software design and development project in building a research prototype; and that he had not previously experienced this research enhancing effort.

To sum up, there appear to be no disadvantages, as departments get part of the overhead. The feeling is that the departments have a lot of knowledge that could be used by industry; they have something to offer and something to sell.

The increased interaction has changed the way professors think. It was commented that professors have to think more strategically, politically and managerially. They have to balance short term and long term goals. However, it is generally believed that the best contacts are those where there are no strings attached; this is usually the case with NSERC funding, and only sometimes with industry funding.

7.1.2 The HEIs in Oxfordshire

Oxford University is the UK's second largest university after London. In line with other UK universities, it has expanded the scale and scope of its links with industry. However it receives far more money from overseas industry (mainly from the USA) than from inside the UK (£2.4m : £1.4m in 1985/86). Officially its role is to carry out research at the cutting edge rather than to apply existing technology (Oxford University Industrial Liaison Officer). Oxford is probably still better at getting money for what it wants to do than having to tailor research to the needs of industry - although this happens too.

Oxford Polytechnic has some 8000 students, and is one of the largest and, according to a report in the Times newspaper in 1989 (October 4), one of the most prestigious in the UK. The Times reported

> *"Polytechnic students at Oxford stand the best chance of getting a first-class or upper-second degree".*

One of the interesting aspects of research into electronics in the UK is that much of it is conducted in physics laboratories, such as Oxford University's Clarendon Laboratory, rather than in Engineering departments: electronic engineering is only a small part of the research activities at Oxford. The shift to software research has also increased the amount of contact between the electronics industry and computer science departments in Oxford as in Ottawa. The major differences between Ottawa and Oxfordshire are the absence of a dominant local industry and the rather different roles played by Oxford University and Oxford Polytechnic at the local and national level, compared to the universities of Ottawa and Carleton. Another factor is the role played by polytechnics in the educational system, which have greater emphasis on teaching and generally have a less well developed research role. This is as much to do with the lack of support within the polytechnics and from research councils as the heavy teaching load. The impact of the Polytechnic on the labour market bears some similarity with the universities in Ottawa.

Departments

The Oxford Polytechnic School of Computer Science and Mathematics (CSM) consists of computing, mathematics and applied statistics staff, 32 teaching staff in all. It has three research groups: Applied analysis research group, Distributed systems group which is mainly concerned with networking and multimedia, Knowledge engineering research group which works on artificial intelligence (AI).

The Oxford Polytechnic Department of Engineering has ten electronics engineers. Research in the department in electronics falls into 2 main areas: medical electronics and analogue electronics - which is to do with the design of transistor circuits which will become integrated circuits.

The Programming Research Group at Oxford University, together with the Numerical Analysis group form the Computing Laboratory. It contributes to two undergraduate degrees in mathematics and engineering and takes about 30 MSc students per year. It currently has 12 academic staff and 25 research staff working on 25 research themes.

Scale of links

Oxford University academics in both the PRG and in those researching into electronics have links mainly outside Oxfordshire with UK based international companies. The PRG claims

> *"Over the years the group has worked with most of the British semiconductor manufactures. It changes with time as they go out of business".*

At the Polytechnic, in engineering, on the analogue research area, the academics have links with many companies in the US and the UK. They have established personal links based on their novel designs using current rather than voltage. They are very active in publicising their work through publication and attending conferences and are now being asked to run workshops at conferences. They have also been approached by companies to look at current mode for a particular design. In contrast on the medical side, although the academic most involved has sought links with industry, local and national, he has found it very difficult to interest them in exploiting the research even though companies have recognised the quality of the ideas.

Changes in the last ten years

The four departments in the two institutions in Oxford are facing rather different trends in links with industry.

In electronics research at Oxford University, the major change in the last ten years in relationships with industry is that there is a lot less blue-skies research in industry. The scale of UK industry has shrunk in world terms. This means that there are not such benefits to be associated with British industry: GEC has not grown in the last ten years whereas Japanese companies have grown considerably. These factors serve to reduce links and they are finding it increasingly difficult to find high level researchers in industry.

The PRG at the University are benefiting from the shift in emphasis in research in electronic engineering. Although the department does not have the physical capacity to cope with more industry research, this is the major constraining factor as the human resources are there.

At the Polytechnic, links with industry have been more recent than those at the University. As a result of these links CSM, which was a small department, has now grown to be the second or third largest in the Polytechnic.

The biggest change in the Polytechnics' engineering department's links with industry in the last ten years has been the participation in the Teaching Company Scheme. This started in 1984 and the department has had about half a dozen liaisons with local companies. This is quite a big initiative as it brings work into the department, and brings teaching company associates into the department. The companies involved are smaller local electronic companies.

Initiation

The academics in the university in these two areas are well plugged into networks through which links with industry are initiated. These are with academics in other universities and with industry in the UK, in Europe and North America.

The situation is rather different in the Polytechnic, and it appears to be the exception rather than the rule that individuals have well developed links. Here, more formal approaches have been important. For example, the Teaching Company Scheme in the Engineering Department was initiated by the local DTI coordinator.

Scope and Form of links

The researchers in both departments at Oxford University are concerned with the potential applications for industry and tend to work on long term strategic applications. As one academic expressed it:

> *"We recognise that our future is tied up with industry, we don't want to be diverging from industry, we want to be working on similar sorts of problems and have them be interested in what we do."*

Partly the work is done because the academics want to be in contact with industry and know what they are doing and where their interests lie. The PRG wants to do are things which are industrially relevant and useful believing that it is pointless doing long-term blue-skies research if it has no use.

Links with industry on semi-conductor research tend to be through LINK schemes and Eureka, although LINK is seen to have severe disadvantages being biassed very heavily in favour of industrial partners. However, such links do not involve direct funding but equipment in kind. Most funding is through the research councils. The semiconductor group interviewed have just started a new CASE student this year, their first one with Sharp.

The PRG's funding is now mainly from ESPRIT and directly from industry. At one time research was funded by the SERC but this has virtually disappeared. ESPRIT funds basic research of a fundamental nature under Basic Research Action and this does not require industrial partners. Large amounts of money are available - for well regarded places. It is PRG policy to get involved only in projects with industry which have longer term significance.

In contrast, the emphasis at the Polytechnic is less long term, and is more orientated towards producing a commercial product. This reflects the different background to research in polytechnics. It is more difficult in polytechnics for individuals to get funding than in universities. Little money comes from SERC. A polytechnic department might use the money it receives for teaching (from industry or the DTI) and divert it into research. CSM's money from outside sources is of the order of 100k a year.

At the moment the only link the CSM department has is through a teaching company scheme linked to the mathematics people. The DTI pays initially 70% although the teaching company scheme overall works out at 50 : 50 with company. That pays for one person in the form of teaching relief at the Polytechnic, and for travel.

There are no secondments and it was felt that secondments in either direction would be very good for the course:- if staff are involved in industry they should spend some time there.

Gains

The electronic researchers in the University accept working with industry because it enables them to get a first look at new materials developed in industry. The PRG has benefited considerably from the large sums of money which come from industry to support research. The Group's high profile gives them considerable choice over which projects they take on, and therefore the nature of the work they do.

In the Polytechnic, the problems associated with working with industry, particularly getting money from them, has lead some of them to wonder what the real gains are. Asked about the motive one academic said

> *"You may well ask. It is not always clear at the end of it what has been got out of links with industry."*

But not everyone voiced such cynicism and pointed to the positive benefits of working with industry and trying to solve real industrial problems which, for example, had useful spin-offs in teaching. One particular project with a local firm will enable CSM to see how that area of mathematics is being used in industry. CSM are hoping to started an M.Sc. in applied analysis - the area of mathematics that this is involved in and this experience will come in useful. They have a powerful research group in that area which is managing without much money from outside. Moreover links on the research side mean that a company is much more likely to take sandwich course students.

The value to the Polytechnic can be quantified in terms of numbers of papers even though that is an over-simplistic measure. Often projects do not produce many papers because the links are not pure research. Nevertheless, there are industrial contacts which are not research but which are still very useful. One such contact was reported which was likened to a research project which feeds back into teaching; although the academic involved did not receive any remuneration it generated a lot of interest.

Barriers to interaction

The feeling in electronics at Oxford University is that there exists a confidentiality trust barrier - that industrialists may not believe that academics will keep things confidential. One academic summed this up as:

> *"The major problem is that they work on quite a fast time scale and they are working on product related work. The things that they are interested in often change completely on a six month timescale. Academics are often not aware of what is important to them and what they are interested in. The only way that (it) can work for the academics to be useful to them, and for them to be useful to the academics is to decide that if (they) go in with company ... (they should) see them regularly and spend a lot of time talking to them. The problem is time to do that. There is a real difficulty because every six months their research interest has changed. They also have reluctance to tell you what they are going to do or what they did last week but will tell you what they did a month ago. This automatically puts academics behind. Then to try to follow what they are doing - the academics work on this for six months to a year - which is as long as it takes because of student supervision etc and then (they) find that (the companies) are not even interested in the conclusions the academics have come to."*

On the other hand, the PRG has considerable freedom, and has been successful in its contacts with industry.

The problems are different at the Polytechnic. Polytechnic lecturers have to teach a wide range of subjects and it is not so easy to build up research groups with graduate students as in the University; there are very small numbers of research students compared to the University. The Polytechnic also does not have the resources to support research students.

Another problem has been that one of the firms with which CSM was working was that decisions on research had to be made at the US headquarters.

IPR and Publication

IPR and publication issues are handled within the institutions. At Oxford Polytechnic it is carried out by Oxford Enterprise PLC. However, since the Polytechnic as a whole is new to research grants linked to industry some academics expressed a lack of confidence in this body. The University has recently established ISIS Innovation, formed in 1988, which is described as:

> *"a wholly owned company of the University of Oxford. The company has been formed to exploit know-how arising out of research funded by the Research councils and funded by bodies where rights are not tied".*

For one development in the Clarendon Laboratory, ISIS Innovation smoothed the way for the group to get a patent, and will now patent their next idea. As well as the normal IPR problems arising where industry is involved in research grants, there can be problems when the MoD steps in. One innovation was classified by the MoD - so the academics cannot tell anyone about it. The Ministry are so incompetent that it took two months to classify it after the patent application was made; and the group had told everyone what it was about before it was classified. In the electronics area what matters more than publication is whether the technology is there to go into production; this is expensive since the product life cycles are short.

In general, publication delays are not seen as a problem. For example, for academics in the Clarendon there is only nominal restriction on publication.

7.2 Industry

7.2.1 Industry in Ottawa

The competitive environment of firms in Ottawa is very fierce. All reported shake-outs and hard times. One manager in a data communications company spoke of "... night of living dead time for datacom industry....". The effect is that some companies have cut back on their R&D and this has affected the money available to place in universities. O... however spent between 10-13.55% of sales income on R&D.

Scale of interaction

All the firms interviewed had links with Ontario universities. Of the ten firms interviewed, two systems integrators and one software house only had links through the co-op schemes with the universities. BNR on the other hand had many links with universities across Canada and with some in the USA.

Establishment of Links

Not surprisingly, links were mainly established through personal contacts, with a key role played by the Centres of Excellence and by OCRI. Several firms mentioned that contacts had been made at conferences or exhibitions.

It was felt that infrastructural mechanisms in universities were not effective. According to one interviewee, a problem in Canada is that:

> *"There is a US framework but British attitudes. There is a notion that things must be done properly. Canadians are not so brash as Americans but are becoming less British and more Americanised. The US model is one of entrepreneurship."*

Scope of links

The pattern has not been consistent as links have been important at different times. The comments from a sample are listed below.

1. One of the systems integrators, which employed nearly 300, has recently been involved in finding graduates to employ who are learning about business applications. The kind of graduates the company is looking for have a good basis in traditional software development. They recruit from the universities of Ottawa and Carleton and local community colleges.

The respondent felt that it was possible that if universities were proactive in finding out what the company does and selling what they do then there would be more interaction. Also if the company explained to academics what they did, the academics would be in a better position to say how they could get involved. The company had been involved in an initiative at Carleton on software in the early 1980s, but was hit by recession. The company has not given any recent consideration to what universities could provide.

2. Another system house has been involved for the last two and a half years in sponsoring students but they do not work with universities as they do not have the necessary expertise or overlap of interest. The company undertakes its own R&D in house. However, it would be happy to support Carleton with donations of equipment and grants believing that there is a lot in it for both sides.

3. A university spin-off company, from Carleton University's Computer Science School, still maintains strong links with that department. However, the company commented,

> *"Most industry short term ... academics sort out open problems.... industry doesn't get 100% return on its money - perhaps gets 40% - rest technology weather vane".*

4. Links between a telecommunications company and the local universities were active when the company started in 1973, then faded and the company became inward looking. It now recognises the need for university expertise and is building up the research base of the company through universities. It expects to extend its links and generate strong productive personal relationships.

5. A systems company has decided to look to Carleton University to develop VME, and has made a significant investment in the electronic engineering department by donating $280k worth of equipment. The company would like the academics to get involved in their VME programme and for them to deliver a company-designed lecture programme to students. The company's motive is to get the best graduates. The company believes that there has not been enough work done in this area and the company should set the ball rolling. This contact is a typical example of one that arose by a personal contact:- the Managing Director had dinner with one of the professors. The company will now start to write grant proposals to work with Carleton.

6. One software company did not use universities for solving development problems. They wanted to know the state of the art in theoretical academic developments. While this might not be classified as basic scientific knowledge it is also not new generic technology (the company do that in-house). The company had never done a deal with a university which led to a commercially successful product.

7. One datacommunications company does not interact much directly through the universities, but funds research through centres of excellence. The company would work with universities if it thought there would be some benefit. It has one area of interaction, with the Department of Computer Science at Ottawa University, on verification of protocol tools.

This company had had an unhappy experience with Carleton. For a long time it had had expert system projects with Carleton but cancelled them last year because, they reported, "essentially they were going to school on our time". This project involved a $30-50k a year grant for 4 years.

Motives

In general, the motives for interaction are not directed at product development although there is an element of cost saving. As one company said:

"This (university interaction) is going to be a source of competitive advantage for the company if the company can figure out how to do it well."

Various more explicit motives were given and are summarised below:

1. For one small company the prime motive was cost saving combined with access to existing information; a secondary motive was acquiring new expertise.

2. A small software house uses Carleton students for consultancy.

3. A large data communications house is looking to the universities for new areas of expertise.

5. For one large telecommunications company the motive was to gain access to software developments. "Software is going to be the key" they said. The company's other motives for linking to universities were: the inadequate scale of its own R&D, to obtain access to existing information, to save costs, and to participate in public programmes.

5. A small system house made a conscious decision to work with universities and es[illegible] rapport with professors. The company is seeking a collaborative effort which [illegible] es universities in the design effort as designer viewers or explorers of avenu[illegible] company thinks are risky. The company will explore ones which are more pragma[illegible] and which do not have as much to gain but are not so risky. It envisages that graduate students might do thesis work as part of this collaboration as members of an overall project team exploring an avenue which the company would otherwise not explore. The motives were characterised as cost saving, small scale R&D, access to new areas of expertise and information.

6. For a larger company the motive was a strategic benefit/opportunity. The company is looking for the best university graduates from the engineering schools in the short term. The medium term goal is to for the university to gain VME experience which will enable the company to transfer overload of R&D effort to universities - an extension of its R&D effort.

The Leading edge?

There was some feeling that the leading edge is shifting from universities to industry - industry has substantial research development resources such as software tools.

Another reason why the leading edge may no longer lie in universities is because the rate of change is so fast - companies are driving universities. One company's assessment of local universities was that "they are behind the times". Some other negative comments from companies about the universities were: "Universities in Canada don't tend to get plugged into things...develop technology in isolation...Electronic engineers at Carleton are plugged in Computer scientists are not", "Professors who form a company and get exclusive rights to exploit a technology don't know much about business and it takes them forever to market a product", "The quality of work in Ottawa is spotty...some very good people at Carleton in software".

However another company felt that the most advanced research comes out of research councils, and industry or in conjunction with universities. It believed that not too many companies had developed a leading edge product in the software market unless it was developed in conjunction with a university, and that most leading edge activities were in companies set up by professors to market their research.

In determining the location of the leading edge the influence of Bell-Northern Research is important. BNR is the largest and most influential company in the region. It spends about $4 million per year in Canadian universities (about one third of this in Ottawa). Research grants account for about $2 million, scholarships to graduates a further $1 million, and the remaining $1 million is spent on sponsoring chairs (3 such chairs are currently staffed in the Ottawa area), funding professors who spend their sabbatical at BNR, and support for consortia and centres of excellence. It believes that "universities in Ottawa supply BNR with most of its clever talent" and recruits about 25% of all graduates in computer science and engineering from the two universities.

Although it remains active in research into fibre-optics conducted in its own laboratories the company is shifting to applied research rather than basic. Certainly it used to have more fundamental research that wasn't tied to any real product development, but that has changed.

BNR's Industrial Liaison officer commented that the universities work is not blue-sky but is middle ground research. Universities in Ottawa are excellent in this and have taken note of BNR's needs over the years and this is one of the strength's of the region. Both Carleton University and the University of Ottawa have taken note of what local industries need. This means that the work is more applied than the professors might want it to be but, he believed, professors at both universities are flourishing rather than suffering as a result. He cited two instances where the synergy between BNR and the universities had achieved international renown. The Industrial Liaison Officer spends his time visiting universities across Canada, acting as broker and bringing people together. During a typical year he might meet 450 professors, and provide funding for about 40 of them. Universities welcome such industrial funding since these funds can often be greatly increased by matching provincial or federal funds.

BNR gains by having research input from academic work and estimates that the academic ideas are some 2-5 years further on than the company's. Clearly this will be good for BNR since it wants intelligence of future developments. It is effectively externalising its research. The changing nature of its R&D (10 years ago 75% of it was hardware, 25% software, and these percentages are now reversed) has had an effect on linkage patterns.

IPR and publication were not a big problem. It was usual, as in the UK, for agreement of a possible delay of up to one year in publication. One manager said "I nearly fell off my chair when I found out how easy it was to set up a contract agreement with Carleton." He was expecting much more difficulty but the academic involved waived IPR.

It is still an issue for both sides though; for one company the fear of something leaking out through publication was one of the reasons why management has cutback on interaction with universities.

What industry thinks

The reaction to the Centres of Excellence from the companies visited was not as positive as it was from the academics.

"TRIO has not achieved the goals it set out with" said one respondent. He believed that the research contacts forged through TRIO would have happened anyway. He suggested that two sets of outcomes were promised through the Centres of Excellence:

1. research results which were industrially applicable,

2. (more important) production of graduate students with the right set of skills and some industrial exposure acquired through a research grant.

He believed that the lasting value will come from the second not the first and that the first one has proved to be something of an illusive goal. His company has not seen any results which they have been able to apply. This is a view shared by other companies.

For one company though, TRIO has provided a focus for coordinating and sponsoring research in a group of universities in the areas of interest. It has eliminated a lot of unnecessary overlap, and provided coordination and forums for the company and universities to work together more constructively than they have done before. Through their regular "Thrust" meetings the company gets a window on what is going on. This means that the company very readily gets to see what the objectives are and what patentable ideas are available. The second benefit is getting to know who is doing what without having to build up a huge network single handedly. Their respondent was convinced through talking to professors that they have needs which the companies can satisfy - they would very much like to be working on things which are relevant and important to local industry, and provide interesting problems for graduate students. The respondent was impressed by an academic presenting a wish list.

Work done with BNR through TRIO is work that the company would not otherwise be doing right now, and BNR try to influence things through TRIO. As their respondent said

> *"it acts as a super-position on top of BNR's own links. It doesn't consume very much of BNR's budget but pays a dividend far in excess of what it spends."*

On the whole, the Centres were seen as good mechanisms for establishing links, and getting industry and universities to rub shoulders, although one company felt that the system was too bureaucratic.

The view was that OCRI had been successful in its role as a talking shop, promoting new initiatives like biotechnology, and funding new chairs. It supports these chairs for a few years and, if they are successful, they are then funded by another body.

Only one company mentioned receiving money from one of the Federal schemes and found it to be a useful means of support in subsidising their efforts.

7.2.2 Industry in Oxfordshire

The notion that the presence of so much research activity and so many high tech firms is a result of concomitance rather than causality (Oakey 1984) is demonstrated in Oxfordshire where is a specific pattern of technical links (Table 4).

Although nearly half of advanced technology companies of 164 Oxfordshire firms interviewed proved to have links with universities, about half of those were with Oxford University. However, important factors contributing to that were that the founders had Oxford degrees and/or were Oxford University academic/technicians. Here, the majority of even innovative firms have no contact with the local university and polytechnic.

For some companies interviewed, the presence of Oxford University was an irrelevance. One major US electronics components manufacturer's potential for links with any university was negligible because its major R&D effort is carried out in the USA, and the engineers in Abingdon performed design functions only.

On the other hand another small electronics company is intimately involved with a research group at the Department of Materials at Oxford on ion beam patterning and repair. The company has access to laboratory equipment and has produced joint papers with academic colleagues.

The most famous recent example of interaction between the University and a company is that of Sharp, the Japanese electronics company. In February 1990, the company set up its European laboratories, first of all in Abingdon, before moving on to the newly created Oxford science park. Although it has links with other universities in the UK, and mainland Europe, the company felt that "there is a first class advantage in working with Oxford people".

7.3 Impact on the local labour market

7.3.1 The Co-op Scheme in Ottawa

An important development in Canada is the rise in Postsecondary Cooperative Education programs which aim to achieve closer relations between universities and business by requiring students to spend one or more terms of their study in monitored employment. This initiative, begun at Waterloo, is growing rapidly. The greatest numbers of co-op students in colleges and universities in 1985-86 were in engineering and computer science (Ellis, 1987).

Ottawa University has 13 Co-op programmes including one in each of engineering and computer science. Unlike Carleton University which handles the co-op programmes in individual departments, Ottawa University has a Co-op office which manages the whole effort. It has 500 students in all programmes. In 1990, 13 computer science students were registered in the computer science co-op program and 33 in electrical engineering. Most students are placed in Ottawa, but some are placed in Toronto, Calgary, and Quebec City.

At Carleton co-op programs in the university are much less well developed with Computer Science being the major exception. There are about 50 students in the computer science co-op option (Engineering has no such program). Again they are normally placed locally, BNR and IBM being the largest recruiters.

Although the two universities operate slightly different schemes entry to the co-op option is competitive (on the basis of grade-point average) and students enter the option in their second year or third year. It should be remembered that Canadian Honours programs are normally of a 4 year duration; however, a co-op student will take longer because of the work terms each one of which carries a weight equivalent to one regular course.

The schemes are very popular with both students and employers. Students view the scheme as providing an entrée into a possible job on graduation and employers are keen to acquire cheap temporary workers. Although the current recession has lessened the demand for co-op students there has been no real difficulty in finding work placements for them. Besides all the technical firms in the city there are many governmental departments who act as employers.

At Ottawa University the co-op programme is preceded by an intensive 2 week period in which students are interviewed by companies, are trained in interview technique and resume writing, and are prepared for the first week of work. This is different to Carleton where the preparation is undertaken by the departmental co-op coordinator who has rather fewer resources.

When students are hired, firms are asked:

1. to be available to see a co-op administrator at the mid-point of the term. Half an hour is spent with the employer and then with the student as a mini-evaluation.
2. to complete an evaluation report at the end of the term.
3. to help the student write the end of term report - with conceptualisation and evaluation. This is sometimes neglected by the employer.

There are benefits to both the companies and the universities. The university viewpoint is that the students acquire a taste of what it is like in industry. They also gain confidence in their studies - professors say that they approach their work with more maturity and question what they are doing although one professor described this as cockiness. The students have the experience to prepare real questions when they return to the classroom. The co-op experience also pays towards their studies. Students can earn up to $500 a week depending on the entry position, which increases each work-term. Students are attracted by the increased likelihood of full time employment, especially in Computer Science. Of course, the placements may play a role in creating links that were not there before.

The response from the companies was very positive for a number of reasons. Primarily these were to do with potential recruitment: the co-op programme allows an extended interview period, and is a source of cheap labour. The larger companies take up to a dozen students each work term. The companies are looking for students who can cope with the pressures of working in that industry and "stars of the future". It gives a student hands-on experience, and prepares them for what that industry is like. There is also the knock-on effect of a student going back to college and talking about what he has done.

The students mostly do real jobs. One company explained that they do exploratory work which the company could not get done any other way. They provide "a good pair of hands and a good mind, low cost". Another company uses students to do labour intensive work which frees other staff to do more creative things.

A rather different kind of outcome is that co-op students are a means of getting visibility for a product. If the student likes it he will talk about it to his friends.

7.3.2 Oxford local impact

Unlike Oxford University which is a low provider of employees to the local labour market (130 graduates in 164 firms Lawton Smith 1989), the Polytechnic has a far greater impact. There is a local bias in its input partly through convenience - many of its students come from within a 60 mile radius. Many of its graduates stay in the area. If they have come from outside the area, many are inclined to stay within Oxfordshire since it is an attractive place to live. Research Machines Limited is a very popular company to apply to; they have recruited every year and are willing to take sandwich students. However, for university graduates there are limited opportunities for working in large establishments. There may be some reluctance to work in the smaller companies in the area.

CSM is in its first year of a sandwich degree course. Oxfordshire is the target for the sandwich students. But at the moment the companies are shedding jobs and cannot afford to take on an extra employee at even a very low salary. In the first year of operation they managed to place about a third of their 65 students locally. The majority of these students are in Computer Science since fewer mathematics students apply. The placements are for a year. Already some interesting links have been forged. The companies are also looking for future employees - although not at the moment as this is a very bad year.

Another initiative affecting Oxfordshire is a government scheme for enterprise in higher education. Its moneys go to certain institutions including universities and polytechnics over a 5 year period. Students are taught "core" activities, such as learning to communicate. The money is being used initially on a pilot scheme for some first year students to improve the quality of input to industry. Word processing, spread sheets, and verbal communications skills such as the ability to give presentations are taught.

7.4 Conclusions

The major differences between Ottawa and Oxfordshire are explainable by and are caused by the different ways that government agencies encourage interaction, and through the very different composition of the industrial structure. Hence there is a contrast between the laissez-faire situation in Oxfordshire and the strategically managed approach in Ottawa. The major ways that, in Ottawa, university and industry interactions are managed are through membership of OCRI and institutionalised through TRIO. These create a strong local effect. The telecommunications industry has a dominant impact on both the patterns of research and on interaction at the graduate and undergraduate level. The Co-op Programmes reinforce the strength of local interaction.

However, academics in Ottawa still prefer to work without interference from industry, and there remains a related problem in industry's perception of what it is paying for.

A conflict between old and new thinking persists, and this is exacerbated by the issue of teaching relief.

The most lasting effect of the Centres of Excellence is likely to be in the quality of opportunity given to graduate students. This is viewed as an essential element in industrial research. Academics, on the other hand, benefit from the financial support of the Centres which support research undertaken by graduate students. On the transfer of technology, a key element in the mission of the Centres of Excellence, the jury is still out on the benefits to industry. The academics in Ottawa are happy with the access to research funds. They and the students have most to gain from the programmes. The co-op scheme is arguably of most significant benefit to industry.

Isolation from the international community in Canada may still affect attitudes in Ottawa. The telecommunications industry is still a domestic one. However, BNR is seeking to be a world leader by the end of the century and is expanding its spheres of influence into other countries - for example by buying STC. Its emerging international role may have a knock-on effect on research in Ottawa.

In contrast, in Oxfordshire there are no formal programmes for interaction in the area, and therefore no equivalent local money. Links between Oxford Polytechnic and the local industrial community are under-developed, although they do exist. A chief reason for this is that research is not well supported by the state or by the institution. However, at the student level the Polytechnic is much more orientated towards the local area than the University, through sandwich courses.

The situation is rather different in the university departments. Academics are linked into major company networks which, because of the structure of the electronics industry, has no local focus.

The changes recorded in Oxfordshire highlight the phases in the evolution in the role of the institutions. Oxford University is relatively secure in its research role, because of its prestigious position and history of research output. On the other hand Oxford Polytechnic would like to join in, and will be expected to do so with the proposed change to university status. The long term implications of this for the local economic development are unclear.

It is interesting to ask whether the Canadian experience is applicable. One of the differences between Ottawa and Oxfordshire is that the Ottawa high tech industry in general is able to absorb the labour resources provided by the universities. This is by no means the case on the same scale in Oxfordshire, in spite of some local companies recruiting, particularly from the Polytechnic. As a solution to local development problems in the UK, the situation is far from clear: national as well as local shortages in the supply of qualified scientists and engineers exist. However, it seems to need some overlap of interest at a local scale for such initiatives to work.

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The Times, October 4, 1991

Table 1. Advanced technology industry in Oxfordshire: employment change by activity, March 1987

Activity heading (1980 SIC)	No. of establishments, 1979	No. of establishments, 1987	Employees, 1979	Employees, 1987	Percentage change
Chemicals/pharmacology/biotechnology	2	8	95	87	−8.4
Engineering	5	9	490	385	−21.4
Computers, office machinery					
Electronic data processing equipment	3	9	39	460	+1079.5
Electrical equipment	5	10	652	988	+51.5
Telegraph and telephone equipment	1	1	20	72	+260.0
Electrical installation and control	22	53	576	1 885	+227.3
Radio and electronic capital goods	6	10	187	562	+200.5
Components and other electronic equipment	2	5	4	46	+1050.0
Racing car manufacture	4	4	109	362	+232.1
Vehicle components	1	1	1000	530	−47.0
Scientific and precision instruments	4	9	260	295	+13.7
Other manufacturing	4	6	2111	2 270	+7.5
Computer software	4	25	302	577	+91.1
R and D/consultancy	13	32	1886	2 140	+13.5
Total	76	182	7731	10 659	+37.9

Source: Lawton Smith 1990

TABLE 1

TABLE 2

ADVANCED TECHNOLOGY SECTORS IN OTTAWA-CARLETON

("ESTIMATED" CURRENT EMPLOYMENT AND 1990 PROJECTIONS)

Sector	1985 (update from OCEDCO Directory)		1990 (projected)	
	Firms	Employment	Average Growth 1985/90 (% per year)	Employment
Service/support	24	560	10	900
Components, assembly and sub-systems	48	2,930	7	4,150
Semiconductors	9*	1,600	13	2,950
Systems:				
Telecom	4	5,430	4	6,600
Defence	7	1,700	7	72,400
Space	6	1,150	13	2,100
Other systems (includes major software activity)	40	2,800	13	2,100
TOTAL	136	16,170	8.4	24,250

* This includes Semiconductor activity in two companies whose other employment is shown elsewhere. The overall total shown for the number of companies is accurate. The discrepancy in adding the column reflects the fact that these companies' employment was split.

TABLE 2

OTTAWA CARLETON RESEARCH INSTITUTE
INSTITUT DE RECHERCHES D'OTTAWA CARLETON

Schedule I - Membership Fees
Year ended December 31, 1990
with comparative figures for 1989

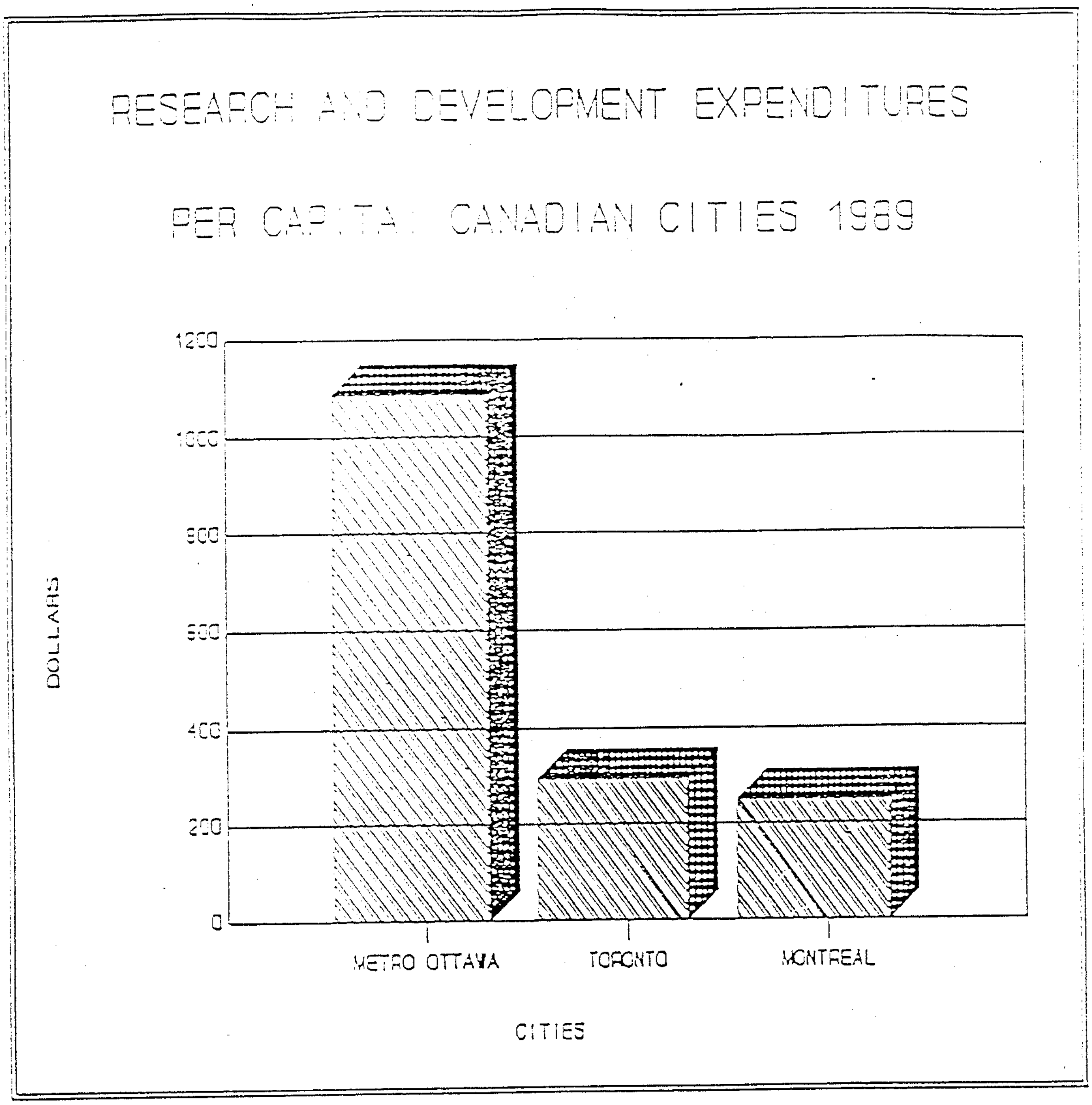
	1990	1989
Corporate members:		
Bell Canada	$50,000	$50,000
Bell Northern Research	50,000	50,000
	100,000	100,000
Institutional members:		
Algonquin College	10,000	10,000
Carleton University	10,000	10,000
University of Ottawa	10,000	10,000
Université du Québec à Hull	10,000	10,000
La Cité collégiale	6,667	1,667
	46,667	41,667
Affiliate Members:		
Atomic Energy of Canada Limited	10,000	10,000
Department of Communications	10,000	10,000
Digital Equipment of Canada Ltd.	10,000	10,000
Gandalf Technologies Inc.	10,000	10,000
Minto Construction Limited	10,000	10,000
Mitel Corporation	10,000	10,000
National Research Council	10,000	10,000
Telesat Canada	10,000	10,000
DY-4 Systems Inc.	5,000	5,000
Connelly Exhibitions Inc.	3,000	-
Corel Systems Corporation	2,667	3,000
Leigh Instruments Limited	2,500	5,000
Mosaid Inc.	1,333	1,000
Atlantis Scientific Systems Group Inc.	1,000	750
Canai	1,000	1,000
NGL Ltd.	1,000	-
Aepos Ltd.	750	-
Object Technologies Ltd.	750	-
Cadence Computer Corporation	250	1,000
Other	-	1,750
	99,250	98,500
Individual members	999	2,066
	$246,916	$242,233

Table 3

Table 4 Oxfordshire Advanced Technology Establishments Having Links with Universities

	Total No. of Firms	Link with Any Univ	% of Total	Link with Oxford	% of any Univ
(a) size					
Number of employees					
0-10	78	34	43.6	21	61.8
11-50	46	19	41.3	11	57.9
51-100	14	7	50.0	2	28.6
101-500	23	13	56.5	9	69.2
501-1000	2	2	100.0	0	0.0
>1000	1	0	0.0	0	0.0
(b) Founder's Academic Background					
Oxford Univ	30	17	56.7	15	88.2
Oxford Poly	8	2	25.0	1	50.0
Other HEI	65	28	43.1	12	42.9
FE	12	3	25.0	3	100.0
Other	12	6	50.0	3	50.0
None	16	7	34.8	3	42.9
Spin-out	21	12	57.1	6	50.0
c) Founders Occupational Background					
Worked for another co.	85	34	40.0	16	47.1
Academic or technician	30	21	70.0	16	76.1
Worked in RI	9	5	55.5	2	40.0
Woked for Commercial RU	3	-	-	-	-
Research Unit	5	3	20.0	1	33.3
Spin-out	21	8	38.1	4	19.0
Worked in a Hospital	5	2	40.0	2	100.0
Made redundant	3	1	33.3	1	33.3
Self employed	3	1	33.3	1	33.3
Total	164	75		43	

TABLE 4

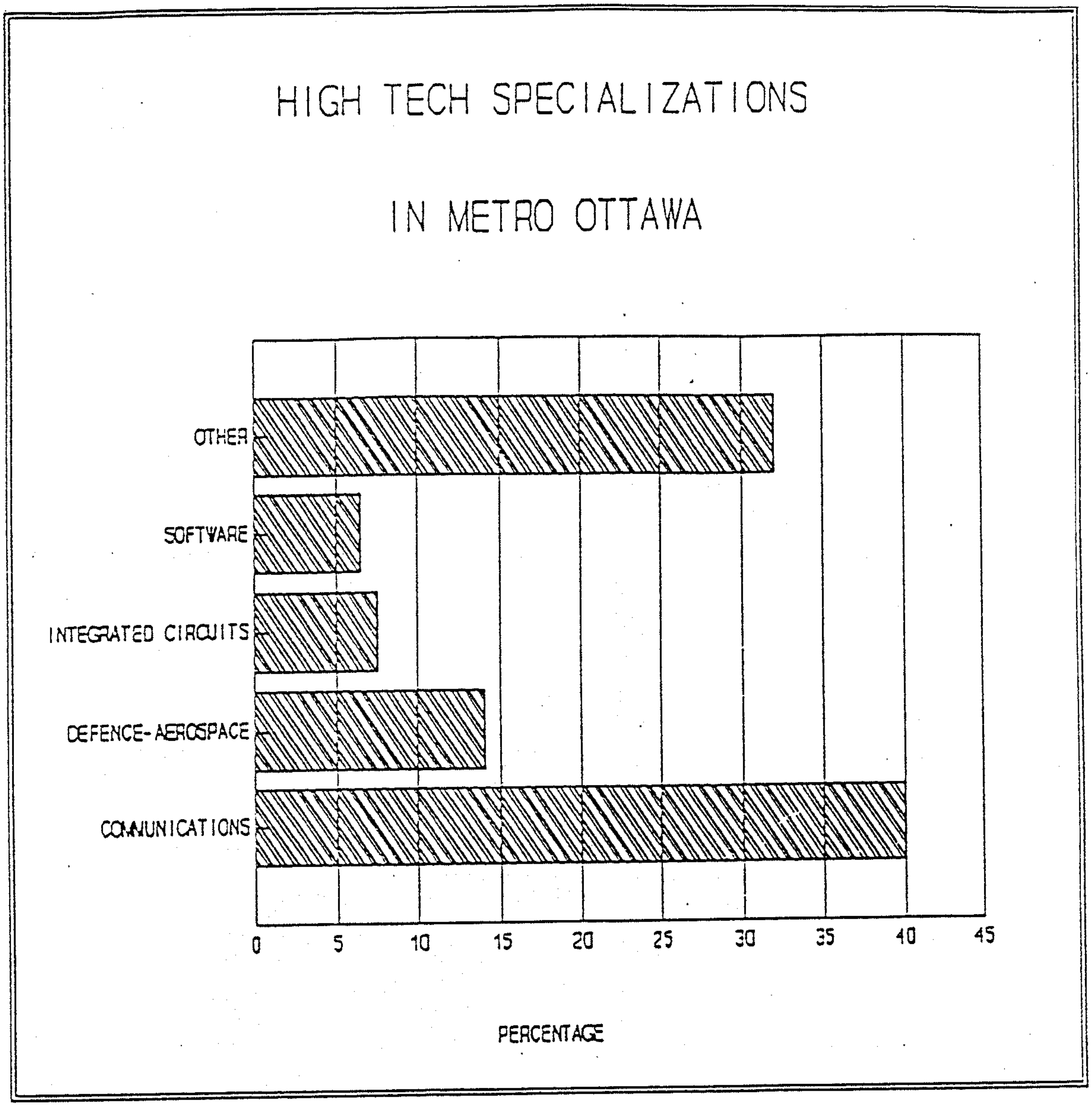


RESEARCH AND DEVELOPMENT EXPENDITURES PER CAPITA:
SELECTED CANADIAN CITIES 1989

METRO OTTAWA	$1 088
TORONTO	$295
MONTREAL	$250

Source: The Ottawa-Carleton Research Institute

FIGURE 1



HIGH TECH SPECIALIZATIONS IN OTTAWA

COMMUNICATIONS	40%
DEFENCE-AEROSPACE	14%
INTEGRATED CIRCUITS	7.5%
SOFTWARE	6.5%
OTHER	32%

Source: Ottawa-Carleton Research Institute

FIGURE 2

School of Computer Science, Carleton University
Recent Technical Reports

SCS-TR-161 (revised) — **Recognizing Sources of Random Strings**
R.S. Valiveti and B.J. Oommen, January 1990
Revised version of SCS-TR-161 "On the Data Analysis of Random Permutations and its Application to Source Recognition", published June 1989

SCS-TR-162 — **An Adaptive Learning Solution to the Keyboard Optimization Problem**
B.J. Oommen, R.S. Valiveti and J. Zgierski, October 1989

SCS-TR-163 — **Finding a Central Link Segment of a Simple Polygon in O(N Log N) Time**
L.G. Alexandrov, H.N. Djidjev, J.-R. Sack, October 1989

SCS-TR-164 — **A Survey of Algorithms for Handling Permutation Groups**
M.D. Atkinson, January 1990

SCS-TR-165 — **Key Exchange Using Chebychev Polynomials**
M.D. Atkinson and Vincenzo Acciaro, January 1990

SCS-TR-166 — **Efficient Concurrency Control Protocols for B-tree Indexes**
Ekow J. Otoo, January 1990

SCS-TR-167 — **A Hierarchical Stochastic Automaton Solution to the Object Partitioning Problem**
B.J. Oommen, January 1990

SCS-TR-168 — **Adaptive List Organizing for Non-stationary Query Distributions. Part I: The Move-to-Front Rule**
R.S. Valiveti and B.J. Oommen, January 1990

SCS-TR-169 — **Trade-Offs in Non-Reversing Diameter**
Hans L. Bodlaender, Gerard Tel and Nicola Santoro, February 1990

SCS-TR-170 — **A Massively Parallel Knowledge-Base Server using a Hypercube Multiprocessor**
Frank Dehne, Afonso Ferreira and Andrew Rau-Chaplin, April 1990

SCS-TR-171 — **Parallel Processing of Quad Trees on the Hypercube (and PRAM)**
Frank Dehne, Afonso Ferreira and Andrew Rau-Chaplin, April 1990

SCS-TR-172 — **A Note on the Load Balancing Problem for Coarse Grained Hypercube Dictionary Machines**
Frank Dehne and Michel Gastaldo, May 1990

SCS-TR-173 — **Self-Organizing Doubly-Linked Lists**
R.S. Valiveti and B.J. Oommen, May 1990

SCS-TR-174 — **A Presortedness Metric for Ensembles of Data Sequences**
R.S. Valiveti and B.J. Oommen, May 1990

SCS-TR-175 — **Separation of Graphs of Bounded Genus**
Ljudmil G. Aleksandrov and Hristo N. Djidjev, May 1990

SCS-TR-176 — **Edge Separators of Planar and Outerplanar Graphs with Applications**
Krzystof Diks, Hristo N. Djidjev, Ondrej Sykora and Imrich Vrto, May 1990

SCS-TR-177 — **Representing Partial Orders by Polygons and Circles in the Plane**
Jeffrey B. Sidney and Stuart J. Sidney, July 1990

SCS-TR-178 — **Determining Stochastic Dependence for Normally Distributed Vectors Using the Chi-squared Metric**
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Frank Dehne and Susanne E. Hambrusch, September 1990

SCS-TR-180	**A Workbench for Computational Geometry (WOCG)** P. Epstein, A. Knight, J. May, T. Nguyen, and J.-R. Sack, September 1990
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SCS-TR-199	**Constrained Tree Editing** B. John Oommen and William Lee, December 1991
SCS-TR-200	**Industry and Academic Links in Local Economic Development: A Tale of Two Cities** Helen Lawton Smith and Michael Atkinson, January 1992