Knowledge Transfer and Innovation: A Review of the Policy Relevant Literature

"Much of our economic challenge can be summarized in two words: knowledge and innovation. These are the new raw materials of the 21st century economy. They are the key to a country that can race forward when the global seas are calm, and ride out the rough weather safely when they are not. Innovation and knowledge are two sides of the same coin – the true hard currency of the future."

Paul Martin, 1999

Maryann P. Feldman[1]
(Rotman School of Management)
Present: University of Georgia
114 Meigs Hall
Athens, GA 30602-6772

&

Ian I. Stewart
University of Toronto
101 College Street, Suite 320
Toronto, ON M5G 1L7
iani.stewart@utoronto.ca

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1. Phone: 706-542-0581, Email: mfeldman@uga.edu

Executive Summary

1.0 Introduction

- Innovation is fundamental to economic growth and development. The ability to create economic value by introducing new products to the market, redesigning production processes, or reconfiguring organizational practices is critical to competitive advantage and growth for firms, industries and regions.
- Knowledge transfer in organizations is the process through which one unit (e.g., group, department, or division) is affected by the experience of another.
- When considering innovation the prime actors who realize economic value are private firms. These firms are heterogeneous, representing different industries, different numbers of employees and different strategic orientations. Other important actors are universities and other public research institutions that are generally more removed from the market but engage in critical, early stage research that directly benefits the innovative activity of private firms. The effective transfer of knowledge between these actors is critical in realizing economic growth and development.

2.0 Knowledge Transfer at the University-Firm Interface

Commercialization of University Generated IP

- The academic, review and policy literature focused on university-firm knowledge transfer is quite extensive. The majority of the literature is based on research focused on U.S. academic institutions and policies and as such has become the benchmark by which most countries measure themselves.
- The primary business of universities is knowledge generation, transmission, integration, and use
- Research conducted at universities, whether at a basic level or in partnership with industry is fundamental to the development of a competitive R&D infrastructure and hence innovation within Canada.
- The university-firm interface consists of interactions between universities, colleges, research hospitals or other publicly funded institutions with an educational/teaching component and industry.
- At the university-firm interface knowledge is transferred through several distinct channels, these involve: commercialization, research publications, the training of highly qualified personnel, research contracts and partnering, and through other forms of direct and indirect communication.
- The commercialization of intellectual property is typically handled by professionals in technology transfer offices (TTO's) or business development offices (BDO's) within an institutions research department.
- The traditional route for commercialization of IP within these offices is through licensing or start-up activities. Other hybrid mechanisms including research contracts supported by industry to further develop IP with an option to license the IP upon favorable results are also widely used.
- Each university or institution may favor different mechanisms, which is largely determined by the culture of the institution, the current skill set of the TTO staff and or the budget available.
- An example of the commercialization supply chain for a licensing opportunity: idea – research – discovery – disclosure – assessment (commercialization contract with TTO and inventor finalized) – patenting – determination of market readiness – if not ready (develop a research contract with option, or secure grant money to develop the technology further) - marketing – negotiation – licensing.
- At Universities, patents are often filed on technologies in an embryonic state as there is real pressure for the academic to publish and disclose their research at conferences to increase their visibility, achieve tenure, and increase their funding potential. This creates a significant challenge.
- The transfer of knowledge from the university to the firm through commercialization is inherently difficult because the intellectual property is often considered 'early stage' and therefore not ready for direct commercialization. As such TTO's and BDO's will often have to invest a lot of time and resources into moving the IP along the commercialization supply chain until it is at a point where the risk is acceptable to industry.
- In Canada there exist several funding (e.g. CIHR POP grants) and newly emerging collaborative mechanisms in Ontario (e.g. OCE, Biodiscovery Toronto) to help advance early stage technologies (IP). Financing provided through these approaches is critical in filling the gap that often exists between a patentable idea and VC or Angel investment or direct licensing by industry. Although established, these approaches must be expanded and maintain a true focus on

1. Phone: 706-542-0581, Email: mfeldman@uga.edu

supporting the development early stage technologies.

- TTO's, BDO's and equivalent offices play important roles in the commercialization of an institute's technology however they are largely viewed as inefficient. As a result, the effectiveness of technology transfer offices has been the focus of many academic studies, from which several conclusions that are relevant from an Ontario perspective may be drawn.
- The effectiveness of a technology transfer office (TTO) is largely dependent on the culture and ability of the institution to support commercialization. For most institutions, the focus is on research and many top level administrator have little or no direct experience in managing commercialization efforts. As a result, adequate funding, staffing, and focus is often not provided or supported by key stakeholders. A greater understanding or awareness of the commercialization process is essential for all senior administrators (e.g VP research) to ensure informed and supportive decisions.
- Professionals working in TTO's or equivalent offices are often, underpaid based on qualification, under-incentivized, under resourced and are often faced with very demanding workloads. As a result many of these offices operate as revolving doors and are seen as little more than training grounds for many staff. Given that many commercialization efforts are relationship based (inventor and industry) and can take anywhere from 6 months to several years to complete, it is often difficult to achieve any continuity in these offices further reducing productivity.
- There is no clear IP ownership policy for research conducted in Universities or equivalent institutions across Canada or Ontario, suggesting that national or provincial policies on the commercialization of IP may be complicated. In the US, the Baye-Dole act, legislates that all IP created through federal research funding should be patented, and the responsibility falls on the institution.
- The Fortier report developed in the late 1990's provides a nice overview of some of the current challenges of University-Firm commercialization.

The commercialization of university research has been a very important topic and certainly one that has gained an enormous amount of attention from both academic scholars and government research agencies. From this research a number of important issues have come to light both from an international perspective and from a more local Canadian perspective on the efficiency of this process. In this regard, the following questions should be considered when considering policy in this area:

- Should Canada or Ontario adopt a national or provincial policy with regards to IP to help streamline the commercialization of university research?
- What specific steps have been taken to implement the recommendations of the 'Fortier' report since 1999?
- What are the staff turn-over rates like in Ontario based TTOs?
- What metrics should be used to measure the efficiency of TTOs in Ontario?
- Do federally funded university and hospital research institutions have governance that supports and fully understands the commercialization process?
- Should universities and research hospitals be involved in commercialization?
- Should research disclosures and IP generated from any federally or provincially funded research be stored in a common data repository that could serve as a node for the local and international business communities, by linking them with institutions that own individual IP, or more importantly, portfolios of common IP that may be of interest?
- Is there adequate funding or mechanisms available to help TTOs advance early stage technology to a more (industry) attractive state?

Training and Retaining HQP

- One of the key contributions that publicly funded universities make to economic growth in a knowledge based economy is the training of highly qualified personnel (HQP's).
- HQP's bring to the firm general knowledge which includes recent scientific research, the ability to solve complex problems, perform research and develop ideas. In many cases, HQP's will also bring additional tacit knowledge in very specific areas and highly advance technical skill sets.
- Although Universities are an excellent training ground for HQP's, a common criticism that is not unique to any one geographical region is that there is not enough emphasis on preparing graduates for careers in industry. This is true also for Canada, however many schools have

adopted co-op programs. Another solution has focused on developing and supporting industrial post-doc positions.

- Finding and retaining HQP's to specific regions will also have enormous effect on knowledge transfer. If Canadians continue to train the best and brightest at our institutions only to see them leave the country for employment. One of the solutions to the retention problem is to create and support high profile research clusters or networks that can capture and retain 'star scientists'.
- High profile research centers/clusters attract scientists and industry (synergy) which in turn attract students and promote training/transfer
- There is also a common perception that Canada does not have a large pool of talented management, especially in the life science biotechnology sectors. As a result, companies are often faced with importing external candidates (e.g from US) with the required experience at a very large premium.
- Other less easily quantifiable factors such as the attractiveness of a location in terms of social issues (crime rates, access to the arts) geographical esthetics and cost of living attractiveness also factor considerable.
- Canada and specifically Ontario produce a large (competitive) number of graduates annually. However it does fall short by OECD standards in producing higher end graduates including PhD's. Furthermore the association of university and colleges of Canada estimates that US universities 50% more per student for teaching and research. Through NSERC, however, Canada is actively involved in creating industrial post-doc positions.

  Although much thought has been dedicated to this subject and the Canadian government has made it a priority, the effectiveness of the current programs and a full gap assessment that would address some of the following questions would be useful.

  - Where do the Canadian graduates go? What percentage of graduate students trained in Canada go to academia (in Canada), small firms, large firms, leave Canada to find work or leave their field of training?
  - Where do Ontario graduates go? What percentage of Graduate students trained in Ontario go to academia (in Ontario), small firms, large firms, leave Ontario/Canada to find work or simply leave their field of training? Is Ontario doing better than other provinces?
  - Is there enough receptor capacity for newly trained Ontario's HQPs every year?
  - What are the major reasons cited by HQP for leaving Ontario (e.g. lack of salary or opportunity)?
  - Are Ontario's research clusters and centers of excellence sufficient for attracting and retaining HQPs?

Tacit and Codified Knowledge Transfer

- The shift to a more knowledge-based economy embodies a number of changes in both the production and application of new scientific knowledge (i.e. codified and tacit dimensions of knowledge) that have critical implications for the processes of knowledge transfer.
- Tacit knowledge refers to knowledge or insights which individuals acquire in the course of their scientific work that is ill-defined or uncodified and that they themselves cannot articulate fully. Although, highly subjective and often varies from person to person, tacit knowledge is often a critical component of knowledge transfer and can significantly affect the outcome of a project.
- Codified knowledge is that which is directly understood and therefore may be easily transferred, either verbally or through written instructions.
- For complicated subject matter, knowledge is most effectively transferred from the university to the firm through both codified *and* tacit knowledge flows. This suggests that a good, strong working relationship exist between both parties in order to facilitate effective knowledge transfer. It may be further strengthened via the flow of HQP's from the university to the firm. In such cases, both the codified and tacit knowledge are transferred implicitly.
- From the firm's perspective, the ability to evaluate and utilize outside knowledge is largely a function of the level of prior, related knowledge within the firm, including basic skills or even a shared language, but may also include knowledge of the most recent scientific or technological developments in a given field. These abilities collectively constitute a firm's "*absorptive capacity*".

University-Firm Research Alliances and Collaborations

- University research involves a rich mix of scientific discovery, clinical trials, beta testing, and prototype development, and industry linkages to university-based research are demonstrated to be complementary to firms' R&D strategies.

- The importance of University-Firm research linkages varies by sector, but is most important in areas where science plays a major role such at biotechnology and information technology (IT).
- By international standards (G8) Canada does well with over 10% of university research being funded by the private sector.
- From the firm's perspective, it is generally accepted that collaboration with universities is primarily a valuable complement to, and extension of, the firm's in-house research, and not a way to replace it. Access to the outside knowledge, expertise and awareness of leading-edge research provides an incentive for a firm to seek collaboration with a university.
- From the Universities perspective, interest in collaboration is stimulated by three related factors: 1) financial pressures (money), 2) public demand to see economic benefit form research (story) and 3) it provided direct proof to the researcher that their research is of direct relevance to industry (ego).
- There is an ongoing requirement to improve the clarity of university requirements for collaboration with industry. Specifically this involves, improving the clarity of the institutional rules for IP, licensing, and overhead costs.
- Key success factors identified as being important to University-Firm collaborations include: good communication, well defined incentives and motivators for the university researcher (i.e. IP ownership, publications, new equipment, salary, etc) and low turn-over in key research personnel on both sides.
- To date, the Canadian government has been active in supporting university-firm research partnerships through many programs such as the national centre's of excellence (NCE's) which are supported by CIHR, NSERC and SSHRC. NCE's are unique partnerships among universities, industry, government, and not-for-profit organizations aimed at turning Canadian research and entrepreneurial talent into economic and social benefits for all Canadians
- In 2004-2005, 830 companies, 266 provincial and federal government departments and agencies, 51 hospitals, 194 universities, and more than 365 other organizations from Canada and abroad were involved in the NCE program.
- In a similar manner, the government of Ontario has established many provincial initiatives including the Ontario Centres of Excellence (OCE) program to strengthen research linkages between academia and industry and promote economic development. The OCE program currently consists of 5 centers that match critical sectors of Ontario business and industry, including: 1) the Centre for Energy, 2) Communications and Information Technology Ontario (CITO), 3) Centre for Research in Earth and Space Technology (CRESTech), 4) Materials and Manufacturing Ontario (MMO) and 5) Photonics Research Ontario (PRO).
- In addition the Government of Ontario has also helped bring academia and industry together in such vehicles as clusters. For example, the Medical and Related Sciences (MaRS) center; is a convergence innovation center dedicated to accelerating the commercialization of new ideas and new technologies by fostering the coming together of capital, science, and business.
- Although the Ontario government is an active supporter of these partnerships it is unclear how successful they are and further research and study will be required to assess the impact these centers have. It is clear that better metrics other than licensing deals be used to assess the magnitude of University-Firm collaborative research partnerships.

University-Firm Conflicts of Interest

- Conflicts of interest may arise when the two cultures of academia and industry are attempting to concurrently fulfill their missions and objectives. As the federal levels of total research funding decrease, and the technological competitiveness of a country continues to be threatened, the benefits of university-industry partnerships have become more attractive
- Creating internal university policies to encourage researcher participation in industrial efforts is important, because the social and organizational structures and environments of universities and corporations are often in conflict. The university's tradition of rewarding publication of basic research conflicts with the needs of industry to delay publications of university-industry research projects. Other conflicts between faculty and industry in multi-party university-industry relationships are based on the fact that, even though the relationship is entrepreneurial-oriented, some of the colleagues will have

opposing views as to how the commercialization of their research should be conducted.
- Another often cited controversy arises from the different missions and objectives of the two cultures. Industrial research is based on the need for specific industrial results to solve specific needs, and developed under secrecy from competitors, while university research is based on scientific inquiry, with open communications and public access to academic research results.
- When entering into formal arrangements, the Universities office of research or TTO must set clear guidelines for how academic staff is to participate in collaborations and what their decision making authority is with respect to IP and commercialization. The university must also make clear its IP and licensing policies to the industry partner as part of an active and diligent management of the collaboration.

3.0 Knowledge Transfer at the Government-Firm Interface

- Government research labs are considered key components of most national science and innovation systems.
- Historically, government research programs and laboratories were developed to fulfill unmet R&D needs that were deemed critical as a matter of national defense, infrastructure development or healthcare. These programs were developed primarily because the capital expenditures, facilities and human resources necessary often exceeded the capabilities or resources of private sector research organizations.
- Today, government labs continue to evolve and define there role; specifically significant effort is being made to liaise with industry and form direct collaborations, or to become more ‘applied’. In some countries, government labs have been developed as separate entities to support both ‘fundamental’ research and ‘applied’ research.
- To be viewed as attractive collaboration partners, government labs must be 1) generators of excellent research, 2) performer of multidisciplinary research, 3) catalyst of collaborative linkages, 4) flexible and empowered and 5) committed to long term research.

Government-Firm Transfer and Government Labs

- In Canada, the premiere government organization dedicated to developing new technologies and strengthening collaboration with industry is the national research council (NRC).
- The NRC typically will engage in long-term, high-risk projects that have potentially high returns for society as a whole. These activities involve active collaborations and spin-out activities.
- Compared with other federally institutions (e.g. Universities), government labs are perceived to understand industry needs better than universities, they are more willing to structure collaborations agreements in a way that is conducive to industry and as well, they tend to have strong applied research capability including facilities, equipment and researchers. In addition they are perceived as providing a access to local and international research linkages through their collaborative networks.
- Some of the major obstacles that firms perceive to exist and may limit collaborations with the federal government include: long term maintenance of research focus on a particular project, continuity in budget for research programs and clear consistent message on the mandate of the lab to support collaborative research. In some cases, these change over time and with governments.
- Compared to University-Firm and Firm-Firm knowledge transfer research, the number of publications on Government-Firm research is considerably less. Additional research should be undertaken to better quantify the success, issues and challenges faced in this area.

Government-Firm Transfer and the National Innovation System

- The national innovation system, a term used to describe both the Canadian S&T institutions and their various linkages, creates, disseminates and exploits the knowledge that fuels a productive economy, which, in turn, makes a prosperous society possible.
- The Government can play a very significant role in strengthening the operation of the national innovation system through 1) the development of infrastructure that facilitates information exchange and networking between government, industry and academia, 2) the promotion of funding mechanisms that promote private/public cooperation for technology development, 3) the promotion of knowledge translation and information exchange between private/public entities and 4) providing guidance on the best organizational arrangements and management practices that will help position firms for success.

- To date there are a number of active and successful organizations that have been established by the federal government to facilitate Knowledge translation. Some of these include: the National Centers of Excellence (NCE), Canadian Foundation for Innovation (CFI), CANARIE Inc., NRC-Industrial Research Assistance Program (IRAP) and Industry Canada Strategis website, Genome Canada, and TR Labs.

Government-Firm Transfer and Provincial (Ontario) Government Labs

- In terms of the incentive for firms to collaborate with Government labs, they are much the same at the Federal and Provincial level. Provincial Labs and Institutions, however, are often seen as convenient places to initiate collaboration and therefore serve as a stepping stone for a firm to enter a new provincial market. As such they provide a direct access point for national or international firms to enter a region or a country.
- As such, Provinces may actively seek to attract outside industry through competitive incentive programs (e.g. tax based) or by liaising with the local expertise that comprises the provinces innovation network in order to help firm's access new markets.
- Ontario has been very active in generating and supporting innovative networks, initiatives, and institutes to help stimulate innovation. Some of the major initiatives that are unique and in some cases provide the local mirror for the equivalent federal programs include: Ontario Research and Development Fund (now ORF), Innovation Trust, Research Performance Fund, Ontario Research Commercialization Program (ORCP), Ontario Centers of Excellence (OCE), Ontario Cancer Research Network, Ontario Research and Innovation Optical Network (ORION), Biotechnology Cluster Innovation Program, Stem Cell Innovation Program, Ontario Regional Innovation Network Program, Premiere's Research Excellence Awards, Premier's platinum awards.
- Although the Ontario Government is actively spending money setting up important programs to support innovation, most of these initiatives will have long incubation times and therefore the direct benefits may not immediately be obvious. Additional research will be required to follow up on the progress, results and direct benefits of these programs. It is unclear at this point however, what metrics might be useful in helping characterize success in each of these specific programs.

4.0 Knowledge Transfer and the Firm

- Although counter-intuitive at times, knowledge transfer between firms is not new and is one of the most prevalent mechanisms by which knowledge is transferred.
- Innovation encompasses both the development of new technologies in addition to incremental improvements to existing products or processes. Therefore, the view that innovation is limited to new science-based or so called high technology industries is myopic, as it ignores the equally transformative nature of innovation in existing mature industries that are already in place.
- Absorptive capacity is a primary knowledge transfer mechanism between firms and refers to the ability to assimilate and replicate new knowledge gained from external sources. The persistent development of the ability to absorb knowledge is a necessary condition for a firm's successful exploitation of knowledge outside its boundaries. Without such capacity, firms are hardly able to learn or transfer knowledge from outside. On the other hand, firms can assimilate new knowledge more effectively if they possess a high level of absorptive capacity.
- A primary mechanism for knowledge transfer between firms is through collaboration. Formally, this may be defined by any joint activities undertaken by two or more firms or between firms and institutions with a common objective.
- Some common types collaborative relationships found between firms include: 1) Collaboration with competitors to a) reduce risk, b) reduce cost, c) access new markets and d) indirectly through imitation, 2) Collaboration with clients to develop better products and reduce market risk, 3) Collaboration with suppliers to improve prototype development, scale-up, and access new expertise and 4) Collaboration with consulting firms to access specific domain knowledge and expertise.

Partnerships and Alliances

- Firms may collaborate through many different organizational inter-firm structures including partnerships, joint ventures and alliances in order to gain competitive advantage in the market place.
- Inter-firm collaboration has increasingly been used to access new markets, to gain skills and

technologies, to share the risks and high costs of technology development, reduce duplication of R & D efforts, and save costs.

- Since the 1960's there has been an overall growth in the world-wide partnerships over the past few decades, while at the same time there has been a decided decrease in the number of join-ventures formed. This has been primarily driven by the growing preference of firms for the greater strategic flexibility that shorter term contractual arrangements offer as compared to long-term more ambiguous joint ventures.
- There is a 'sectoral' preference for short term contractual partnerships in technology development; since the 1990's partnerships have been dominated by companies in the information technology, pharmaceutical and biotechnology sectors. This is largely reflective of the need for short term flexibility in executing projects yielding competitive advantage. JV's are typically found in medium-tech and low-tech industries where technological development is usually less turbulent and of a more gradual nature.
- Research indicates that knowledge transfer performance is positively affected by the explicitness of knowledge and the firm's absorptive capacity; that equity-based alliance will transfer tacit knowledge more effectively, while contract-base alliance is more effective for the transfer of explicit knowledge (codified). The ability to transfer knowledge will be impacted by the nature and strength of the relationship formed.
- The size of the firm will also have an impact on a firm's preference or need to enter into inter-firm collaborations. In the face of mounting global economic uncertainty, inter-firm collaboration is regarded as a mechanism by which small firms can overcome at least some of their problems (notably, credibility, limited market information, inadequate finances, distribution issues and labor shortages) and survive. Since the 1990's this type of arrangement has increased approximately 250%.
- Common interests, complementary expertise, and goodwill are important ingredients in establishing and maintaining collaborative arrangements between organizations. Common interests, complementary expertise, and goodwill are important ingredients in establishing and maintaining collaborative arrangements with other organizations.
- The transfer of knowledge through collaborative ties with other firms through international joint ventures is often problematic and exhibits a high rate of instability. The instability of the joint venture is related to changes in the bargaining power of either partner. Specifically, this occurs when either partner acquires sufficient knowledge and skills to eliminate a partner dependency and make the international joint venture bargain obsolete.
- A firm conclusion that can be drawn from studying the interaction of knowledge transfer on the formation of partnerships and alliances, especially R&D partnering, is that it is largely dominated by companies from the world's most developed economies (e.g. U.S.).
- This dominance has not only led companies from other countries to actively search for R&D partnerships with U.S. companies, the U.S. dominance of technological development in many of the above-mentioned fields has also led to a situation where most of the recent R&D partnerships are formed between companies within in the U.S.A
- Interestingly, the high rate of partnering within national systems such as the US is not directly linked to the Governments investment in R&D, but is likely more affected by factors such as the anti-trust policy which allows for greater collaboration in addition to other international policies related to trade barriers (e.g. Uruguay round).

Knowledge Transfer within Firms

- Knowledge transfer within firms or between divisions of the same firm, either within a national system or multi-national system has been the subject of a recent upsurge in interest among scholars. The primary focus of this research has been on the
- Research has largely focused on two streams: 1) how 'timing' affects the successful transfer of knowledge between divisions or from an R&D center into a subsidiary and 2) a companies experience in the transfer of technology within an organization.
- Two important conclusions may be drawn: 1) Knowledge outflows from a subsidiary are positively associated with value of the subsidiary's knowledge stock, its motivational disposition to share knowledge, and the richness of transmission channels; and 2) Knowledge inflows into a subsidiary would be positively associated with richness of transmission channels, motivational disposition to acquire knowledge, and the capacity to absorb the incoming knowledge.

- The transfer of knowledge within an organization is even more difficult for multi-national companies where divisions or departments may exist in different countries or cultures. As firms expand into new international markets, their organizational learning processes differ significantly. These variations stem from both the nature of the knowledge itself and from differences in firms' organizational structures. In some firms, each division learns about a new market largely, if not wholly, on its own, whereas in other firms there is a great deal of internal knowledge transfer, resulting in significant shared learning across different divisions.
- In general, it is found that (similar to inter-firm transfer) that direct or codified knowledge is more easily transferred, whereas the transfer of tacit information that would accompany a new technology was more difficult to transfer. This stresses that even within organizations, effective communication and strong working relationships between individual actors and divisions is essential for successful knowledge transfer.
- A secondary knowledge transfer mechanism that may technically be considered a pseudo intra-firm is transfer through merger or acquisition (M&A). M&A is a very common event especially for small start-up companies whose goal is to develop their business to a point where their company and technology make excellent take-over targets for larger multinational companies. This is especially prevalent in the biotech industry.
- Knowledge transfer process in acquisitions is distinctly different from the process under other modes of governance, because of the rapidly-evolving relationship between the two parties. While many of the facilitators of knowledge transfer are likely to be the same (tacitness of knowledge etc.), their relative importance and the process itself is dynamic. In the early stages, knowledge transfer is undertaken in a relatively hierarchical manner (dictated by management), but this then gives way to a more reciprocal process. And over time the type of knowledge being transferred shifts in emphasis from relatively articulate (e.g. patents) to more tacit (know how).

Promoting Firm-Firm Collaboration within Canada

- Inter and intra-firm collaborations are fairly active within Canada and knowledge transfer through these mechanisms are typically governed by the issues described above. Compared to OECD countries Canada compares and the size of Canada's economy inter-firm collaboration is quite competitive at the local level, however international exposure is less well developed and primarily involves the US. Although this is not unexpected, it may represent a potential long term risk and suggests that there may be value in increasing its international linkages.

Clusters

- A key priority of the Government of Canada's innovation and commercialization strategy is to support the development of globally competitive industrial clusters.
- Firms within an industrial cluster are in the same – or related – field, and linked by a variety of interdependencies and networks. These include academic networks, common funding resources, a common pool of skilled labor, and industry associations. An industry cluster is a group of companies that benefit from an active set of relationships among themselves to increase individual efficiency and competitiveness.
- For a cluster to become competitive it must have access to a rich infrastructure present in the local economy that can provide specialized services and resources to support activities at each stage of translating an idea into a commercial product, or a viable self sufficient company. This includes access to human capital from scientific and management capability.
- Although clustering can be found in many industries, there is a definite focus on the life sciences/Biotech/Pharma and hit tech or ICT industries where the majority of these clusters are found in British Columbia, Ontario and Quebec.
- Compared with other active regions, ICT cluster behavior appears strongest in Ottawa and Vancouver where it is fairly well developed. In Toronto, cluster behavior is less developed and can vary significantly throughout the GTA (e.g. more so in Markham and less so in Toronto). In the life sciences sectors, the Vancouver and Ottawa clusters are located in smaller municipalities and appear to have achieved a higher profile and cohesion within their respective locations as compared to clusters in Toronto and Montreal. This later observation is due mainly to the fact that clusters in Toronto and Montreal are situated in high industry activity areas and therefore have to compete with several sources for attention.

- While the federal and provincial governments have initiated a variety of programs to fund infrastructure, research and ventures that support cluster developments, these programs often do not achieve there full potential impact. One of the primary factors for these failures, that may vary regionally, arises from the lack of coordination among federal, provincial, non-profit organizations, and companies. This lack of coordination results in the absence of a long-term vision and strategy for the development of the cluster, and a dilution of the impact of public sector resources.
- There are also insufficient communication and feedback loops between the various public sector institutions established to promote entrepreneurship and the communities of entrepreneurs they serve. This may be attributed to not only the fragmentation of public sector efforts but also to the lack of private sector leadership that can articulate a cluster's needs and vision.

Tax Rates

- The corporate and personal tax rates are important factors in reducing the overall costs of operating a firm and in making a country an attractive location for MNE's and therefore competitive in the global marketplace. Specifically, some important facts concerning Canadian Tax incentives can be summarized as follows: 1) Governments compete to attract R&D investment through tax incentives, 2) investment in R&D is an important channel for transferring knowledge, experience and technology to Canadian Firms, 3) Canada's R&D D tax incentive program is being increasingly viewed as a principal fiscal incentive to R&D investment by both Canadian and foreign investors, and 4) from a throne speech, the government has set a goal to become fifth in the world in terms of R&D intensity by 2010.
- In Canada, the overall average tax burden is close to the OECD average (37 per cent), but is significantly higher than in the United States, as well as Japan and Australia.
- In stimulating firm growth, sustainability and collaboration, Ontario must offer an attractive R&D, taxation, regulatory, entrepreneurial, and investment environment. These incentives can include specific government programs in addition to generous R&D tax credits, lower corporate income tax rates, tax holidays for foreign researchers, matching foreign VC investments with loans, and refundable tax credits.

Intellectual Property

- Intellectual property (IP) laws attempt to remedy the market failure in R&D markets by granting property rights that recognize the inventor's (firms) exclusive right to make, use or sell an invention. To be competitive, Canada therefore has an obligation to maintain intellectual property policies that are effective regionally and are in-line with internationally recognized policies.
- A number of policies relevant to IP protection and competition that impact Canada on the national stage are: 1) Uruguay Round Agreement on Trade Related Intellectual Property Rights (TRIPS). This agreement helps set the stage for the preservation of an IP created in one country being protected equally in other jurisdictions, and 2) In Marrakech, 1994 the WTO "Agreement on Subsidies and Countervailing Measures act was signed and is designed to prevent countries from creating unfair competitive advantage on the global scale through excessive support of industrial and pre-competitive research.
- The development of IP policies is a difficult task within a national system and even more difficult on the international stage. On one hand knowledge dissemination and combination with other information is essential to help create new products and processes, on the other hand knowledge must be protected in order to provide a competitive advantage for firms.

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1.0 Introduction

Innovation is fundamental to economic growth and development. The ability to create economic value by introducing new products to the market, redesigning production processes, or reconfiguring organizational practices is critical to competitive advantage and growth for firms, industries and regions. The question then becomes how best to organize resources to create, diffuse and sustain innovation and, moreover, how to leverage investments made in science and technology, research and development and related capabilities with the ultimate goal of reaping rewards in terms of wealth creation and increased standards of living.

Innovation is becoming more complex and knowledge relevant to realizing economic value often resides in different organizations. Organizations increasingly work together to realize economic value. Organizations transfer knowledge, either formally through such vehicles as contractual strategic alliances or informally through knowledge spillovers realized through personal friendships or observation.

When considering innovation the prime actors who realize value are private firms. These firms are heterogeneous, representing different industries, different numbers of employees and different strategic orientations. Other important actors are universities and other public research institutions who are generally more removed from the market but who have assets that might benefit the innovative activity of private firms.

The intention of this paper is to provide a literature review that identifies and describes the influence of knowledge transfer on innovation between three categories of organizations. First, we consider knowledge transfer between public research institutions such as universities and government labs and private firms. Next, we consider knowledge transfer between firms, with specific emphasis on the transfers between different sizes of firms and participation in industry R&D alliances. Finally, we consider cross border knowledge transfers within firms, such as knowledge flows within the divisions of multinational firms and within national systems. We will make extensive use of empirical academic literature and government, industry and association reports (Section 5) written over the past decade.

Our goal is to provide a solid overview of the recent literature and thought pertaining to university-firm, government-firm, and firm-firm knowledge transfer. This is a significant task. Our objective focuses on identifying key challenges that Ontario faces in these areas, including specific issues that may influence Ontario's ability to design and implement effective policy. In many cases, however, there is a paucity of literature that is directly relevant to Ontario. As such, we will draw on the existing empirical literature and some of the key past and/or current policy initiatives in comparable jurisdictions in Canada, the U.S., and Europe that influence the formation and efficacy of knowledge-transfer alliances in general. Where applicable, we will identify areas where further policy-oriented empirical research is needed. We begin by clarifying some terms.

1.1 Clarifying Terms

When an issue is significant the popular discussion may easily become muddled, terms may be used interchangeably and without precision and as a result the debate becomes superficial. To avoid this, a series of definitions that discriminate between the components of innovation will be provided in order to advance the discussion and enrich the choice of policy options.

In daily conversation, terms like *invention* and *innovation* as well as *science* and *technology*, among others, are often used interchangeably. However, for academics and policymakers there are important distinctions between these terms and these distinctions give each term a unique meaning and enrich discussion. Invention is about discovery and the creation of something novel that did not previously exist. Innovation, on the other hand, carries invention further with the commercial realization of the value of the invention or the receipt of an economic return. This is a subtle but important distinction. Thus, patents, the legal protection of an idea reveals an invention while, for example, the marketing and consumer acceptance of a new drug is evidence of an innovation.

Science, in a broad sense, is the unfettered search for knowledge for the sake of understanding. That search is based on observed facts that may be replicated through experimentation or theory. Thus, science begins with conventional preliminary conditions and searches for some unknown results to address fundamental questions related to hypotheses about the world. The process of investigation is known broadly as research, and research may be *basic* with the intention of advancing science or *applied* with the orientation towards some practical end. These are two ends of a continuum of problem-solving, as basic research suggests avenues of inquiry that are advanced by applied research. Likewise, research is enriched, made more complex and significant, as applied work creates the need for more theoretical work and suggests new avenues for further basic research. In addition, and most critically, while science is classified by disciplines that define traditions of inquiry, and scientists are trained within these specific traditions, applied problem-solving frequently creates the need for multidisciplinary teams or even creates new disciplines to colonize the frontiers of knowledge. Examples would be the rapidly evolving fields of biochemistry and biomedical engineering or the emerging fields of nanotechnology, genomics or proteomics.

In contrast, industrial *Research and Development* (R&D) is the systematic augmentation or deepening of knowledge by applying it to some practical problem or new context with the idea of generating a commercial return. While science is typically conducted by universities and institutes of higher learning, R&D is typically conducted by private firms. An important distinction is that private firms have a responsibility to earn returns for their shareholders. In general, the more basic the science involved in a research project, the more difficult it is to appropriate the resulting returns. This is due to particular characteristics of the knowledge that research creates. A variety of government incentives and public-private partnership programs have evolved over time from government's desire to steer private investment towards more basic types of scientific activity, and to stimulate the development of new technologies that private firms would not consider attractive investments in the absence of some incentives. These incentives include direct grants, R&D subsidies or other programs that encourage firms to conduct projects with universities or government laboratories.

Knowledge has characteristics such as being *nonrival* and *nonexcludable* that classify it as a public good. *Nonrival*, in the economists' terminology, indicates that one person's use of knowledge does not impede another's use of it. Consider the example of a mathematical formula. Knowledge is created when the formula is first derived and formal proofs are demonstrated. The result is most likely a scholarly publication which would codify the knowledge, rendering it easy to diffuse and put into practice. Once the formula is known, the fact that one scientist uses it does not diminish its usefulness or utility to other scientists. In fact, the value of the formula may actually increase as a result of its more diffuse use and acceptance. Thus, knowledge, once created, is *nonrival* in that many economic actors may enjoy it simultaneously. *Nonexcludability* refers to the fact that once knowledge is discovered it is difficult to contain or to prevent others from using that knowledge. Once an idea is known it frequently seems obvious to others and can be simply replicated at what is known as zero marginal cost. As a result of these two conditions, the social value of knowledge is greater than the value that the creator may be able to capture, a classic case of an externality. Private firms are likely to under-invest in knowledge production since the returns to the firm are smaller than the returns to society. This is the traditional justification for government funding for research. The majority of university research (35.4%) in Canada is funded by the federal government. In Ontario, 18% of university research is funded by the provincial government. In addition, there are several government funded and government operated labs in Ontario that also perform foundational research that might benefit private firms.

Intellectual Property (IP) can take many forms including products and processes that can be protected through patents or trade secrets, or authored works protected through copyright. Most governments, including the Canadian government, will consider certain kinds of creative endeavors as “intellectual property” and allow inventors legal recognition for these endeavors. For example, some forms of IP include software, databases, plant varieties and other biological materials, as well as "tangible research property". The latter includes items such as circuit chips, organisms, drug targets, formulations and engineering prototypes. It is however, up to the creator to decide whether an invention, discovery or new idea is to be treated as IP. For example, a researcher who immediately publishes a discovery has made the decision that it is not to be treated as IP and that it should be freely available to the public for use.

Commercialization is the process that turns an invention into an innovation and involves defining a concept around who is willing to pay for the new idea, what attributes they value and how much they are willing to pay for the added value. The ability to legally protect an invention therefore forms the basis for commercialization activities, as it precludes others from copying the invention and entering in the market and competing for a share of the economic profit. More importantly, if firms did not have the ability to protect their discoveries, they would have no incentive to invest in many important research and development (R&D) activities such as clinical trials, thus interfering with the creation and diffusion of knowledge. As such, IP creation is a fundamental ingredient of the commercialization process and an important vehicle for knowledge transfer between legal entities and the public.

While patenting measures invention, commercialization requires the additional steps of translating inventions into consumer needs and product markets. At its earliest stages, before applications are easily described or generally appreciated, realizing the potential of an invention requires a sophisticated understanding of consumer needs, existing markets for product innovation and factor inputs. Commercialization, even when ideas are abundant, may not be completed because outcomes are highly uncertain, risk aversion may cause projects to be delayed or abandoned or the relevant organizations may not be able to collaborate.

Technology is information that is put into use to accomplish some task (Eveland 1987). This information may take many forms including both hardware (physical, material objects) and software (digital or procedures) or combinations thereof. As such, technology has a fairly broad definition and includes anything that helps increase the efficiency and quality of our daily lives. For example, electronic and computer technology help use share information and knowledge quickly and efficiently. As well, vitamins, new biochemical formulations and drugs alter our health and improve our lifestyle making up another important class of technology. Using this definition, technology may often be considered a form of intellectual property. In general, technologies are often broadly classified based on their area of application and therefore terminology such as information technology (IT), biotechnology and nanotechnology have become common place.

Technology transfer is the application of information into use where transfer is essentially the communication of information or technology. Technology transfer is therefore a distinct and important subset of knowledge transfer (Rogers 2002; Gopalakrishnan and Santoro 2004). In the management literature, technology transfer is often considered within or across firms, such as the dissemination of information through transfers of employees from one division or country to another. For example, Allen (1984) focused specifically on the flow of technology transfer within a large R&D organization, or an R&D subunit of a larger organization. Agmon and Von Glinow (1991) examined the role of the multinational corporation in facilitating commercial knowledge transfers across countries. Another significant area of technology transfer activity focuses on the process of moving ideas from R&D laboratories into the marketplace (Dorf and Worthington 1989; Kennedy-Minott 1983). In this process, technological innovation derived from research in a scientist's laboratory is linked to individual users in a receptor organization, which may commercialize the technological innovation into a product or service to be sold in the marketplace. Or the receptors may be nonprofit organizations that adopt a new technology such as a new treatment idea to better serve their clients (see, e.g., Cunningham et al. 2000). Technology transfer is often handled by specific offices or departments within an organization such as technology transfer offices (TTOs) or business development offices (BDO's).

2.0 Knowledge Transfer at the University-Firm Interface

The primary business of universities is knowledge generation, transmission, integration, and use. As knowledge is the commodity of the new economy, and universities are one of the primary creators of this currency, it is therefore the responsibility of the university to create effective mechanisms to transfer this knowledge to the public, whether it is for social or economic development, or simply to increase the pool of knowledge. Most modern universities will have well-developed infrastructure and policies in place to support the transfer of knowledge from the university to the public via several of the channels highlighted in Figure 1. In this section, we describe how knowledge is transferred from the university to firms (public) through traditional and non-traditional academic vehicles described in Figure 1. Specifically, we will focus on the commercialization of intellectual property generated at the university, the training of highly qualified personnel (HQP), the formation of research alliances, and various forms of direct and indirect communication common to university research and education.

Initial assessment of the academic review and policy literature focused on university-firm knowledge transfer indicates that these areas have been extensively studied, especially in North America, and more so now in Europe. There is in fact an enormous body of literature that is constantly growing and evolving, the majority of which is based on research focused on US academic institutions and policies. Although U.S. and Canadian academic institutions have developed independently, the two systems share a fair deal of similarity in their operation, goals and infrastructure. The U.S.-based research is therefore very relevant to Canadian institutions and the development of policy surrounding academic-firm knowledge transfer.

2.1 University-Firm Transfer via Commercialization

As described above, commercialization is the process that turns an invention into an innovation and involves defining a concept around who is willing to pay for the new idea, what attributes they value and how much they are willing to pay for the added value. Although one of the major purposes of commercialization is to transfer knowledge and put into practice technology from the university to the firm, an additional goal of these activities is to stimulate regional economic development (e.g. Feldman and Desrochers, 2003) either by attracting firms to locate close to the university, or though the creation of start up or spin off companies (e.g. Feldman 2000). While patenting captures the invention, commercialization requires the additional steps of translating inventions into consumer needs and product markets, before economic gain can be realized. Commercialization, at the university level typically involves early-stage technology and is an intensive process that requires significant commitment on behalf of the university to accomplish this task in any scale. Not only does the university have to support the research that produces an invention, but it must have an effective infrastructure to capture (evaluate, patent and protect) and exploit (i.e. license or spin-out) the IP. Normally this activity will be conducted through the department of research at the university and specifically through its liaison, business development office, or more commonly a technology transfer office (TTO). The generation and capture of intellectual property by these offices is therefore a critical part of the commercialization process and, correspondingly, there is a wealth of literature created on the subject (e.g. Jorda 1999).

The knowledge that forms the basis for new IP may be generated through different mechanisms, the origins of which must be considered when developing a commercialization strategy (ARA and Brochu 1998). For example, intellectual property is often generated by individuals from various institutions and sectors working in partnership. In these situations, the intellectual property generated in this manner will be in the form of know-how, or will be "incremental", i.e. leading to better processes or products. The research is generally supported by strategic grants, university-industry grants, or contract research with industry and government. The IP is the result of an exchange of knowledge, not a simple transfer from a researcher to a user; partners potentially interested in the results are part of the team. This is "market pull". This type of research has grown tremendously in the past decades in most disciplines, including the social sciences. From a government policy perspective, this interactive mode is more interesting, for it is more conducive to practical training and has more chance of being "picked up" (licensed) in the near term.

On the other hand, investigator-driven research may lead to an entirely new development with a high potential for eventual exploitation. This is "technology push". Research of this nature is generally supported by operating grants and commercial partners (receptors) have not been identified ahead of time. Discoveries stemming from basic research may generate very high paybacks. These discoveries however, may still require further development to reach their commercial potential. It is therefore very important to identify these innovations and select the right protection and exploitation mechanisms, including ways to add value during the process.

2.1.1 Technology Transfer

In the context of commercialization, technology transfer and the flow of knowledge from the university to the firm, is dependent on the characteristics of the firm, the university and more importantly the efficiency of the technology transfer office (hereafter TTO) in bridging this gap. As such there are many important actors involved in this process. Figure 2 provides an overview depicting how technologies flow from the university to industry. Based on this process the key stakeholders are: 1) university scientists, who discover new technologies; 2) university technology managers and administrators, who serve as a liaison between academic scientists and industry and manage the university's intellectual property; and 3) firms/entrepreneurs, who commercialize university-based technologies. A summary of these key stakeholders, their roles and motivations in the process are listed in Table 1 as described by Siegel et al. (2004).

With reference to Figure 2, the technology transfer begins with a discovery by a university scientist in a laboratory, who is typically working on a federal research grant (e.g., a research project funded by the NSERC or CIHR). The academic must then decided whether to file an invention disclosure with the TTO and, more importantly, whether they wish to work with the TTO in commercializing the invention. This process will be largely governed by the prevailing invention disclosure and IP policy of a given institution, and by the perception/awareness the researcher may have of the TTO. In the U.S., the Bayh-Dole act of 1980 (Bremer 1993) requires that all discovery originating from federal research grants be disclosed through the university TTO. There is no equivalent policy in Canada (for a more thorough discussion of this act and other related tech transfer policy, see Section 2.1.2). Of course, the academic may elect to forego commercialization and publicly disclose the invention through a research publication, making it freely accessible to the public. When the discovery is disclosed through the TTO, however, the TTO managers must evaluate the technology and decide whether or not to patent the innovation and protect the intellectual property. The evaluation step is very important and requires experience and sound judgment because the process requires time and many universities have limited budgets for filing patents, which is quite expensive if *global* patent protection is sought. Universities may choose to apply for *domestic* patent protection, which safeguards the technology at a much lower cost, or use provisional patents as a way to stop the clock. Provisional patents will cost less and may be used when more time is required to evaluate the technology and its marketability, or to buy time to collect more data to file a stronger patent. In general however, the review process will consider IP reviews, technical analysis, market assessments and commercialization strategies. If there is known interest in a technology by an industry partner, the decision to file a patent is often expedited. Once the IP has been protected, the technology will be marketed. The business development portion of this activity will be led by the TTO, however, faculty members will often provide additional technical input and help identify industry partners. Once the TTO has secured interest by an industry partner, it will enter into negotiations to license the technology focused on obtaining a royalty stream against future revenue streams from a commercialized product or an equity stake in a new venture (Feldman et al. 2002). The reader may wish to review Feller et al. (2002) who have provided a nice overview of technology transfer practices at American universities (similar to those described above) based on a review of the literature and national surveys. Furthermore, the association of university technology managers (AUTM 2005) has summarized some key elements of the TTO's role in commercialization.

- The practice of technology transfer provides significant contributions to the economy. Of 4,543 companies established since 1980 to commercialize cutting-edge technology from U.S. universities, hospitals and research institutions, two thirds are still operating. This very high survival rate demonstrates the successful application of these technologies in the market.
- Technology transfer serves as the bridge between researchers who spend thousands of hours producing a new concept or product and business people in corporations who can turn the invention into a product for public use. One example is Oragenics Inc., which is developing a mouth rinse that will be administered by a dentist and can protect against cavities for a lifetime. This product would not exist if Oragenics Inc. had not licensed the technology from the University of Florida.
- Technology transfer professionals work with researchers to patent the outcomes of their research and license them to corporations that are ready and able to develop them as new products and services.
- Technology transfer professionals consider it their duty to ensure that inventions emerging from publicly funded research are licensed in a manner that facilitates and encourages their development and use for the benefit of the public.

The simple description of technology transfer implies that it is primarily a one way or linear translation of research results into various commercial applications. In practice, however, the technology-transfer process, is more adequately viewed as a transaction process in which questions, answers, clarifications, and other information flow in both directions. In such cases, research has suggested that the efficiency of the transfer of technologies is related to the firm's connectedness with the university research and or inventors (Agrawal 2001). Using this approach, the receptor organization transforms the research-based technology into a product or service that can be sold in the marketplace by constructing a common, shared meaning of the technology with the inventor/university through a better transmission of tacit knowledge. Where the technology gets spun-off as a start-up, faculty members and TTO officers may serve as technical advisors or on boards of directors, and might also have an equity stake in the start-up.

Drivers: Although the transfer of technology from academic practitioners to industry is an easily described process, the nature of the drivers of these processes can be quite complex. As described by Siegel et al. (2004) in Table 2, it often requires consideration of the actions, motives, and organizational cultures of scientists, university administrators, and firm/entrepreneurs. For example, Merton (1957) suggests that a primary motive of university scientists is recognition within the scientific community, which emanates from publications in top-tier journals, presentations at prestigious conferences, and federal research grants. They are also motivated by financial gain, both for personal reasons and to secure additional funding for graduate students and laboratory equipment. The fraction of a licensing royalty payment that is allocated to a faculty member is determined by the university's "royalty distribution formula". It typically ranges from 25 to 50% (although it can be as high as 75% in Canadian institutions) as discussed by Friedman and Silberman (2003). In these arrangements, the TTO works with the scientist and firm or entrepreneur to structure a deal, where the primary motive of the TTO is to safeguard the university's intellectual property, but at the same time, market that intellectual property to private firms (Siegel et al 2003). Secondary motives may include securing additional research funding for the university via royalties and licensing fees, sponsored research agreements, and an intrinsic desire to promote knowledge transfer. Firms and entrepreneurs seek to commercialize university-based technologies almost exclusively for financial gain and therefore seek to maximize their returns. As such, control becomes a major factor when a firm enters into a relationship with an academic or university and the firm will often require exclusive rights to new technologies and focus on the "time to market," since the benefits from innovation may depend on rapid development of a new product or new process. Differences in the motives, actions, and organizational cultures of the three key stakeholders highlight the complexity of this relationship and its importance to efficient knowledge transfer from the university TTO to a firm.

Given the importance placed on this step, it is easy to understand that the university TTO has become a primary focus of study for those looking to understand and increase the efficiency of knowledge transfer at this interface. For example, Bozeman (2000) has conducted a fairly in- depth and fundamental review of the literature where he considered approximately 200 references on the subject. In this work he had concluded that there were five key drivers that will impact the efficiency of the process: 1) the process orientation of the TTO (i.e. process *vs* results driven); 2) the probability of market impact (the commercial success or resulting economic development derived from the transfer); 3) the possibility for political gain (i.e. does fulfilling the technology transfer process have a political impact?); 4) the opportunity costs (does the prevailing culture view this to be important or a waste of time), and 5) the scientific and technical human capital (skill and quality of the participants in the process). Further, Table 2 summarizes the conclusions from a selection of more recent articles focused on TTO effectiveness tend to confirm the view that the organizational structure and culture of the TTO in addition to the skill sets and motivation of the managers are critical to the effectiveness of commercialization-based knowledge transfer. Specifically, the university TTO manager must play a boundary-spanning role to effectively bridge the boundaries of the university-firm interface and manage the process (Katz and Tushman 1983; Tushman 1977; Roberts 1988). For example, the TTO may scan the industrial landscape for ideas and information about potential markets for new technologies bringing the manager in direct contact with entrepreneurs and 'intrapreneurs' in the business domain. These sorts of interactions provide a necessary feedback mechanism and more adequately transmit the needs and interests of both the university and firm to each other. The boundary spanning performed by the TTO manager could involve relationship or network building that helps to facilitate effective communication with both stakeholder groups, and that forges alliances between scientists and industry. In many universities, the TTO director may have limited discretion and responsibility for technology transfer. That is, a vice-provost or vice-president for research will bear ultimate responsibility for these activities. In many cases however, the core focus of the research offices is on publications and increasing public funding including research contracts with firms. They may however have limited experience with commercialization, and as such fail to fully appreciate the challenges and importance of technology transfer as a source of revenue, impact and local economic development. In such cases, where a university president or provost is be responsible for establishing an organizational culture that fosters technology transfer, they may fail to devote a substantial amount of time and effort to supporting and monitoring performance in this area. University technology transfer would then simply become a bureaucratic process, with no goal. Also, standards for promotion and tenure in science and engineering might reflect these objectives. In sum, an organizational culture that fosters technology transfer is also likely to be one that places a strong weight on developing good relationships with customers and suppliers, and a strong organizational emphasis on university-firm technology transfer (UFTT). Thus, it is clear that various organizational and managerial variables could be critical in explaining variation in the effectiveness of UFTT across universities.

Spin-off and Licensing: The commercialization of IP may take on several forms but the two most common are licensing of the technology and 'spinning-off' the technology as a separate vehicle. The latter is usually achieved through the formation of a start-up company. The approach a university will take considers many factors as discussed below, but will largely be determined by the culture of the institution and the experience of the managers involved. Culturally, there have always been stigma or ethical issues associated with the perception that Universities are now 'in business' that are only now slowly being overcome (Lenetsky 2002). As such, some universities create many spin-offs, whereas others are more focused on licensing than on spin-offs: their approach is to file a patent, search for a partner and hope that license fees and royalties will help support the research. Spin-offs are more prevalent in information technologies and biotechnology (except pharmaceuticals), while licensing is more common in pharmaceuticals and agriculture. The existence or absence of potential local receptors also plays a role. Both spin-offs and licensing are appropriate mechanisms for commercialization and are applied broadly in the U.S. and Canada. The following factors are generally taken into account in deciding which route to take:

- Where the innovation is narrow, small, short-term, or incremental to existing technology, and there is already an existing receptor, it makes sense to license it
- Where there are broader, long-term, platform technologies for which there is an existing firm capability (or where capability can reasonably be developed during the course of a joint research program), it makes sense to license the IP if appropriate agreements can be made
- Where firm capability does not exist, the option may be to spin-off platform technologies into a new venture if the researcher is fully committed, if a sound business plan can be developed (including sound marketing, management, and capitalization) and especially if incubator support is available
- Where none of these conditions apply, it may be better to look for offshore licensing opportunities, with some (Canadian) content (such as manufacturing or R&D) built in somehow if possible

In general, the formation of new firms has become an attractive alternative by which universities transfer technologies to the commercial realm for several reasons. First, based on the successful examples of the Massachusetts Institute of Technology and Stanford University, credited with playing an active role in the genesis of industrial clusters in Route 128 and Silicon Valley respectively, university spin-offs are seen as a means for local economies to capture the benefits of proximity to local research universities (Feller 1990). Spin-off firms are local phenomena – the stay close to the source of their competitive advantage. For university-based spin-offs the university serves as the source of advantage providing skilled labor, specialized facilities and expertise. As universities and state governments have provided incentives for faculty to start companies or engage in joint research projects with companies the attraction of proximity to universities has grown. On average, 60% of university licenses are granted to small firms. In 1999, the Association of University Technology Managers (AUTM 2000) reports that university licensing led to the formation of 344 new companies, with 82% operating in the same state as the university that provided the license.

Over the past two decades much has been learned about the management of university-based spin-offs. A recent article by Lerner (2005) highlights a number of lessons learned from a variety of sources including traditional academic research, case studies on specific programs, service on advisory panels, and special projects that have sought to address the needs of particular organizations. Although the study focuses primarily on U.S. based data, the conclusions are broad and could certainly apply to Canadian institutions. Four of the key lessons learned from the study are:

- Starting new ventures based on university technology is hard. Despite the confidence of many academic entrepreneurs and university administrators, the process of creating a sustainable new company is a very challenging one
- In the vast majority of cases, new firms will not generate enormous wealth for academic institutions. Much more modest returns are the norm
- Directly financing firms through internal venture capital funds is unlikely to be a successful strategy for universities. Nonetheless, universities can add considerable value to young firms that faculty begin
- Old frameworks about conflicts-of-interest must be rethought in light of the special needs of start-ups

Similarly, in a much earlier review by Levin and Stephan (1992) focused on the motivation of universities and scientists to support this activity, they concluded that there were a number of important issues associated with spin-offs. First, the creation of spin-off companies provides a means to demonstrate an immediate and quantifiable impact. Second, university technology is often very early stage and larger firms may not be interested. Third, life-cycle models of scientists suggest that scientists invest heavily in human capital early in their careers to build reputation and establish a position in a field of expertise. In the later stages of their career, scientists typically seek an economic return for their human capital. For scientists, starting a company serves the purpose of appropriating the value of their intellectual property as well as providing access to additional funding mechanisms to further the scientist's research agenda. In the U.S., the potential financial rewards of starting a company coupled with tightening university budgets and competition for the relatively fixed pool of public funding, create incentives for scientists to engage in entrepreneurial activity (Powell and Owen-Smith 1998). In this regard, the ability of individual scientists to appropriate the value of intellectual property will be affected by national policies and variation in intellectual property procedures is one factor that may influence the academic scientist's decision to start new companies. From this, we can say that individual scientists who received grants and awards for basic research have the intellectual capital required to start a company; however, they may not possess the entrepreneurial spirit or the business acumen to run a company. In many cases, the TTO will play a major role in working with the scientist to put together a business plan, arrange funding and help establish the company.

In Canada, the lack of industrial receptor capacity and of knowledge-based industry (especially in the resource sectors) is still a major problem, even in the more industrially developed regions of the country such as Toronto. McFetridge (1993) finds that Canadian academics are relatively immobile and have no incentives to engage in entrepreneurial activity. This makes it very hard to move ideas stemming from basic research to existing companies. For spin-offs, this often means the establishment of firms based on a single technology, with the corresponding vulnerability (not mentioning the delays). In some cases, however, TTO managers may be able to bundle IP to provide the basis for a wider product offering, however the capital requirements will be proportionally larger. More importantly, there are few federal or provincial programs that support the R&D efforts of spin-off companies. For instance, most of NSERC's Research Partnership programs encourage joint efforts with existing companies and the National Research Council's Industrial Assistance Research Program (IRAP) supports existing companies but not spin-offs.

University Commercialization Issues within TTO's: The most recent Statistics Canada study focusing on IP management shows that the operational budget (in other words, the operational budget of tech transfer offices) at Canadian universities totaled ~$37 million in 2004. That is, less than 1% of the $3.5 billion budget of sponsored research. In 2004, Canadian university commercialization offices collectively employed 280 people (full time equivalents). This translates into less than one person for every $10 million in sponsored research conducted. One-half of these people are likely providing administrative support, leaving few bodies to undertake core commercialization and innovation functions.

Perhaps as a direct result of such deficiencies, universities account for less than 5% of Canadian inventions patented in the United States. According to a 1997 study by the AUTM, (AUTM 1998) North American universities generated US$28.7 billion in total benefits to the economy, supporting an estimated 245,930 jobs. Canada's share amounted to only US$0.5 billion in economic benefits and 3,935 jobs (This estimate corresponds to the economic impact of the 14 Canadian universities which report to AUTM, and which account for 50% of Canadian university R&D expenditures). The study shows that, had these Canadian universities generated economic returns at a level commensurate with their share of the research investment, they would have contributed almost US$1.5 billion more in economic benefits and created 12,788 more jobs in 1997.

Recently, however, the federal government, through a tri-council initiative (consisting of NSERC, CIHR and SSHRC), has funded an Intellectual Property Mobilization (IPM) program. Its purpose is to accelerate the transfer of technology and knowledge residing in Canadian universities, hospitals, and colleges to the private and public sectors. The program provides funding to support the management and transfer of intellectual property resulting from research falling under the jurisdiction of the three federal granting agencies. Two types of grants were awarded in the 2005 competition: network grants and internship grants. Network grants encourage groups of institutions to undertake cooperative activities. Internship grants increase the pool of trained technology transfer personnel. The grants cover up to three years. Thirty-two applications were received, requesting a total of $32.7 million. Twenty-two applications were approved for funding (a 69% success rate), for a total of $17.2 million. The results from these grants are given in Table 3. Although these grants are important and allow TTOs to address many outstanding issues, they do not result in hard line changes to an individual TTOs operating budget, and therefore will not contribute to other important issues such as attracting and retaining talent or sustainable increases in patenting budgets.

2.1.2 Technology Transfer Policy Initiatives

Although each country will have developed their own set of policies regarding university-firm commercialization initiatives, it is true to say that policies introduced in the U.S. have had significant influence and often serve as a benchmark for other OECD countries. This is largely due to the unusual structure of the U.S. higher education infrastructure, which blends financial autonomy, public funding from state and local sources, with federal research support on a substantial scale. This provides strong incentives for university faculty and administrators to focus their efforts on research activities with local economic and social benefits. Rather than being exclusively concerned with fundamental scientific principles, much of U.S. university research throughout the late nineteenth and twentieth centuries focused on understanding and solving problems of agriculture, public health, and industry. As a result, U.S. universities have made important contributions to industrial innovation throughout the past century, primarily by combining advanced research and education. The strong links between education and research sustained a close relationship between the evolving scientific research agenda and problems of industry or agriculture, while at the same time providing a powerful and effective channel (in the form of trained students) for the transfer and application of much of this knowledge to industry and other economic sectors. Given this history and accumulated research the U.S. system and policies therefore provides an important and relevant reference for the development of policy for other OECD countries including Canada.

We therefore begin our discussion by reviewing three of the major U.S. legislative acts that have paved the way for the current technology transfer policy currently in place in most U.S. academic institutions. Specifically, in the late 1970's the U.S. congress was influenced by many years of negative trade balances, and decided to change U.S cience and echnology policies. Congress recognized the need to use the research and technological resources of U.S. research universities and federal R&D laboratories by increasing the flow of knowledge and personnel to industry (Lee, 1995). The need for increased and faster technology transfer from universities to industry emerged as major legislation in 1980 when Congress passed three laws: the Bayh-Dole Act, the Stevenson-Wydler Technology Innovation Act, and the Cooperative Research Act (Lee 1995).

> *The Bayh-Dole Act.* The Act provided an incentive for universities to market their innovations to industry, and for industry to assume high-risk investments for the leasing of university inventions (AUTM, 1998). Prior to passage of the Act, it was the policy of government agencies to take title to all inventions that were invented through the use of federal funds. The federal agencies holding title to the inventions were unsuccessful in transferring the technology of those inventions to industry. The bureaucracy that accompanied any attempt at leasing an innovation from the federal government was too great for many companies. As a consequence, government agencies held patents on many inventions, but the technology represented by most of those inventions was never transferred to industry because no technology transfer policy existed for the government agencies (Bremer 1993). The Bayh-Dole Act created a patent policy for the federal agencies that funded research, and enabled small businesses,

non-profit organizations, and universities, to retain the title of inventions made under federally funded research programs. The legislation was co-sponsored by Senators Birch Bayh of Indiana and Robert Dole of Kansas, and was enacted on December 12, 1980 (AUTM 1998). Prior to the Bayh-Dole Act, fewer than 250 patents were issued to universities each year, but in the past few years, U.S. universities have averaged more than 1,500 patents annually (AUTM 1998). The Act allowed universities an option to receive title to inventions, and manage the marketing of their patents to industry (Bremer 1993). The most important aspect of the Bayh-Dole was to provide universities with the title of the inventions, and this assisted in the expansion of university-industry relationships (Bremer, 1993).

Stevenson-Wydler Act. The Stevenson-Wydler Act (1980) was designed to increase university-industry technology transfers. It authorized federal laboratories to transfer technologies to industry, establish centers for industrial technology at universities and nonprofit institutions, and provided for the exchange of scientific and technical personnel among universities, industry, and the federal laboratories (Lee, 1995).

Cooperative Research Act. In 1984, Congress increased the linkage of universities to private industry with the passage of the Cooperative Research Act. The legislation allowed universities and businesses to form technology transfer alliances without the fear of antitrust litigation (Lee and Gaertner 1994). As a result, there was a growth of UIRCs (University-Industry Research Centers) that assisted in establishing relationships between universities and industry (Lee 1995). The Act allowed patent holders to determine the length of an exclusive license up until the life of the patent, a minimum of seventeen years (Novis 1993). Previously, exclusive licenses were good only for five years from the first commercial sale or eight years from the patent date, which ever is shorter. The intent of the Act was to reduce research and development costs. Historically, industry had been fearful of collaboration with federal and university basic research projects, but the Act helped to reduce the risk for industry to develop university and federal basic research projects (Novis 1993).

All three pieces of legislation were important in providing the necessary foundation for universities to develop the infrastructure required to build and support knowledge transfer (commercialization) activities with industry. Of these three pieces of legislation and subsequent amendments, the Bayh-Dole act has received the highest degree of attention and critical review both from academics and industry observers. The act has been in place for over 20 years now, and organizations such as AUTM have made public large amounts of data collected annually from university TTOs, primarily in the U.S. but also from some Canadian institutions. These data have provided research with a significant amount of material with which to assess the effectiveness of the legislation and understand the key drivers involved in the effective commercialization of IP generated at universities. There is little doubt that these are important pieces of legislation that have significantly increased the commercialization potential of the U.S. schools however some academic and philosophical review has been somewhat critical. Like all important legislation it is often the center of debate.

December 2, 2005, marked the 25th anniversary of the passage of the Bayh-Dole Act, an event that did not go unnoticed in academic and business circles. In the past three years, two of the most prestigious and respected business magazines in the world, *Fortune* (Leaf 2005) and *The Economist (Dec 12, 2002)*, have arrived at diametrically opposing views on the impact of the act. *Fortune* decries Bayh-Dole; *The Economist* embraces it. More specifically, *The Economist* has gone so far as to say that it is "*possibly one of the most inspired pieces of* *legislation in the U.S. in the last 50 years*". *Fortune*'s criticism is largely related to the unintended consequences of increased litigation that amount to very significant 'hidden costs' associated with this process. As pointed out by an AUTM editorial by Crowell and Greenwood (AUTM 2005), however, the legal costs associated with enforcing this legislation are largely those associated with patent protection rather than pure litigation. Further context on the impact and issues associated with this legislation may be found in the current academic literature.

For example, Shane (2004) has studied data associated with the impact of the Bayh-Dole act on university patenting in the United States and its effect on university entrepreneurship. In his study he found that the effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. This result is consistent with the argument that the Bayh-Dole Act gave universities an incentive to take a more commercial approach to patenting than they had adopted in the past. Because universities can appropriate the returns to technological invention only if inventions can be transferred through licensing, and licensing is not effective for all technologies (Levin et al. 1987), this policy led universities to shift their patenting at the margin towards technologies in which licensing is more effective. Understandably this will result in TTOs focusing their commercialization efforts in more lucrative areas or technologies resulting in a sort of 'natural selection' order for commercialization.

Furthermore, the post-Bayh-Dole shift in the focus to university patenting has important implications for understanding the conflict between university departments over technology transfer that has developed in recent years. Traditionally, all academics adhered to a norm of open dissemination of ideas for the benefit of the public good. However, the demands of private industry have led norms in fields closely tied to industry to move away from this tradition in the post-Bayh-Dole era (Feller 1990). Because academics' views about technology transfer and their academic norms are shaped by the potential commercial value of their research (Lee 1996), the focus of universities on patenting in fields in which licensing is effective in the post-Bayh-Dole era, may explain the conflict over technology transfer between academic units that transfer technology routinely, and those that do not.

Finally, the results suggest that the effects of changes in public policy be considered at the industry level (Levin et al. 1987). Appropriate technology policy in one technical field may not be appropriate in another because blunt instruments may have industry-specific effects that are inconsistent with their overall goals (Klevorick et al. 1995). In the specific case examined by Shane, the Bayh-Dole Act appears to have led to a greater university emphasis on patenting in lines of business in which licensing is effective (i.e. natural selection). Since most university inventions are early stage and require additional development before private firms may invest in their commercialization (Jensen and Thursby 2001), patent protection becomes critical in safeguarding emerging technologies. As such, this implies that policies which give universities the property rights to their inventions will lead universities to focus their patenting efforts in lines of business in which patenting and licensing is more effective, which does not broadly apply to all fields.

Although this is a valid concern, the use and effectiveness of patenting on commercialization is being *adopted* and being *applied* to other fields. For example, Hearn et al. (2004) have studied and recommended this approach in the case of 'creative industries'. Still, when designing policies to harness the power of their research universities, policymakers in emerging regions need to keep this tendency in mind. Specifically, other policies may be necessary to encourage university patenting and attract investment to embryonic university technology in lines of business in which licensing is not the primary commercialization vehicle.

Bayh-Dole Act, An International Perspective: Mowery and Sampat (2005), have recently undertaken an in-depth study of the Bayh-Dole Act specifically as a model for other OECD governments to follow. They conclude that, in light of existing government-supported academic infrastructure, the Bayh-Dole Act appears to have been neither necessary nor sufficient for much of the post-1980 growth in university patenting and licensing in the U.S. Moreover, given the very different institutional landscape in the national higher education systems of much of Western Europe and Japan, it seems likely that the "emulation" of Bayh-Dole that has been discussed or implemented in many of these economies is far from sufficient to trigger significant growth in academic patenting and licensing or university–industry technology transfer. Indeed, there is some question as to the necessity of a ''patent-oriented'' policy to encourage stronger research collaboration and technology transfer and whether the potential risks associated with such policy changes have received enough attention.

Although the debate still rages and OECD governments are cautioned not to blindly adopt Bayh-Dole strategies, the fact remains that governments around the world recognize the importance of developing a national policy and will often look to the U.S. model. For example, Germany, Korea, and Taiwan are the most recent countries allowing academic institutions, as opposed to individual professors, the right to own inventions resulting from research in their labs. In Japan, the government is privatizing the entire university system in part because they want Japanese universities to become economic catalysts, like their U.S. counterparts. Similarly, Europe is poised for change. The conventional wisdom is that American universities transfer technologies more rapidly and more effectively than their European counterparts. However, a closer look at the cultural differences, the fragmentation of patent laws in Europe, and the widely differing regulatory framework (including the lack of a grace period) by Schmiemann and Durvy (2003) has shown that European academics are as "patentable" as their American counterparts. The technology transfer function at European higher education institutes and research organizations, however, needs to get much more visibility, enhanced public policy support, better credentials for the professionals working there, and a professionally managed network to benchmark experiences and to exchange good practice. Policies to accelerate the commercialization of academic research now play a central role in U.K. government strategies for promoting regional economic development and enhancing national competitiveness (e.g. USHSC 1998; OST 2002; European Commission 2004a; 2004b). In addition, the European Commission is committed to taking its share of related responsibility and has recently fostered the PROTON network of European technology licensing offices. An intense discussion on the (re-)introduction of a grace period has recently begun across Europe. Additionally, some EU member states have abolished the "professor's privilege," and their universities will consequently soon take up patenting on behalf of the institutions. It is not unlikely to expect similar trends than in the U.S. after the changes to their regulatory framework in the 1980s.

Notes on the Current Canadian Policy Landscape: As described above, the U.S. has taken a rather systematic approach to the ownership of IP stemming from federally supported research, by vesting it with the institution through which the research was conducted. As a result, the commercialization efforts will largely be driven by the institutions that own the IP or the inventors to which the IP may be assigned. In Canada, there is no single national or provincial policy regarding federally or provincially funded research. As a result, individual institutions have been responsible for setting their own ownership policies. This has contributed to considerable variation, not only across the country, but also from province to province. In some universities, ownership is vested solely with the institution (e.g. Laval, UBC), in others with the inventor (e.g., Waterloo, Simon Fraser). The ownership policies of a number of major Canadian universities and research hospitals are summarized in Table 4 and reflect this variation. Ownership policy is a major consideration in the commercialization process, however, even when the ownership is exclusively owned by the institution, revenue-sharing models between the inventor and the institution are often structured to provide the inventor with sufficient incentive to actively engage in the disclosure and commercialization process.

In universities where ownership is vested with the inventor, researchers must transfer ownership to the institution if they want the institution (TTOs) to help commercialize the innovation. In such cases, the efficiency of the process is largely determined by the factors outlined in Section 2.1.1. The decision to use the university TTO is therefore driven by the confidence of the inventor in the TTO management team and ultimately the commitment and the quality of the TTO (or other administrative structure). Each institution, regardless of who originally owned the IP, will then share potential net revenues with the inventor. The formula varies across Canada, with 50-50 being the most prevalent. The case of the University of Toronto is a special one, the ownership is considered 'joint' at the time of invention. The academic, however, has the right to pursue commercialization independently. In such cases, the net revenues are shared 75% inventor, 25% institution. The inventor may also elect to take ownership and then subcontract that UT TTO for 15%, resulting in a final overall split of 60% owner and 40% institution (i.e. 25% institution, 15% TTO). If the inventor assigns ownership and the commercialization risk to the institution then the university may claim up to 75% of the revenues.

There are primary ways to approach IP ownership, institutional ownership or inventor ownership. Institutional ownership has the benefit of being systematic and more complete, which possibly results in a larger number of commercialization events. Inventor-owned policies may result in a fewer number of commercialization events, by only the most entrepreneurial of inventors, but with better overall returns per invention. For institutional ownership to be effective, it requires clear policies and agreements in place that support the efforts of the TTO both politically and through proper budget and incentives. If these are in place, several fundamental arguments can be made (as described by ARA and Brochu 1998) by comparing inventor-driven versus institution-driven commercialization. These include:

- The inventor has no incentive for maximizing returns to Canada
- The potential for conflicts of interest is higher (especially if researchers decide to commercialize themselves)

- Researchers tend to have unrealistic expectations of potential benefits. They also tend to underestimate the research, infrastructure, overhead, and salary support provided by the university and governments during the research phase (this probably applies even if the university owns the IP)
- Investors and companies will have more opportunities to play one institution against another in the case of joint research across institutions (such as a university and its various research hospitals), if the universities involved have different policies

This last point is important and goes far beyond whether the university or inventor owns the IP and far beyond inter-institutional projects. The heart of the matter is lack of common university policies (or of best practices) with respect to transferring ownership to a third party versus granting licenses. The preferred mechanism for contracting and exploitation from the investor or receptor point of view is exclusive licenses or outright ownership (perhaps in exchange for shares in the company if a new company is created). Some universities are prepared to transfer ownership, if the sharing of benefits can be negotiated successfully. Others want to keep control of the IP and keep first right of refusal should the venture fail. All generally wish to keep using the IP for research or teaching purposes. On the industry side, some firms push very hard to retain ownership, making negotiations very difficult and time consuming. Dealing with these issues is currently a "hot topic".

Within one institution the assignment of ownership and commercialization revenue percentages is fairly straightforward, but becomes quite complex when more than one institution is involved, and even more so when a receptor is involved (see above). The situation in research hospitals is particularly complex, given that some researchers are regular faculty members, some are hospital or research center employees, and others are in temporary "soft-money" positions. Not all hospitals have IP management policies and it is not always clear whether the university policy applies. With reference to Table 4, it is clear that even within close geographical regions such as Toronto (e.g. the University of Toronto and its many affiliated research hospitals), there are many research institutions and a variety of different policies. In such a complex environment of intense research, improving the efficiency of a single office is important, but it is a relatively small problem. There exist many issues that are often in conflict with each other and, therefore, compromise the efficient transfer of knowledge. Some of these observations include:

- Each of these institutions have established commercialization processes that have been 'functioning' at some level for several years now and for the most part will have strong identity and self preservationist attitudes leading to pronounced vertical silos. This may complicate the sharing of information and present a barrier to change
- Research in the university and university research hospital environment is becoming more integrated. Many academics are cross-appointed to more than one institution, department or specialized institutes. As such, determining where the research was performed and which institute lays claim to it is often a negotiated process
- Furthermore, many of the higher dollar value funded research projects will have a team focus or translational objective. As such, they involve a diverse group of researchers from different institutions all of which may have their own cross appointments
- IP authorship, ownership and revenue generation models represent different and negotiable problems. Each institution will have a set of 'rules' in place to help determine the institute's position in each of these areas, however, at the end of the day, each case is unique and often must be negotiated. The time spent negotiating inter-institutional ownership issues can be quite substantial and might be viewed as an unnecessary burden on an office, especially one with staffing issues
- In some cases, IP may be more easily transferred to the public as part of a suite or family of IP

because it makes for a stronger or more attractive commercialization case. There is some sharing of knowledge between institutions, however, most managers may not have the time, ability or incentive to identify IP present at other institutions in order to create a suite of patents for commercialization

- Even within a local area or region, managers from each institution will spend a significant amount of time managing their IP portfolio. This includes identifying individual patent agents/lawyers with the appropriate scientific expertise for a given patent class, finding and negotiating pricing agreements with the various patent agents, either freely or within a prescribed pool, as well as managing or relying on the various patent agents to manage the timely preparation of applications and payment of fees or annuities. Each institution will pursue these activities individually suggesting low synergy and loss of purchasing power

These observations suggest that although federally-funded research is attempting to cross institutional and academic boundaries, institutional cultures focused on commercialization are not necessarily moving in the same direction with the same purpose. Moreover, examination of the innovation and commercialization indicators from the University of Toronto given in Table 5 indicate that, although disclosure and hence innovation is up, licensing has been decreasing over the past few years. Although there are many interpretations for this, it is clear that in some cases commercialization is not keeping pace with innovation and that new mechanisms should be considered to help transfer this knowledge at an increased pace, or revise the metrics for tracking commercialization progress.

Although it would be desirable to implement a common 'technology transfer language' at a regional or provincial level, developing and implementing policies to guide this will remain a challenge, largely due to the well established cultures firmly rooted in many of the institutions. A more circuitous route, however, might focus more on increasing the communication and information exchange between TTOs, especially where the original research was supported by public funding. A good example of this sort of strategy may be found in Ontario's regional innovation networks (RINs, see Table 6)). These are multi-stakeholder organizations that were established by the Ontario government in 2004 to increase innovation in the province and to foster better academic-industry partnerships globally. They are funded through various granting agents administered through the federal, provincial and municipal governments.

For example, BioDiscovery Toronto (BDT) is an organization linking nine of Toronto's internationally recognized biomedical research institutions for the commercialization of research in the metro Toronto area. The BDT is also funded through IPM (discussed above). The purpose of the organization is to provide a storefront for companies seeking access to break-through biomedical and related technologies and expertise, which results from the annual funding of more than 800 million dollars that feeds the network. The BDT seeks to develop full collaboration with the business development offices of its member institutions to fulfill its mandate and achieve the following goals:

- Support early stage commercialization projects
- Involve industry and business expertise at the earliest stages of invention and technology development
- Build partnerships between academic, entrepreneurial, industrial, financial and government partners
- Provide mentorship and training opportunities to researchers, graduate students and entrepreneurs in the Toronto region
- Support a central point-of-entry vehicle to facilitate industry/VC access to Toronto's biotechnology

At this stage however the efforts are primarily collaborative, and there is no budget dedicated to supporting the operations for such networks as hard line items beyond the 3-5 year funding period. A major concern is that, by providing no long term commitment to such entities, there is no incentive to develop any long-term programs or initiatives that may make a meaningful impact in the way commercialization is performed in this province. Moreover, as the funding cycle matures, these entities must focus on self-sustainability and therefore may lose focus on core initiatives. What this can mean, is that entities like Biodiscovery will seek to collaborate and support financially (in some capacity) projects that are 'later stage' and have commercial partners lined up rather than helping with true early stage inventions typical of Universities due to the shorter commercialization cycle time. In such situations, these entities will act more like VC's than 'early stage' investment partners with Universities. As stated above, due to publication/disclosure needs of inventors, most University derived IP is early stage and pre-investment in nature. In such scenarios, these entities will do little to help the early stage support and financing gaps. In principle, this program is definitely useful and would serve to provide a vehicle in which important issues could begin to be addressed. As a crude analogy, however, one might liken this effort to the provincial government taking a 'stick-pointing' approach to commercialization.

Summary of Commercialization Issues: Ontario will face a number of specific challenges moving forward, if it is to increase its knowledge transfer and hence innovation capacity from its federally and provincially funded universities and research hospital networks. In a report entitled "Public Investments in University Research: Reaping the Benefit" issued through the Advisory Council on Science and Technology (ACST, 1999), a number of key recommendations have been made. These are summarized in Appendix 1 of this paper. As described above and summarized nicely by Afshari (2005), three of the major themes may be identified:

1. Lack of a coherent university IP policy: In sharp contrast with the U.S. where the Bayh-Dole act requires ownership of the IP generated by federally sponsored research to vest in the university, in Canada, the federal granting councils do not require full disclosure by researchers of any IP generated from federally funded research grants, and they do not claim ownership of any resulting IP. In the absence of Canadian federal or provincial policies on ownership and disclosure, a wide variety of institutional practices have emerged. Some universities have established policies which specify whether the university or its researchers own IP, and whether the disclosure of IP created by researchers is required. Other universities have elected not to establish explicit policies. In these circumstances, IP ownership rights belong to the creators (whether faculty, graduate student or post-doctoral fellow), and they are not required to disclose IP to their university.

Multi-institutional partnerships are recognized as an effective way to generate higher value research and facilitate the transfer of innovations to the private sector. Yet the wide array of IP ownership policies poses a serious barrier to creating R& D consortiums. All parties wishing to collaborate must first negotiate IP ownership rights. This contributes to a time-consuming negotiating tax that will be imposed on all TTOs reducing their already meager commercialization capacity. As such, the absence of a coherent national policy on IP ownership and disclosure in Canada is viewed as resulting in the immediate loss of commercialization opportunities, leaked benefits to other countries, costly litigation, and is limiting the longer-term innovative potential of Canadian firms.

2. Researcher ownership**:** Vesting IP ownership with university researchers is one of the single biggest factors accounting for lost commercialization opportunities in Canada. Since most university discoveries involve multiple researchers, this approach has resulted in much co-ownership of IP in Canada. This is making it very difficult to negotiate licensing agreements with established firms. Under a co-ownership model, it is equally difficult to entice risk capital providers and skilled managers to support the establishment of spin-off companies.

In Canada, co-owners of patents cannot grant exploitation licensing rights without the agreement of the other co-owners. As a result, in the event of a conflict, licensing is paralyzed. This approach has made it difficult, if not impossible, to interest a manufacturer in the technology unless all co-owners agree to grant an exclusive license. In contrast, in the United States any co-owner of a patent may grant non-exclusive exploitation licenses without the consent of the other co-owners. Co-ownership also introduces an element of uncertainty and risk that is enough to dissuade many in the private sector from participating in technology transfers from Canadian universities. Before private sector partners invest considerable amounts to bring a discovery to the marketplace, they require certainty over who has title to the discovery for which they will be negotiating exploitation rights.

Under the present arrangement, they are reluctant to negotiate with the owner or co-owners before them because they cannot be sure that additional researchers will not materialize at a later date claiming that they contributed to the discovery, and challenging the terms of the deal that was struck. Challenges may arise, for example, if a researcher is excluded from revenue sharing arrangements, does not agree that the discovery should be used for the purposes intended, believes that another company could more successfully commercialize the discovery, etc. There are also cases where the researchers with IP ownership entitlement are simply not interested in exploring commercial opportunities.

Sometimes Canadian researchers having created IP with public funds, enter into consulting contracts with foreign (mainly U.S.) firms, and are generously rewarded through consulting fees in return for assigning away IP rights. Vesting IP ownership with researchers also creates a potential legal nightmare that is expensive and time consuming to unravel. Universities can expect to face higher levels of litigation when individual researchers, with limited business experience, commercialize their own research results. Cases are already emerging where universities are being sued due to the actions of faculty researchers (e.g. negotiating royalty payments without due consideration of graduate student contributions, negotiating exclusive licenses with multiple firms, etc.). The greater the number of individuals commercializing research without professional qualifications and experience, the greater the risk of litigation.

3. Underdeveloped university technology transfer capacity: The Natural Sciences and Engineering Research Council of Canada (NSERC) provides $3 million annually to fund university commercialization offices through its Intellectual Property Management Program. The program supports a research investment of almost $500 million by the same granting council. That is, less than 0.6% of the research base is invested in commercialization. Three provinces (British Columbia, Alberta and Manitoba) provide limited additional assistance on a project-by-

project basis. Most recently, Quebec has announced new initiatives to assist universities in this area. Other than access through RINs, it is unclear what other programs Ontario has in place to boost its technology transfer capacity.

2.2 University-Firm Transfer via Highly Qualified Personnel (HQP)

Among the key contributions that publicly-funded universities make to economic growth in the knowledge-based economy are the performance of research and the training of highly-qualified personnel (Wolfe 2006). Many studies of the economic benefits of publicly-funded research highlight the role of skilled graduates as the primary benefit that flows to firms from the government's investment in scientific research. New graduates, who have had the opportunity to participate in the conduct of basic research, enter industry equipped with training, knowledge, networks and expertise. They bring to the firm knowledge of recent scientific research, as well as an ability to solve complex problems, perform research, and develop ideas. The skills developed through their educational experience with advanced instrumentation, techniques and scientific methods are extremely valuable. Students also bring with them a set of qualifications, helping set standards for knowledge in an industry. Senker (1995) suggests that graduates bring to industry an 'attitude of the mind' and a 'tacit ability' to acquire and use knowledge in a new and powerful way. Nelson (1987) also notes that academics may teach what new industrial actors need to know, without actually doing relevant research for industry. Basic techniques in scientific research are often essential for a young scientist or technologist learning to participate in the industrial activities within the firm. Gibbons and Johnston's (1974) research in the 1970s demonstrated that students provide a form of benefit that flows from research funding. Studies by Martin and Irvine (1984) in the 1980s also showed that students trained in basic research fields, such as radio astronomy, move into industry over time and make substantial contributions. As such, there is a critical need to maintain, support, and strengthen this crucial link between student training and government-funded basic research. Students provide a key transfer mechanism for the benefits of public-sector funding to be channeled into industry and the broader society. However, according to a survey of Ph.D. recipients conducted by the ACS Committee on Professional Training published in 2000, one criticism of Ph.D. programs is that they could do a better job of preparing graduates for a career in industry.

Industrial postdoctoral positions serve as an important transition between academic training and industry. In many cases high profile companies such as Genentech and other industry leaders have adopted industrial postdoctoral training programs to help absorb new knowledge. The statistics on industrial postdocs from both the American Chemical Society and the National Science Foundation are sparse (Marasco 2003). A total of 48 people in industrial postdoctoral positions were identified through the annual ACS survey of new graduates between 2000 and 2002. Most of the industrial postdoctoral graduates surveyed were working in development and design, research, or management. The most common employer was the pharmaceutical industry, followed by professional services and research institutions, and hospitals or clinical labs. The median salary reported during this period was $34,000. Data from NSF are even less descriptive. The best source of information is the Survey of Doctorate Recipients (SDR), which provides demographic and career history information about individuals with

Ph.D.s. SDR is a sample survey that includes only U.S.-educated postdocs and excludes those who earned doctorates outside the U.S. The NSF's Survey of Earned Doctorates, which is a census of people who receive research doctorates from U.S. institutions, asks only about post graduation plans for further research. According to Joan S. Burrelli, a senior analyst in the Human Resources Statistics program at NSF, the number of industrial postdocs in chemistry is simply too small to analyze in any meaningful way. Out of the 1,800 chemistry (excluding biochemistry) postdocs who were identified by the 2001 SDR, just 170 were in industry. Most of them worked in biotechnology, health services, and research.

In the U.K., the Cooperative Awards in Science and Engineering (CASE) studentship program of the U.K. research councils provides one example of wider efforts internationally to encourage so-called "knowledge transfer" and thereby harness publicly-supported university research more closely to the goals of national competitiveness, regional economic development, and local regeneration (Demeritt and Lees 2005). The CASE program is designed to provide participating Ph.D. students with the transferable skills and applied research experience to make them employable beyond the academy. The ESRC, in particular, sees the "collaborative awards scheme linking academic and non-academic partners in the training of Ph.D. students" as crucial to ensuring "that future social scientists . . . have the skills to work in a non academic as well as an academic environment" (ESRC 2004). Likewise, in its own in-house review, the Engineering and Physical Science Research Council (EPSRC) judged the success of its CASE program partly in terms of its ability to increase "the number of students immediately taking up industrial careers" (Holtum 2003).

A number of recent studies have also identified that finding and retaining talent is a critical factor influencing the development of clusters and the growth of dynamic urban economies. Locations with large talent pools reduce the costs of search and recruitment of talent – they are also attractive to individuals who are relocating, because they provide some guarantee of successive job opportunities. Recent research by Varga (2000) into the concentration of high tech activity indicates that a concentration of high technology employment is the most important factor in promoting local academic knowledge transfers. According to Florida (1999), numerous executives confirmed that they will "go where the highly skilled people are." Highly educated, talented labor flows to those places that have a "buzz" about them – the places where the most interesting work in the field is currently being done. One way to track this is through the inflow of so-called "star scientists", or by tracking the in-migration of tomorrow's potential stars (postdocs). In their path-breaking research on the geographic concentration of the U.S. biotechnology industry, Zucker and Darby (1996) document the tendency of leading research scientists to collaborate more within their own institutions and with firm scientists located close by. As a consequence, "where and when star scientists were actively producing publications is a key predictor of where and when commercial firms began to use biotechnology."

Another approach, employed by Florida and colleagues (Florida 2002, Gertler et al. 2002) utilizes a more broadly-defined measure of "talent", and documents its strong geographical attraction to the presence of other creative people and activities locally. Inbound talented labor represents knowledge in its embodied form flowing into the region. Such flows act to reinforce and accentuate the knowledge assets already assembled in a region. Ultimately, the most valuable contribution that universities make to this process is as providers of highly skilled and creative members of the labor force and attractors of talent. Learning processes are eminently person-embodied in the form of talent. According to Florida (1999), "universities . . . are a crucial piece of the infrastructure of the knowledge economy, providing mechanisms for generating and harnessing talent." This means that the role of public policy in stimulating economic development, particularly as it applies to the research-intensive universities, is critical.

Basic university research advances fundamental understanding and provides a substantial rate of economic return through the preparation of a highly-skilled workforce, contributing to the foundation of many new technologies, attracting long-term foreign (and domestic) investment, supporting new company development and entrepreneurial companies, and participating in global networks. In this role, government funding and programs are the primary support for these activities.

Training Canadian HQPs. Canada's competitiveness and capacity for commercialization depend on the talent and ingenuity of people who combine knowledge and resources in new ways. Canada needs a well-educated workforce whose skills, knowledge and creativity can compete with the best in the world — and it needs to put their skills and education to work in a way that spurs innovation and benefits businesses.

In many respects, Canada is doing well in the supply of talent. Canada ranks first among Organization for Economic Co-operation and Development (OECD) countries in terms of the share of its working-age population with post-secondary education. Ontario has a strong post- secondary education system comprised of 20 universities and 25 colleges of applied arts and technology. Ontario has an experienced, adaptable and well-educated workforce of over five million people, over 50% of whom have a post-secondary education. The graduation of over 29,000 students a year in math, engineering, sciences and health professions, ensures a steady pipeline of new talent.

But this same OECD data reveals that Canada has proportionately fewer university graduates and — at the very high end — is producing new Ph.D. graduates at a much slower pace than major competitors such as the U.S. (OECD 2005). The research by Wolfe and co-workers (Wolfe 2000, Wolfe and Lucas 2001, and Lucas 2005) focusing on Ontario programs that promote international collaborative research, as well as university-industry partnering, suggests that the movement of doctoral and postdoctoral students into industry frequently provides the most effective method for transferring research results from the laboratory directly to industry. These benefits are often difficult to anticipate or measure, yet the evidence indicates that students bring a wide range of skills and techniques to industry. They enable firms to increase their base of tacit knowledge and expand into new activities. Firms also indicate that students fresh from their educational experience bring to the firm an enthusiasm and critical approach to research and development that stimulates other members of the research team. Over the entire career of the new hire, the skills acquired in their education and research experience are valuable and often serve as a precursor to the development of more industry-related skills and knowledge that appear over time.

Given the fundamental role of the trained student in knowledge transfer and economic development, there is significant concern about the extent to which Canada's universities have the capacity to significantly increase the number of graduate students. In particular, the Association of Universities and Colleges of Canada estimates that U.S. Universities have 50% more funding per student for teaching and research. The Canadian government has partly addressed these problems by establishing programs such as the Canada Millennium Scholarship Foundation and the Canada Graduate Scholarships to allow more Canadians to pursue a post-secondary education. Federal funding has also been increased for the granting councils and other funding organizations, in order to support Canada's research community.

The Natural Sciences and Engineering Research Council (NSERC) is one of Canada's leading funding agents for post-secondary education. It has scholarship awards programs designed to support students at the undergraduate, graduate, and postdoctoral levels. Currently it is estimated that NSERC supports over 16,000 students a year. Of special importance are the postdoctoral fellowships. These fellowships provide support to a core of the most promising researchers at a pivotal time in their careers. The fellowships are also intended to secure a supply of highly qualified Canadians with leading-edge scientific and research skills for Canadian industry, government, and universities. NSERC also provides support for industrial postdocs. These fellowships provide financial contributions that support the most promising recent doctoral graduates directly engaged in industrial research and development. Their objective is to:

- Encourage excellent recent Ph.D. graduates in science and engineering to gain experience and seek careers in Canadian industry
- Promote awareness in Canadian industry of the capabilities of Canadian universities and university research
- Facilitate the transfer of expertise and technology
- Provide an opportunity for Ph.D. holders seeking university careers to gain experience in industrial research and development

The presence of highly qualified personnel through these fellowships promotes the development of a long-term research capacity in Canadian companies (especially small and medium-sized ones).

The current national research initiative on the growth and development of industrial clusters across Canada conducted by members of the Innovation Systems Research Network provides compelling evidence of the central role played by the presence of a "thick labor market" in grounding individual clusters in a specific geographic location – and the essential role that research-intensive universities play in feeding the supply of talent to those thick labor markets (Wolfe et al. 2004). On balance the public interventions which have the most enduring effect in sustaining the process of local economic development are those that strengthen the research infrastructure of region or locality and contribute to the expansion of its talent base of skilled knowledge workers. To help support these efforts in part, the Premier's Research Excellence Awards Program (PREA) was created by the Government of Ontario to help Ontario's best and brightest recently-appointed researchers build their research teams of graduate students, postdoctoral fellows and research associates. To date, 10 rounds of competition have resulted in awards given to 612 recipients from 17 Ontario universities. PREA recipients have received over $61.0 million from the province, and approximately $30.9 million in matching funding from their institutions and/or private sector sponsors.

Training of HQP Related to Licensing and Spin-out Commercialization. The exploitation of intellectual property is a people business, and the nurturing of human resources is a paramount issue. Competition for highly-skilled individuals is fierce: universities, firms and investors are all looking for experts who understand technology, business, and finance, are at ease with the three sectors, and are respected by them. There are few such people and as a result:

- It is difficult for university business development or technology transfer offices to retain professional staff, as they are quickly attracted elsewhere (salary, career progression)
- It is difficult for investors or agents to find the people with the right skill mix who understand both the research side and the business side
- It is difficult for Canadian companies to attract and keep certain kinds of professional staff

For example, in biomedical fields, it can take salaries as large as $400,000 or more to tempt CEOs from the U.S. with roughly equivalent take-home compensation. Since few small firms can offer this salary level, they supplement the salary with equity in the firm. This is not necessarily a solution. If the company is successful, the shares will rise quickly and capital gains taxes will eat a significant part of the profit. There are other problems related to intellectual capital:

- Inventor-owned spin-off companies often suffer management problems a year or two into their existence, as scientists are often poor at managing ongoing business operations
- Existing companies (partners and potential receptors of research results) often do not have staff who understand the technology they are incorporating

Finding solutions to these problems is not easy. However, educating researchers, training professionals who already possess some of the critical skills, and generally improving management and business programs, including business training for science and engineering students, could help. In this regard, a greater challenge for Canada's commercialization performance is inadequate demand for talent. In general, Canadian businesses have a weak record for hiring people with the skills needed for the full range of commercialization activities. For example, Canadian managers are only half as likely as American managers to be graduates of business programs. Among financial professionals, 18 percent in the U.S. have a master's degree or higher, compared with only 8 percent in Canada. In addition, US, Japanese and German companies employ significantly more researchers per thousand employees than do Canadian firms (OECD 2005). Most tellingly, the wage premium for highly qualified personnel is lower in Canada than in competitor countries, particularly the U.S. The wages for highly skilled workers have not risen relative to the Canadian average in recent years (Morissette 2004). Placing highly qualified personnel — from all education disciplines — in business environments may spur demand by influencing the way firms create opportunities, encourage greater involvement by firms in research, increase the flow of knowledge to businesses from academia, and broaden understanding of international markets.

2.3 University-Firm Transfer via Communication Channels

The shift to a more knowledge-based economy embodies a number of changes in both the production and application of new scientific knowledge that have critical implications for the processes of knowledge transfer. One of the most significant of these changes involves the relation between the codified and tacit dimensions of knowledge. The dramatic expansion of the higher education sector and the increased funding for research associated with the postwar contract for science has generated substantial increases in scientific and research output which largely take the form of codified knowledge, transmitted relatively easily between researchers through published scientific papers and formal presentations. But as the stock of scientific knowledge has grown and become more widely accessible through electronic and other means, the relative economic value of that knowledge is diminished by its sheer abundance.

Often access to the key elements of the knowledge base depends upon the second or tacit dimension. Following the work of Polanyi (1962) and Nelson and Winter (1982), tacit knowledge refers to knowledge or insights which individuals acquire in the course of their scientific work that is ill-defined or uncodified and that they themselves cannot articulate fully. It is highly subjective and often varies from person to person. Furthermore, individuals or groups working together for the same firm or organization often develop a common base of tacit knowledge in the course of their research and production activities. This common base of tacit knowledge arises from the internal procedures and the heuristic techniques developed by firms in the process of applying new scientific knowledge to improve existing products and processes, or develop new ones. This underscores the centrality of learning for the innovative process. Lundvall and Johnson (1994), among others, argue that the knowledge frontier is moving so rapidly that access to, or control over, knowledge assets affords merely a fleeting competitive advantage. It may be more appropriate to describe the emerging paradigm as that of a "learning economy", rather than a "knowledge-based" one. They argue that innovation is a *social process* triggered by consumers (or users) who engage in a mutually beneficial dialogue and interaction with producers. In this way, users and producers actively *learn* from each other, by 'learning-through-interacting'. It involves a capacity for localized learning within firms, among firms that deal with each other, and between firms and the supporting infrastructure of research institutions, that comprise a critical component of the national or regional innovation system. Learning in this sense refers to the building of new competencies and the acquisition of new skills, not just gaining access to information or codified scientific knowledge. In tandem with this development, forms of knowledge that cannot be codified and transmitted electronically (tacit knowledge) increase in value, along with the ability to acquire and assess both codified and tacit forms of knowledge, in other words, the capacity for learning (Lundvall and Johnson 1994, and Ludvall 2004).

Analyzing this process from the perspective of the firm, Cohen and Levinthal (1990) argue that the process of knowledge-transfer from universities and research institutes is strongly conditioned by the capabilities of firms. Firms need to build an internal knowledge base and research capacity to effectively capture and deploy knowledge acquired from external sources. The ability to evaluate and utilize outside knowledge is largely a function of the level of prior, related knowledge within the firm, including basic skills or even a shared language, but may also include knowledge of the most recent scientific or technological developments in a given field. These abilities collectively constitute a firm's "*absorptive capacity*". The overlap between the firm's knowledge base and external research allows the firm to recognize potentially useful outside knowledge and use it to reconfigure and augment its existing knowledge base. Research shows that firms which conduct their own R&D are better able to use externally available information. This implies that the firm's absorptive capacity is created as a by-product of its own R&D investment. A key implication of this argument is that firms require a strong contingent of highly qualified research scientists and engineers as a precondition of their ability to absorb and assess scientific results, most frequently recruited from institutions of higher education. The members of this scientific and engineering labor force bring with them not only the knowledge base and research skills acquired in their university training, but often, more importantly, a network of academic contacts acquired during their university training. This underlines Pavitt's (1991) oft-repeated point that the most important source of knowledge transfer is person-embodied. Pavitt stresses that scientific and technological knowledge often remains tacit (i.e. embodied in the knowledge, skills and practices of the individual researcher). Building on the above argument, Pavitt maintains that the most effective mechanism for knowledge transfers between research institutions and commercial firms is through the flow of researchers. Policies that attempt to direct basic research towards specific goals or targets ignore the considerable indirect benefits, across a broad range of scientific fields, that result from the training of highly qualified personnel in institutions of higher education, and the kind of unplanned discoveries that invariably result from the conduct of basic research. This view reinforces the idea of knowledge as the capacity to acquire and apply research results, rather than as an end in itself. In this perspective, knowledge is the ability to put information to productive use. It provides the basis for understanding new ideas and discoveries and places them in a context that enables more rapid application. The development of such internalized or "personal knowledge" requires an extensive learning process. It is based on skills accumulated through experience and expertise. It also emphasizes the learning properties of individuals and organizations.

Of crucial importance are the role of skills, the networks of researchers, and the development of new capabilities on the part of actors and institutions in the innovation system. The findings of a number of recent studies employing both survey research methodology and qualitative interview techniques strongly reinforce the perspective that a key aspect of the process of knowledge transfer from universities and research institutes is through personal connections, and that the knowledge being transferred is thus "tacit" and "embodied". To deploy university-generated knowledge in a commercial setting, firms need to capture both its tacit, as well as its more explicit, or codified, component. Senker (1995) and Faulkner and Senker (1995) explored the relationship from the perspective of the innovating organization, focusing on its knowledge requirements and trying to develop a better understanding of the knowledge flows from academia to industry. While the findings differ slightly by industry, they conclude that partnering with universities contributes most to firm innovation through an exchange of tacit knowledge, and that the channels for communicating this knowledge are often informal. Such informal linkages are both a precursor and a successor to formal linkages, and many useful exchanges of research materials or access to equipment take place through non-contractual barter arrangements. The flexibility inherent in such arrangements promotes the goodwill between partners that supports more formal linkages.

2.4 University-Firm Transfer via Research Alliances & Collaborations

The historical conceptualization of innovation, the linear model, places universities at the earliest stage of knowledge creation – the so-called basic research, which is removed from firms' more applied R&D (Deeds and Rothaermel 2003). Yet, in practice, university research involves a rich mix of scientific discovery, clinical trials, beta testing, and prototype development, and industry linkages to university-based research are demonstrated to be complementary to firms' R&D strategies (Bercovitz and Feldman 2006). While many university breakthroughs address fundamental scientific questions, they may simultaneously provide practical implications for current commercial products (Stokes 1997). Cohen, Nelson, and Walsh (2002) find that more than one-third of industrial R&D managers use university research as an input. The importance of such linkages varies considerably among industry sectors; however, generally university-industry partnerships are more important in sectors where science plays a major role, as is the case in the biotechnology and information technology fields (Hall 2005). The Yale and Carnegie Mellon Surveys of R&D labs have tended to emphasize industry differences, noting that pharmaceutical firms spend the greatest percentage of sales on R&D and tend to use university research disproportionately (Cohen et al. 2002; Klevorick et al. 1995).

Research linkages between the private sector and universities in Canada are strong by international standards. Canada is well ahead of other G8 countries with over 10% of university research being funded by the private sector (see Figure 3). However, in absolute terms, private sector funding still plays only a small role as a source of university research funding. Typically, expenditure on university-performed research accounts for a very small percentage of private sector R&D budgets. According to the OECD, it does not exceed 2 to 3% of these budgets in the member countries. Surprisingly, Canada, with 5.8% in 1996 (more than twice the level of 1985), is among the leaders in the OECD. In 1999, universities received Can. $18.9 million in royalties from licensing to other firms. Although they do not measure collaboration, these payments are an indicator of linkages between universities and private sector firms. They can be used as a proxy for the size of the knowledge transfer from universities to industry.

From the firm's perspective, it is generally accepted that collaboration with universities is primarily a valuable complement to, and extension of, the firm's in-house research, and not a way to replace it. Access to the outside knowledge, expertise and awareness of leading-edge research provides an incentive for a firm to seek collaboration with a university. As one industry research manager expressed it (Conference Board of Canada 2001), "The university shows us the frontier. Their research enables the firm to see that the ideal solutions are chosen from among the array of next-best solutions." Clearly, reducing the product's time to market is not the private sector's prime driver for collaboration with universities. Universities are the only institutions that firms collaborate with mostly for high value-added reasons. According to Schaan and Nemes (2002), firms involved in collaboration with universities are 34% more likely to mention the need for access to R&D, than firms not involved in such collaboration (Zieminski and Warda 1999). The fact that collaborative R&D projects involving universities are frequently supported by matching funding from various levels of government, thus reducing the cost of doing research, is also important. Firms involved in collaboration with universities are 27% more likely to mention the need to share costs as a reason for their involvement in collaborative research than are firms that do not collaborate with universities. Table 7 highlights some of the primary drivers for partner selection in collaborations, partnerships, and alliances.

For the university, interest in collaboration is stimulated by three factors. Two relate to the financial pressures resulting from growing public demand to see economic value from the public investment in university research, and from the fact that a larger share of public funding of university research is contingent on finding private sector co-funders. The third factor is the interest of university researchers in seeing that the results of their work are relevant and being applied by industry.

When examining the key obstacles to collaboration (Table 8), it is clear that lack of communication—on both sides of the partnership—resulting in a low level of awareness and understanding of each other's needs and capabilities is still firmly rooted, particularly in the university system. Both company and university managers see the low level of awareness as an important reason why collaboration may not occur. Another factor is the lack of adequate incentives for university researchers to engage in collaborative research with industry. Many universities have no formal mechanisms to reward their researchers who are involved in collaboration. This may be a minor irritant for established faculty members, but for young researchers collaboration can easily get in the way of their careers within academia. Consequently, mechanisms promoting collaboration need to include incentives for university researchers. Often times however, such collaborations are accompanied by significant financial contributions that may pay for salaries, capital equipment, or general operating expenses. In some schools or faculty, there will of course be prestige associated with having extensive industry collaborations and networks.

It is interesting to note that the seeming incompatibility of the basic research focus of universities and their culture with the approach of businesses is important, but does not prevent university–industry collaboration from growing. It is often the case that the advantages that both partners see in collaboration are more important than the potential problems. Given that these problems are well-known, especially to those with experience in collaboration, both parties can prepare themselves in advance to avoid potential clashes. In these situations, then, when experienced managers are involved, the obstacles tend to arise from more practical issues. "Despite common perceptions, the barriers to effective collaborative research are typically not related to technical capabilities nor differences in motivation, perspective, or culture between business and universities," said Brian Guthrie, Director, Innovation and Knowledge Management. "The major barriers are turnover of staff—especially student researchers who do much of the work—and the so-called "institutional fog" of rules and regulations surrounding intellectual property, contracts and overhead costs" (Schaan and Nemes 2002). Unfortunately, although firms tend to cite restrictive intellectual property (IP) policies as an obstacle, there are reasons for universities' restrictive IP policies. For example, one of the principle goals of university research is to disseminate findings in order to share knowledge. Collaborative research that prohibits dissemination may undermine this goal.

It is certainly recognized that the key benefits of collaboration between business and publicly-funded researchers include developing new programs and disciplines, launching new business lines, and creating new companies. As such, there has been a significant interest in developing mechanisms to promote and foster these relationships. For example, to help increase the interaction between universities, industry, and government, the Canadian government has established the Networks of Centres of Excellence (NCE) program. The NCE program has been operating successfully for fifteen years and has been the subject of many studies (e.g. Fisher et al 2001). In February

1997, the government established the NCE as a permanent program. Two years later, it increased the program's budget by $30 million bringing it to $77.4 million per year. Currently, three Canadian federal granting agencies – the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council of Canada (SSHRC) – and Industry Canada combine their efforts to support and oversee the NCE initiative.

Networks of Centres of Excellence are unique partnerships among universities, industry, government, and not-for-profit organizations aimed at turning Canadian research and entrepreneurial talent into economic and social benefits for all Canadians. These nation-wide, multidisciplinary and multi-sectoral research partnerships connect excellent research with industrial know-how and strategic investment.

In 2004-2005, 830 companies, 266 provincial and federal government departments and agencies, 51 hospitals, 194 universities, and more than 365 other organizations from Canada and abroad were involved in the NCE program. The active involvement of Canadian industry provides stimulating training environments and employment opportunities for students. In 2004-2005, the NCEs attracted over $71 million in outside investments. This includes more than $28 million by participating private-sector companies. In addition, the NCE reports that, about 88 percent of network graduates are successful at finding jobs.

In a similar manner, the government of Ontario established the Ontario Centres of Excellence (OCE) program to strengthen research linkages between academia and industry and promote economic development. The OCE's focus to achieve these goals is to support directed research, commercialization of new technology and the training and development of highly qualified personnel through which knowledge may be transferred. The OCE program currently consists of 5 centers including: 1) the Centre for Energy, 2) Communications and Information Technology Ontario (CITO), 3) Centre for Research in Earth and Space Technology (CRESTech), 4) Materials and Manufacturing Ontario (MMO) and 5) Photonics Research Ontario (PRO).

These five areas match critical sectors of Ontario business and industry. They are sectors in which Ontario must excel in order to be competitive in global markets – to get past the "tipping point" to achieve innovation-based economic growth in Ontario. In addition to supporting these objectives, the Conference Board of Canada (2006) report: "Lessons in Public-Private Research Collaboration: Improving Interactions between Individuals" outlines four opportunities for action to continue to build this knowledge:

- Help publicly funded researchers manage students: Although students play a critical role, research advisors currently have few tools and resources to select and retain those students with both the required technical skills and the ability to thrive in a collaborative environment
- Engage executive champions: Projects without executive-level support in both universities and corporations become vulnerable when difficulties arise on either side of the partnership
- Improve the clarity of university requirements for collaboration: Ongoing efforts to improve clarity of institutional rules for intellectual property, licensing, and overhead costs should be continued
- Provide tax incentives to businesses collaborating with university researchers: In addition to matching research funds, the federal government could provide tax credits to businesses that make large or long-term investments in collaborative research projects with universities

The Government of Ontario has also helped bring academia and industry together in such vehicles as clusters. For example, the Medical and Related Sciences (MaRS) center; is a convergence innovation center dedicated to accelerating the commercialization of new ideas and new technologies by fostering the coming together of capital, science, and business (see also Section 4.3). Located in downtown Toronto, MaRS is well situated at the heart of many world-renowned teaching and research hospitals, the University of Toronto, Canada's financial core and the Ontario legislature. The concept originated in 2000, however, the first tenants of the facility were not in place until 2005. The facility currently houses University research, early and later stage biotechnology companies, business development offices (for many of the world's largest pharmaceutical companies), commercialization offices, and a variety of federal, provincial, and local biotechnology institutes and associations. Currently, the facility construction and tenancy is still not completed. Like many of Ontario's most recent initiatives, it will take time to determine how successful the facility is in stimulating university–firm knowledge transfer and, more importantly, the impact of the center in stimulating true local and provincial economic development.

2.5 Conflicts of Interest at the University-Firm interface

In the previous sections we have concentrated on reviewing many of the primary channels through which knowledge may be transferred from the university to industry. During the discussion we have touched on other important underlying issues, such as conflict of interest, that can have a dramatic effect on the way knowledge is transferred, or, more importantly, whether it is done or not. Because this is such an important area, we have included a general discussion of some of the major conflicts that may be encountered, in order to give the reader a greater appreciation of this issue, especially in light of policy development. It may be intuitive, but it is by no means comprehensive.

Conflicts of interest may arise when the two cultures of academia and industry are attempting to concurrently fulfill their missions and objectives. As the federal levels of total research funding decrease, and the technological competitiveness of a country continues to be threatened, the benefits of university-industry partnerships have become more attractive. Some personnel in academia fear that, as industry provides more funding for research and equipment for university laboratories, industry may attempt to influence the university curriculum.

Universities can study the organizational cultures of successful companies, but the industrial knowledge that they gain does not necessarily involve the best techniques and practices more suitable to the production of new innovations. Similar to businesses, universities have to admit the limits of their knowledge, and they can no longer assume that their research will produce a product that leads to a better society. In contrast, the academic culture may be a model for business, as industry adapts to a knowledge-based economy (Allan 2000).

Some universities have been accused of conflicts of interest by a few sectors that are not on campus. The conflict develops when some sectors attempt to shield academic research from all outside influences, and keep universities in the ivory tower (Killoren 1989). In contrast, some interests want universities to change academic curriculum to meet industrial needs, and grant exclusive licensing and patent rights to industrial sponsors for university innovations. Concurrently, universities cannot afford to distance themselves from the needs of other sectors because the institutions need the financial support from those sectors. They must combine the commercialization of their research with their missions of teaching and research, which is a difficult challenge for academic institutions, because industry usually funds more applied research and less basic research (Sparks 1985). Universities play a major role in pushing their technologies into the commercial sector where they benefit all of the sectors (Killoren 1989).

Creating internal university policies to encourage researcher participation in industrial efforts is important, because the social and organizational structures and environments of universities and corporations are often in conflict. The university's tradition of rewarding publication of basic research conflicts with the needs of industry to delay publications of university-industry research projects (Killoren 1989).

Research partnerships with universities have provided industry with processes and technologies, and have shortened industry's learning process within R&D companies. Industry has gained access to students and faculty, and has the opportunity to hire graduate students with experience in specific technologies. University-industry partnerships have allowed industry to maximize their educational efforts through scholarships, fellowships, internships, and sponsored research (Sparks 1985). Some faculty conflicts that occur with multi-party university-industry relationships are based on the fact that, even though the relationship is entrepreneurial-oriented, some of the colleagues will have opposing views as to how the commercialization of their research should be conducted. A 1995 NSF Report by Lee detailed faculty responses to university technology transfer policies concerning university-industry partnerships (Lee 1995). Lee's study revealed that U.S. faculty in the 1990s believed they were more accepting of research policy awarding credits on research leading to patentable inventions, and approving applied industrial research as appropriate in the university, than they were in the 1980s. In addition, Lee reported that faculty strongly supported their university's active participation in regional economic development, and commercialization of university research. Similarly, the faculty endorsed an institutional policy that promotes faculty consulting for private industry, but faculty members were reluctant to endorse policies designed to privatize academic research. While 56 percent refused to go along with involving their university in start-up assistance to new technology-based firms, nearly 74 percent refused to support their university becoming involved in business partnerships with private firms (Lee 1995). An additional finding in Lee's research was the perceived fear of close university-industry collaboration, which has shaped faculty attitudes toward technology transfer. Faculty fears about collaborations between university and industry were the major factors in the shaping of faculty attitudes toward university technology transfer. Faculty support for university technology transfer appeared to be connected to the assumption that close university-industry cooperation will improve the core values of the research university. For faculty, the less the fear of intrusion, the greater the support for technology transfer and conversely, the greater the fear of intrusion, the less support (Lee 1995).

Another controversy arises from the different missions and objectives of the two cultures. Industrial research is based on the need for specific industrial results to solve specific needs, and developed under secrecy from competitors, while university research is based on scientific inquiry, with open communications and public access to academic research results (Muir 1997). Profit from the results of academic research is another concern among some sectors. Some argue that profit diverts the attention of faculty from teaching and encourages the delay of research publications. They fear that university faculty with industrial support for research, consulting projects with industry, and as equity participants, may compromise their responsibilities to the public. Some sectors argue that the goal of universities as centers of research, teaching, and service may be compromised by financial gain from their research, and that the research may favor short-term industrial interests (Muir 1997). Sparks reported that university research leans toward specialization for each institution in specific technological fields, with some research projects requiring large investments in equipment. New equipment and facilities attract qualified academics and highly qualified research personnel, lowers industrial sponsorship costs, and allows the sharing of basic, applied, and development research (Sparks 1985). Most of the basic research in the U.S. is carried out in universities, and improving relationships between the two cultures ensures that industry uses the results of basic research in improving their competitive advantage. Concurrently, industry provides universities with direction for their research, which may eventually fulfill the needs of the public. Students and faculty generally adopt values of their environment, which is the university, and of the sponsors of their research, which has largely been the federal government (Sparks 1985). Therefore, if students are to be employed by industry, the industrial culture can be introduced into the university environment. Concurrently, universities need to be willing to perform research that industry can use, and industry must be willing to use the research and technologies that are created at universities. Frequent and personal involvement between the university researcher and industry personnel is necessary in order to accommodate the university's research strength with industry's need for improved products (Sparks 1985).

There must be flexibility in the relationship between industry and the university in order to work out problems concerning ownership of intellectual property, confidentiality of proprietary data, authorship for technical journals, and the selection of personnel who present the research and journal articles at the technical conferences. Additionally, universities have often been accused of not adhering to research schedules and of not recognizing the time constraints of business. In contrast, universities have reported that they are business-oriented, use strategic planning, and have adhered to timely projects (Sparks 1985).

Faculty attitudes toward university technology transfer policies vary with several institutional and organizational characteristics. The differences in faculty responses to various institutional alternatives are a function of different academic disciplines (Lee 1995). Faculty in the applied fields of chemical and electrical engineering, computer science, and material science are much more supportive of various technology transfer policies than faculty in the basic or social sciences (Lee 1995). The pressure for external research grants plays an important role in the shaping of whether a faculty member is favorably or unfavorably disposed to various technology transfer policies. Faculty members who feel pressured to seek external grants reported more favorable attitudes towards technology transfer policies. While R&D expenditures have but a moderate effect on faculty technology transfer attitudes, the rankings of institutional prestige reflected an unexpected pattern. The support for technology transfer was stronger among faculty in institutions ranked in the lower quartiles, and faculty ranked in the top quartile were less supportive of various technology transfer policies (Lee 1995).

In summary, conflict occurs when two different cultures with different missions and objectives attempt to form research partnerships. Some interests have fears that collaboration between universities and industry may cause industry to control academic curriculum, delay academic publications, and cater to industrial research that encompasses more applied and development research than basic research. The majority of faculty members have fears about the collaborative effort between industry and universities, while industry has fears over intellectual property ownership issues, bureaucratic administrations, confidentiality of proprietary data, authorship of professional papers, and the ability of universities to adhere to deadlines. Universities and companies benefit, as well as the public when universities produce quality basic research that can be advanced by industrial researchers for use in the market. Faculty that choose to be employed in an ERC understand that some of their colleagues may object to their performing of research that has been financed by industry, but the faculty eventually publish their research in the professional journals, and satisfy their academic and industrial colleagues.

3.0 Knowledge Transfer at the Government-Firm Interface

In addition to corporations and universities, government laboratories perform basic and applied publicly-funded research. Established with the goal of advancing science and securing economic and national defense interests government-owned laboratories, regardless if they are government-operated or contracted to outside operators which is increasingly the case, are considered a key component of most national science and innovation systems (Nelson and Rosenberg 1993).

The engagement of government laboratories with industry has a long-standing history. For example, the National Institute of Standards and Technology (NIST), the United States federal government's first physical science research laboratory, has been collaborating with industry since 1905. The foundations for national research institutions were laid out in the nineteenth and early twentieth centuries, especially in the pre- and post-World War II period when European and North American governments increasingly set up government laboratories to promote large scale R&D programs (Heim 1988). Mission-oriented assignments such as the Manhattan Project in the U.S., or substantial scientific projects like the nuclear energy and space programs, led to the establishment of many new laboratories, and the expansion of existing government-owned laboratories. The capital expenditures, facilities, and human resources necessary, exceeded the capabilities or resources of private sector research organizations. In addition to scale, security issues, in particular associated with defense-related R&D, and mission and regulatory requirements, which demand from some agencies, such as the Food and Drug Administration, that they carry out a certain amount of R&D to fulfill their mandate and ensure the impartiality and fairness in the market, are other rationales that explain the need for national laboratories. The contribution of government laboratories to innovation and technological progress are widely recognized, however, despite the magnitude of public funding and the potential impact on economic development, they have attracted “little academic scrutiny” (Jaffe and Lerner 2001).

More recently national laboratories have been subject to drastic changes in legislation and regulatory framework concerning technology and skill transfers, in order to support civilian industry (Rood 2000). In the United States a series of technology transfer-related legislation was enacted in the 1980s to provide better access to federally-funded R&D. In particular the Stevenson-Wydler Technology Innovation Act, which required the installation of technology transfer offices in federal laboratories, and the Federal Technology Transfer Act, which allows federal and defense laboratory directors to enter into cooperative research and development agreements (CRADAs) with private partners, appear to have contributed considerably to an increase in industrial patents and company-financed R&D (Adams *et al.* 2003). In addition, the National Cooperative Research Act that eased antitrust criteria for research consortia of companies led to further cooperative research between the public and private sector. One important example is the SEMANTECH (SEmiconductor MAnufacturing TECHnology) consortium initiated in 1986 with the aim of strengthening the U.S. semiconductor industry, which at that time was rapidly losing ground to other national economies. This industry-government cooperation is just one instance of how competitive R&D consortia are established, and are efficient in restructuring an industry that is losing competitiveness (Browning et al. 1995).

The political, economic, and technological changes that have occurred over the past few decades have also initiated a reassessment process, which has led to a radical restructuring of the regulatory framework of national laboratories in many countries. This has resulted in an increased level of awareness concerning the technology and skill transfer functions, and their impact on the utilization and exploitation of national scientific and technological resources. Some of these interrelated trends and series of events include the end of the Cold War, which consequently resulted in R&D funding cutbacks for military research facilities. The military-industrial complex, which in some countries has been instrumental in the development and advancement of whole industries in the past, had to be reorganized towards the commercial market. This included the application of dual uses for its technologies and promoting its products to a multitude of customers rather than only to the Defense Department.

Increased international competition due to globalization is another reason why national science and technology, and in particular government laboratories, have become the focus of S&T policy initiatives in the past decades. High-technology sectors, which are knowledge intensive and complex in their structure, conduct more R&D than traditional industries and pay higher wages, which makes them the drivers of the modern economy. Although national laboratories still play a significant role in this economic structure their role has changed significantly. Basic research funding is now often substituted with applied research funding and the commercialization of science becomes the focal point. Rather than undertaking individual research tasks, laboratories are now embedded in a system of collaboration between public and private sector innovation systems. CRADAs are one of several technology-based industry-government collaboration tools available in the United States. Other types of collaboration include patent licensing, technical assistance, materials and other technical standards development, and use of instrumentation or other equipment. In addition, as federal funding for basic research has decreased, funding for national technology programs such as technology development funds or technical assistance programs, have been increasing.

Different models and institutional practices exist with regards to the extent and application of government laboratories for securing national competitiveness and to supporting industry in various countries. For example, in Germany a distinct network of laboratories has separated basic science, which is carried out in Max Planck Institutes, and applied research, which is conducted at the Fraunhofer Laboratories and is aimed to support industry.

Regardless of the mechanism, it is fairly clear that most government research is or should be focused on supporting both fundamental research and also the translation of this research through industry support and added value services including information and commercialization services. Although the above summary is largely based on American experience, the issues tend to be based on fundamentals and therefore broadly applicable from an international perspective. In a fairly recent survey conducted by the Conference Board of Canada (Warda 1999) focused on improving government and private sector collaboration, they asked the following question:

> *…we talked to the private sector about whether and under what circumstances they would be interested in collaboration with government labs in the future. In return, we received a robust vision of the lab of the future. A future government lab must be a center of excellence, where world-class applied research in the area of its mandate is being carried out*

From the results they concluded that in the future, government labs must encompass the following attributes to ensure effective collaboration and knowledge transfer from government to the private sector:

1. Generator of excellent research
2. Performer of multi-disciplinary research
3. Catalyst of collaborative linkages
4. Flexible/empowered
5. Committed to long-term research

Below we take a more detailed look at the effectiveness and impact of government-firm collaboration and knowledge transfer in a Canadian setting.

3.1 Government-Firm Transfer and Government Labs

Along with supporting private sector research, the federal government devotes significant resources to developing new technologies within federal labs. In Canada, the National Research Council (NRC) is the premier government organization for research and development. It has a fairly broad mandate (Table 9) that encompasses 20 institutes and national programs located across Canada, which span a wide variety of disciplines and offer a broad array of services to meet these objectives. The NRC institutes and programs are organized into five key areas: 1) Life Sciences 2) Physical Sciences, 3) Engineering, 4) Technology and Industry Support, and 5) Corporate Services. This framework focuses on supporting and promoting research excellence, collaborations with companies and communities across Canada, and leadership in building the national R&D infrastructure and the Canadian system of innovation. As such, many of the general changes in the role of government labs described above are largely reflected in the current mandate of the NRC. On paper therefore, the policies of Canada's premiere national government laboratory appears to be well aligned with the current thought on this subject, although no clear scorecard exists as to how effective the policies are. It should be noted that the NRC is one of many important government labs focused on R&D and technology development that will be described below (Section 3.2).

The basic technology research undertaken by government agencies such as the NRC tends to involve long-term, high-risk projects with potentially high returns for society as a whole. As in the case of other government programs, there is need for the development of clear objectives that are based on the identification of market inadequacies and that are reasonable given the resources and competencies of the department or agency. Public institutions, however, are well suited for basic technology research, or what one recent report describes as a "need-driven, creative research on new kinds of materials, new processes or ways of exploring or measuring, and new ways of doing and making things"(Branscomb and Keller, 1998). The unique contribution Canadian government laboratories, with their strong applied research capacity make in these areas is recognized by Canadian firms (Warda 1999). Basic technology is a "grey area" which is outside the fundamental research that primarily occupies academic institutions, and also outside the commercial-oriented research that is the primary focus of firms subject to competitive pressures and increasingly compressed product development cycles. As a recent U.S. study warns, without direct government involvement, there is a danger of serious underinvestment in this critical area of innovative activity (Branscomb and Keller, 1998).

Trying to assess the extent and effectiveness of collaboration between industry and federal government laboratories and hence knowledge transfer, is not easy. There is no single source of data on collaboration, and data collected by various departments are not always uniform in methodology. Based on available information, the Conference Board of Canada, as part of its second annual innovation report, estimated in 1999 that the amount that industry spends on collaborative projects involving government labs as being in the range of $100 million to $150 million annually. More recent data available on the NRC website indicate that, in 2003-2004, the NRC alone signed 411 new collaborative agreements with Canadian partners, totaling more than $106M. Currently, the NRC has 1,026 active collaborations, of which NRC was engaged in a total of 462 formal international agreements with private, public and university partners. NRC also has a growing track record of new company creation, establishing over 60 new companies in a variety of sectors since 1995. These firms have already generated employment for some 500 Canadians, sales in excess of $300 million and have attracted private-sector investments of over $375 million. In addition, the limited data show that federal government labs in Canada are doing fairly well at transferring knowledge to the private sector. In 1993, total royalties received by federal laboratories in the United States amounted to around U.S. $19 million (Abramson et al. 1997). In comparison, in 1998, royalties from patents held by federal government labs in Canada amounted to $7 million (CDN), of which the National Research Council alone accounted for $1.7 million (Ref 43 CBC-1999). In addition, one fairly recent report by the Government of Canada (1999) observes that technology developed at two federal research institutions, the National Research Council and the Communications Research Centre (CRC), have alone given rise to 114 spin-off companies with about 11,600 employees and 1996 sales of around $2 billion. These numbers are primarily reflective of the significant activity in the information and communication technologies (ICT) sector relative to other areas of scientific research during that time period and moving forward.

Why Collaborate with Government Labs? Firms tend to seek collaboration with federal government laboratories primarily to gain access to R&D and share costs (Table 7). In this regard, the Conference Board of Canada (2000) has identified a number of specific features that firms value in selecting federal government laboratories as business partners, these include:

- Access to skills and knowledge
- Strong applied research capacity
- Ability to manage large projects
- Willingness to collaborate
- Clear roles and responsibilities
- International science linkages

Although there is much similarity between various institutions, there are many reasons why firms would choose to partner with government labs over other federally funded institutions such as universities. First, there is a feeling that government labs understand industry needs better than universities do. Their willingness to partner is greater, and they seem to be more willing to structure collaborative agreements in a way that is suitable for business partners. In addition, government labs have a stronger applied research capability, supported by access to specialized physical facilities and equipment, and a specialized workforce—scientists, researchers, technicians, and technologists. Industry also sees government labs as having greater ability than universities to work with business on large research projects.

The obstacles to more collaboration between firms and federal government laboratories often cited by firms are: stability of funding, clarity of the lab's mandate, and maintenance of the research focus (Warda 1999). Effective labs flourish in a stable and transparent policy environment because there is a greater stability and predictability to the overriding funding base. This in turn creates a more attractive environment for highly qualified personnel to develop their careers. This stability will allow labs to develop entrepreneurial behavior and allow them to accept risk and improve protection of intellectual property arising from collaborative research, and become more adept at communicating and selling their scientific knowledge to the ultimate constituent-society. Collaboration is one of the most effective tools for technology transfer and therefore needs to be promoted.

Conflict of interest however arises when governments seek to replace core program funding (which supports fundamental research) with revenue generated from research activities. In such cases, the government is removing focus from targeted basic and mission-oriented research in favor of short-term commercial research, which ultimately competes with industry. As such, self-financing strategies should be selected carefully and focused on areas where they do not compete with the private sector.

Technology transfer from government labs. Although many of the large government research labs have technology transfer offices and policies regarding commercialization, there is a paucity of academic literature describing this area. It has been assumed that the same issues encountered in university TTOs are also encountered in government and provincial research laboratories. The government offices might, however, operate at a more bureaucratic level. Clearly more research is required in this area.

3.2 Government-Firm Transfer and the National Innovation System

The national innovation system, a term used to describe both the Canadian S&T institutions and their various linkages, creates, disseminates and exploits the knowledge that fuels a productive economy, which, in turn, makes a prosperous society possible. To function effectively and to realize these social objectives, this system depends on the complementary strengths of three key sectors: the private sector, universities and other not-for-profit institutions, and governments. Each of these sectors has a unique role to play in the system but, in terms of the federal government, it has subsequently identified and assigned itself the dual role of performer and facilitator of research (Government of Canada 1996):

> In addition to [its] traditional activities, the government will increasingly emphasize a new role: that of information analyst, knowledge disseminator and network builder - critical elements in the successful evolution of the Canadian innovation system.

The federal government fulfills these roles both by performing research, using intramural capabilities and facilities, and by funding extramural research and fostering partnerships among the various research-performing sectors. As such, innovation systems are essentially national in orientation because national institutions finance and equip them, but they are largely organized and executed at the local level. Canada's national innovation system thus comprises a number of geographically-concentrated sectoral clusters devoted to innovation.

In their role as leaders, governments can promote the dissemination of fundamental research findings, which have many of the characteristics of a public good and should be widely and freely disseminated. They can help reduce the transactions costs and remove the barriers, including the cultural barriers that prevent fruitful collaboration among researchers in different disciplines and sectors. In addition, governments can exploit the economies from a collective approach to gathering information on, and evaluating, new technologies. The contribution governments can make by distributing information that help potential users form better expectations about the profitability of adopting new technologies is discussed in a recent paper by Boyer et al. (1998). Studies suggest that better informed producers are, in turn, likely to invest more in the adoption of new technologies (Saha et al. 1994). As such Hirshorn et al. (2000) suggest that governments may therefore significantly strengthen the operation of the innovation system through activities such as:

- the development of an infrastructure that facilitates information-sharing and networking among researchers in industry, government, and universities
- the establishment of mechanisms that facilitate private and private/public cooperation in technology development, and that allow firms to benefit from economies of scale and scope, along with available synergies from joint R&D activities
- the creation of vehicles to promote the transfer of information on new technologies, including both the results of innovative activity that are in the public domain, and information on advanced technologies that can be acquired through machinery and equipment purchases
- the dissemination of information on the types of organizational arrangements and human resource and management practices that will help position firms for success in a knowledge-based economy

In this context, the examples presented below represent but a "selection" of leading Canadian multi-partner or multi-stakeholder collaboration mechanisms. More examples can be found. These entities, although initiated by government (federal and provincial), are now self-sustaining and have contributed to the growth in innovation nationwide. Specifically, they have been successful in attracting the participation of many private sector companies, universities, and government labs, creating not only effective collaborations, but enabling the players to become a large network for innovation:

- The Networks Centres of Excellence (NCE) program facilitates collaboration among leading researchers in universities, industry, and government and helps accelerate the commercialization of research. In 1997/98, 463 companies, more than 100 provincial and federal government department and agencies, 44 hospitals, 61 universities, and more than 200 other organizations were involved in the NCE program

- The Canada Foundation for Innovation (CFI), a government-funded corporation, provides grants for research infrastructure in universities, colleges, and teaching hospitals - such as the development of national online databases that facilitate access to academic articles and their use both in teaching and research
- CANARIE Inc. promotes the development of the crucial communications infrastructure of a knowledge-based economy. This private non-profit organization, which is supported by Industry Canada, has 120 members and over 500 project partners, and focuses on accelerating advanced Internet development and maintaining Canada's leadership in the use of information technology
- The National Research Council's Industrial Research Assistance Program (IRAP), provides technology advisors to help Canadian companies develop and exploit advanced technology. IRAP's network of 260 advisors provide technical advice to over 10,000 companies per year
- The Industrial Research Fellowship program, another component of IRAP, encourages recent Ph.D. graduates in science and engineering to gain experience in Canadian industry. It serves to help Canadian firms develop a research capacity and to build links between businesses and universities
- Industry Canada is an important disseminator of information on technology developments and opportunities. Its STRATEGIS Website includes, for example: distCovery, a database of more than 35,000 licensable technologies around the world; the Canadian Technology Gateway, a listing of Science and technology activities and capabilities in Canada; and Trans- Forum, a technology transfer tool for universities and colleges
- Genome Canada is a not-for-profit corporation that acts as the primary funding and information resource relating to genomics and proteomics in Canada. Dedicated to developing and implementing a national strategy in genomics and proteomics research for the benefit of all Canadians, it has received $600 million in funding from the Government of Canada, which, when combined with funding from other partners, totals $1.25 billion in more than 100 innovative research projects and sophisticated science and technology platforms
- *TRLabs* is Canada's largest not-for-profit information and communications technology research consortium, and is internationally recognized as a model for industry–university–government collaboration. TR*Labs* operates five laboratories in data networking, network access, network systems, photonics and wireless communications. Industry–university–government lab collaboration is the cornerstone of the TR*Labs* research program. The roles and responsibilities of each partner are clear. Industry sets the direction of the program, specifying general areas of interest, and contributes funding, equipment and research personnel. Universities contribute professors and students, who develop and execute original research projects within these strategic areas. Government contributes funding and the expertise of their research talent, with the aim of creating a critical mass of information and communications technology talent, and business. The TR*Labs* collaborative research program bridges this gap to produce original, industry-relevant pre-competitive research that looks three to seven years into the future (See Figure 3 for example of achievements)

The OECD (OECD-draft) has included a number of Canadian initiatives in its list of "best -practice policies and programs" to promote a knowledge-based economy. The Centres of Excellence program, for example, has been singled out for establishing links between industry and science, and the IRAP Fellowship program has been cited for promoting personnel and tacit knowledge transfer between universities and industry. The OECD points to the NRC's IRAP program and Strategis as examples of initiatives to promote the diffusion of technologies. Since programs in this area focus on improving aspects of the economy's innovative capacity, it is inappropriate to assess them simply by examining their contribution to increasing R&D investment. In the case of IRAP, for example, criticisms that have been made about the difficulty of applying a narrow incrementality test do not represent a substantive indictment. Applying their broader criteria, Lipsey and Carlaw

(1998) find that there is "a very strong case for regarding IRAP as a success".

Among other considerations, it is significant that IRAP focused on filling an important gap - i.e. developing the tacit knowledge base of firms with weak technological capabilities; spreading support spread among a number of small-scale initiatives; and, as IRAP was administered by the National Research Council, operations were removed from the political limelight. At the same time, however, policymakers need to be sensitive to the risks associated with overly ambitious programs to promote Canada's innovation system. Part of the appeal of existing programs is that government is mainly acting as a facilitator or catalyst, and public expenditures are relatively modest. With larger program expenditures, there is a danger that marginal benefits will be less than those that could be achieved by reducing tax rates. In addition, U.S. research has pointed to the potentially high costs of policies which promote collaboration between public and private sector researchers by offering firms intellectual property rights over publicly funded R&D. Technological change could be adversely affected if government policies restrict access to publicly-supported research results with potentially wide application.

3.3 Government-Firm Transfer and Provincial (Ontario) Government Labs

The reasons that drive firms' collaboration with government labs at the provincial level are much the same as those that drive collaboration with federal government labs. The Conference Board of Canada (2000) research, however, indicates that there is one important difference related to a firms need to enter new markets. In such cases, firms may view provincial labs and institutions as stepping stones in establishing a foothold for expansion into provinces that were not previously considered to be markets for the company. Becoming involved in collaboration with provincial labs is thus viewed as a tool for obtaining competitive information on potential clients and distribution channels. More importantly, provincial labs and institutions may offer tangible *business incubation capabilities*, i.e., they know the requirements of the market in the province, and they provide linkages to key people and help in finding sources of financial support. These are non-technical services that firms view as helpful in gaining access to new distribution channels outside of the province, or in entering new markets. As such, provincial labs and other specialized institutions may serve as important catalysts in stimulating networking and collaboration opportunities, leading to increased knowledge transfer between the public and private sectors. More importantly, these labs and institutions may serve as important ambassadors to the international scientific community and private sector firms, promoting international trade and cross border knowledge transfer.

In this regard the Ontario provincial government has been quite actively engaged in creating many important institutes and initiatives to help stimulate innovation and support knowledge transfer. Table 10 lists many of the major initiatives, however, it should also be noted that many other initiatives of smaller scale have also been sponsored at some level by the Ministry of Research and Innovation. For many of these initiatives, it is still too early to determine how effective they have been in stimulating knowledge transfer to industry and serving other broad mandates.

4.0 Knowledge Transfer and the Firm

It is important to remember that innovation also encompasses incremental improvements to existing products or processes. Indeed, the vast majority of innovation may be attributed to minor improvements, adjustments, and refinements to existing products, manufacturing process and organizational practices. While not particularly glamorous, these activities add economic value and, in sum, provide a basis for sustained competitive advantage. In addition, while science is important to innovation, new ideas are frequently suggested by individuals who work on the shop floor, who use products, and who supply machinery or materials. Indeed, innovation spans the spectrum of industrial activity. The view that innovation is limited to new science-based or so called high technology industries is myopic, as it ignores the equally transformative nature of innovation in existing mature industries that are already in place.

It is not surprising therefore that knowledge transfer between firms, specifically through the development of inter-firm relations is not new. In fact, they may easily be traced back to works such as Adam Smith's eighteenth-century treatise on the division of labour between firms, which focused on productive efficiencies and specialization. In these relationships, the specialization of firms often requires the outsourcing of the production of inputs upwards in the supply chain, and the distribution and use of products downwards, all of which require inter-organizational relations and networks to exist. In accomplishing this through collaboration, both parties must adjust in order to accommodate the utilization of complementary resources. Although desirable, this does not always result in a perfect balance of dependencies and of mutual value between firms. As such issues associated with conflict of interest, rivalry, and firm competition are embedded in classical business relationships, either blatantly or subtly, they require careful management to ensure an effective transfer of knowledge. In today's world, fast developments in technology and globalization have led to increased opportunities for international alliances, and an upsurge in the interest in inter-firm relations

With the emerging complexity of technology and rapidly changing markets, competition has increasingly become a 'race to the market' with new or improved products. To have any chance of winning such a race, firms need to shed activities that are not part of the core competencies that constitute competitive advantage, as much as strategically possible. Other complementary competences must then be sought from outside partners. Such outside sourcing also maximizes the flexibility in configurations of activities that is needed under rapid change. For example, in order to reduce the development times of new products and help maintain customer satisfaction, suppliers may be brought in as partners in the development and launching of new products. The sourcing decision-what to make and what to buy-is a special case of the more general decision of what to do inside one's own organization, and what to do outside in collaboration with other organizations. Sourcing entails vertical collaboration in the supply chain, including marketing and distributions relations, which may also be horizontal with competitors, or lateral with firms in other industries.

In this section we review briefly some important knowledge-transfer concepts related to the firm and many of the basic collaborative relationships through which knowledge may be transferred and are commonly observed between firms as outlined in Table 7.

Absorptive Capacity. Absorptive capacity refers to the ability to assimilate and replicate new knowledge gained from external sources (Cohen and Levinthal 1990). Absorptive capacity results from a prolonged process of investment and knowledge accumulation within the firm, and its development is path dependent (Mowery et al., 1996). Therefore, the persistent development of the ability to absorb knowledge is a necessary condition for a firm's successful exploitation of knowledge outside its boundaries. A parallel line of research in the broader technology-transfer literature suggests that possession of relevant technical skills facilitates inward technology transfer (Rosenberg and Frischtak 1991; Agmon and von Glinow 1991). Gambardella (1992) further argued that higher levels of absorptive capacity would improve a firm's ability to exploit sources of technical knowledge outside its boundaries. Firms with a high level of absorptive capacity are likely to have a better understanding of the new knowledge and to harness new knowledge from other firms to help their innovative activities (Tsai 2001; Makhija and Ganesh 1997). Without such capacity, firms are hardly able to learn or transfer knowledge from outside. On the other hand, firms can assimilate new knowledge more effectively if they possess a high level of absorptive capacity.

General Definition of Collaboration: Refers to joint activities undertaken by two or more firms or between firms and institutions (for example, universities) with a common objective. The relation can be either informal or formal, and may occur as a result of a wide range of motives, including the desire to learn or simply get connected to the source of knowledge, or to enhance the competitive position of the participants. Anderson (1995) defines it more broadly as a strategic mode of integration in which two or more organizations co-operate on parts or all stages of production, from the initial phase of research to marketing and distribution. Collaborative agreements can be short-term or long-term and encompass a spectrum of co-operation that lies between outright merger/acquisition and arms-length market transaction. Some examples are:

Collaboration with Competitors: Obviously managers would prefer that valuable knowledge not get transferred to other firms, but the reality is that the process does occur. The Conference Board of Canada (2000) reports that firms collaborating with competitors are driven more by defensive motives such as risk, sharing cost, and gaining access to new markets, than by opportunistic motives such as obtaining access to R&D, or expertise. Moreover, firms that collaborate with competitors are 45% more likely than firms that do not collaborate with competitors to mention "spreading risk" as an important reason for their decision to become involved in collaboration. Similarly, they are 29% more likely to mention "reducing the cost." Thus, it can be expected that collaboration with competitors will occur on projects that are at very early stages, where risks are significant and rewards uncertain. Such circumstances reduce the firm's natural anxiety about working with competitors. A third, quite intriguing, finding is that firms collaborating with competitors are 22% more likely to mention the need for access to new markets as a reason for collaboration. Understanding why competing firms would be interested in helping each other enter a new market is somewhat counter- intuitive, when the market is new to both parties, the competitor can be viewed as an ally in an attempt to gain access to the new market and take on other competitors.

As discussed above, there are also other less direct routes in which knowledge is transferred between competitive firms that should be acknowledged. These paths often include some combination of imitation, reverse engineering, movement of personnel, or business intelligence. For example, Mansfield (1985) found that a decision to develop a major new product or process was known to competitors within 12-18 months. Levin et al (1987) studied the cost of imitation, and showed that "major innovations" incurred higher imitation costs than "typical innovations". Further, Zander (1991) found that the level of difficulty of an intra-firm knowledge transfer is not necessarily the mirror image of the level of difficulty of its imitation.

Collaboration with Clients: The summary data in Table 7 indicate that firms will typically collaborate and foster knowledge transfer with clients in many areas. For example, when firms expand into new markets they need to understand the requirements of potential new clients and how best to change/adjust the product/service they offer and, as such, firms are driven to collaborate with clients in order to gain this knowledge. Such collaboration is most likely to occur when the firm enters a new market and looks for new distribution channels. The Conference Board of Canada (2000) has found that firms that collaborated with customers were, respectively, 78 and 62% more likely to mention these two reasons than were firms not involved in customer collaboration as primary reasons. It is generally accepted that it is important to involve clients in the development of new products (Cooper 1993) and this is especially true the closer a project comes to market. For example, activities related to the later stages of product or process development, scale-up and prototype development, are frequently cited reasons that motivate firms to collaborate with clients.

By collaborating with clients, firms seek to develop a product that is more likely to sell well and therefore 'hedge' product development risks. As such, firms will often use these collaborations as means of obtaining valuable information that will help reduce risk associated with product acceptance. It should be noted therefore that this type of risk is different than that associated with collaboration with competitors. Collaboration with clients can be expected to reduce the risk of a particular product's failure. Collaboration with competitors, on the other hand, focuses on earlier stages of product development and thus allows the firm to become involved in a larger number of products. This spreads the risk (without reducing the risk of a failure on any particular project). In addition, collaborating with clients for the purpose of gaining access to R&D will, therefore, often be directly linked to R&D associated with a product, as opposed to early stage or exploratory research into concepts. Therefore, collaboration with clients is driven by activities that are closer to the market than to research. Firms collaborate with potential clients when they plan an expansion into a new market, or when ideas for new products have already been turned into prototypes. All of these activities are also used to reduce the risk of failure in new product introduction.

Collaboration with Suppliers: Firms collaborate with their suppliers for many of the same reasons they collaborate with clients. Specifically, suppliers may contribute knowledge associated with prototype development, scale-up, and access to expertise relevant to new projects. With prototype development or product scale-up, the technical parameters for sub-components that suppliers provide become better defined than in the earlier stages of product development; thus, the involvement of suppliers becomes more important. What differentiates collaborations with clients from those with suppliers is that firms engaged in collaborations with suppliers are more likely to enter them due to a need for access to expertise present within the supplier's firm.

A number of researchers (Sako 1994; Teece 1992; von Hippel 1976) have even gone so far as to say that when collaborators have customer-supplier ties, they are more conducive to technology transfer. However, the sheer number of such linkages may increase a firm's opportunity to learn something new from other businesses, and for the organization itself to be central in the circulation of knowledge about technical advances throughout the broader information network (Powell, Koput and Smith-Doer 1996). By contrast, close ties with a small number of organizations limited to the same industry may actually inhibit learning about technical advances developed outside that industry (Glasmeier 1991).

Collaboration with Consulting Firms: Firms also develop relationships with consulting firms as these firms provide ready access to specific areas of domain knowledge. Although smaller firms may engage consulting firms to help launch a business, the majority of these relationships are focused on transferring key knowledge that an established firm needs in order to expand its business through scale-up operations, or to help mitigate operational or financial risk to the organization. Either way, firms that collaborate with consulting firms are generally seeking to transfer knowledge into the firm through ready access to critical expertise.

Although knowledge may be transferred through many different channels and for different purposes as described above, this is typically achieved through formal or informal alliances between firms of varying sizes. The following sections describe the nature of these relationships in more detail.

4.1 Knowledge Transfer at the Firm-Firm Interface

4.1.1 Partnerships and Alliances

Over the past decade and a half, the concept of inter-firm collaboration has attracted increasing attention within the academic literature (see, for example, Dodgson 1992, 1993; Hagedoorn 1995; Rosenfeld 1996; Suarez-Villa and Karlsson 1996; Gertler and DiGiovanna 1997; Andersen 1999; Raco 1999; Archibugi and Iammarino 2002, Hagedoorn 2002). In general, the consensus is that most authors conclude that collaboration is a key element to most new industrial production strategies. Much of the discussion in the literature can be reduced to three recurring and interrelated themes.

First, there has been a proliferation of production partnerships and inter-firm arrangements in many industries, particularly in high technology sectors such as electronics (Morgan 1991; Smith *et al.* 1991; Bettis and Hitt 1995; Gulati 1998). These new corporate strategies, according to some authors, are a response to global competition, rapid technological advancement, and changing market structures that require firms to be both innovative and competitive. Inter-firm collaboration has increasingly been used to access new markets, to gain skills and technologies, to share the risks and high costs of technology development, reduce duplication of R & D efforts, and save costs. (See amongst others: Das et al 1998; Eisenhardt and Schoonhoven 1996; Hagedoorn 1993; Hagedoorn et al 2000; Lorenzoni and Lipparini 1999; and Mowery, Oxley and Silverman 1996).

For example, Hagedoorn (2002) has looked at major trends in inter-firm R&D partnerships since the 1960's and has made some interesting observations. In general, there has been an overall growth in the world-wide partnerships over the past few decades, while at the same time there has been a decided decrease in the number of join-ventures formed, see Figure 5. As such, the increase in partnerships is largely due to an increase in the number of contractual agreements, i.e. R&D pacts and joint development agreements. It is estimated that about 90% of the recently established partnerships are of a contractual nature. Contractual R&D partnerships enable companies to increase their strategic flexibility through short-term joint R&D projects with a variety of partners. This flexibility in R&D partnerships ties into the more general demand for flexibility in many industries where inter-firm competition is affected by increased technological development, innovation races, and the constant need to generate new products. There is a relationship between strategic incentives that serve to increase the flexibility of the companies, and between cost-based incentives that correspond to the sharing of the increasing costs of innovative efforts with some other companies for, at least part of, the costs of the overall R&D budget.

The role of technological development in all of this is also apparent in the sectoral background of R&D partnering (Figure 6). Since the 1960s, there has been a gradual increase in the share of high-tech industries in R&D partnering. By the end of the 1990s however, over 80% of the newly made R&D partnerships were found in the information technology sectors and the pharmaceutical industry. In this space there is also a strong representation of contractual partnerships, largely reflective of the need for short term flexibility. Joint ventures (JVs), however, are less flexible in nature due to the fact that both firms will have to setup a separate organization with a variety of functions. As such, JV's are typically found in medium-tech and low-tech industries where technological development is usually less turbulent and of a more gradual nature. In contrast, contractual R&D partnerships that regulate relatively small-scale collaboration in a flexible setting of multiple companies are major drivers of inter-firm networks that have become so apparent in many high-tech industries.

Research into knowledge transfer through alliances and joint ventures is a relatively recent phenomenon. Kogut (1988) was the first to explicitly argue that joint ventures could be motivated by an organizational learning imperative. He proposed that a joint venture "...is used for the transfer of organizationally embedded knowledge which cannot be easily blueprinted or packaged through licensing or market transactions" (Kogut 1988: 319). At around the same time, Westney (1988), Hamel (1991), and Inkpen (1992) developed related perspectives on the ways in which learning can be achieved through alliances and joint ventures. Since then, there has been a proliferation of research into the knowledge transfer process across alliance and joint venture boundaries (e.g. Inkpen and Crossan 1995; Doz 1996; Mowery et al. 1996). For example, Chen (2004) has studied the effects of knowledge attribute, alliance characteristics, and firm's absorptive capacity on the performance of knowledge transfer based on a regression analysis of 137 alliance cases. The findings suggest that knowledge transfer performance is positively affected by the explicitness of knowledge and the firm's absorptive capacity; that equity-based alliance will transfer tacit knowledge more effectively, while contract-base alliance is more effective for the transfer of explicit knowledge (Figure 7); and that trust and adjustment have positive effects while conflict possesses a curvilinear effect on knowledge transfer performance. This makes intuitive sense as tacit knowledge is better transferred through longer term, closer, and interactive relationships. Although there are many forms that a partnership can take, it is important to realize that there is a dynamic aspect to the formation and dissolution of these relationships, and that they will change over time due to both developments in the company itself, its environment, and changes within the partnership (Harrigan 1988). As such, the ability to transfer knowledge will be impacted by the nature and strength of the relationship formed. We explore this in more detail below.

Second, small firms are important in national economies but are constrained by internal and external conditions (notably limited market information, inadequate finances, and labor shortages), and so face critical challenges in the present unstable economic environment (Smith *et al.*, 1991; Malecki and Veldhoen, 1993; Malecki and Tootle, 1996). In the face of mounting global economic uncertainty, inter-firm collaboration is regarded as a mechanism by which small firms can overcome at least some of their problems and survive. Indeed, this type of alliance has become very popular and internationally, during 1970-1990 there were about 2300 small with large firm alliances formed (Barley, Freeman and Hybels, 1991; Kogut and Kim, 1991). There is evidence that during the 1990s, this type of alliance further increased by 250%.

In these situations, most typical is the start-up pioneering a new technology with a large firm that has marketing and distribution capabilities (Chen and Hambrick 1995). The advent of new technologies such as biotechnology and microelectronics presents opportunities for small entrepreneurial firms to pursue targeted innovation in niche markets (Gomes-Casseres 1996). Research on entrepreneurship suggests that ties with larger firms are vital for two reasons. First, small firms, lacking financial resources, use alliances to infuse resources to aid their commercialization efforts. Second, partnerships with prominent industry players increased the small firm's chances of survival (Baum, Silverman and Calabrese 2000).

Kalaignanam et al (2006) find that R&D alliances provide significant financial gains to the market capitalization of publicly-traded small firms. An alliance with a larger firm helps to establish the smaller firm's credibility, especially if the larger firm is a market leader. With these alliances large firms can diversify their portfolios and also use the experience to search for acquisition targets. Of course, in this type of alliance there are great asymmetries: large firms have market power and greater financial power, while technology-intensive smaller firms have R&D expertise.

Third, because of the growing significance of inter-firm collaboration and networking for the survival of small firms, some writers have suggested that public policies and programs should be used to bring firms together (Britton 1989; Michalet 1991; Morgan 1991; Malecki 1997). They especially favor policies that create linkages between small firms and larger organizations. The assumption here is that policies encouraging inter-firm collaboration will enable small firms to remain competitive and to keep abreast of changing technology and market dynamics.

A few writers, however, have mixed views on collaborations. For example, Porter (1990) has expressed doubts about the long-term sustainability and efficacy of collaborative practices. Anderson (1995) has described collaboration as both a "threat" and a "savior" to local and national economies, while Pisano et al. (1988) have noted with concern the lack of clear understanding of inter-firm linkages and their long-run implications. Indeed, Gertler and DiGiovanna (1997) have even questioned how far these practices have been adopted. Whether collaborative arrangements are a transitory phenomenon or a permanent and enduring feature of the production landscape remains uncertain.

Difficulties in establishing and maintaining collaborative ties to other firms have been shown to limit the extent and the duration of inter-firm collaborations (Harrigan 1988). Common interests, complementary expertise, and goodwill are important ingredients in establishing and maintaining collaborative arrangements with other organizations (Gould 1993). Moreover, Sako (1992) has shown that the willingness to voluntarily share information that benefits the other partner is affected by the institutional context in which firms undertake a collaborative initiative. New collaborative arrangements involve a great degree of risk when the partners have little prior experience working together. Common interests, complementary expertise, and goodwill are important ingredients in establishing and maintaining collaborative arrangements with other organizations.

The transfer of knowledge through collaborative ties with other firms through international joint ventures is even more problematic and often exhibits a high rate of instability. Instability is defined as a major change in partner relationship status that is unplanned and premature from one or both partners' perspectives. In spite of the basic popularity of international joint ventures (JV) however, there is significant dissatisfaction with their performance (Beamish 1988). This is intuitively inconsistent and indicates that, although firms may perceive the need for JVs, they find them difficult to manage. In their study Inkpen and Beamish (1997) argue that the instability of the joint venture is related to changes in the bargaining power of either partner. Specifically, this occurs when either partner acquires sufficient knowledge and skills to eliminate a partner dependency and make the international joint venture bargain obsolete.

Many managers are therefore leery to enter into international JVs and often express a high degree of dissatisfaction with such collaborations. Madhok (2006) in his review of international JVs has gone so far as to argue that overemphasis on the outcome has resulted in a neglect of the social processes (including like trust, reciprocity, opportunism, and forbearance) underlying the outcome. The paper elaborates upon the rationale for a cooperative approach toward inter-organizational collaborative relationships based on trust. More importantly, the level of perceived trust will have a dramatic effect on the decision a multinational firm will have on partnering, or actually gaining knowledge directly through acquisition of a foreign firm.

4.1.2 Within National Systems

A firm conclusion that can be drawn from studying the interaction of knowledge transfer on the formation of partnerships and alliances, especially R&D partnering, is that it is largely dominated by companies from the world's most developed economies. Specifically, 93% of these partnerships are made among companies from North America, Europe, Japan, and South Korea (Hagedoorn, 2002). Although startling, this statistic is consistent with the current worldwide distribution of R&D resources and capabilities (Freeman and Hagedoorn 1994). In that context the dominance of North America, particularly the U.S.A., also reflects the leading role that this continent plays in R&D and production in major high-tech industries, such as the information technology sectors (computers, telecom, software, industrial automation, semiconductors) and pharmaceutical biotechnology (OECD 1992). This dominance has not only led companies from other countries to actively search for R&D partnerships with U.S. companies, the U.S. dominance of technological development in many of the above-mentioned fields has also led to a situation where most of the recent R&D partnerships are formed between companies within in the U.S.A.

The growing importance of intra-U.S. R&D partnerships also largely explains why international partnerships, despite a strong growth in absolute numbers, still take only about 50% of all R&D partnerships and why the trend toward further globalization appears to be stagnating. Apart from the technological dominance of U.S. companies in major high-tech sectors, there are probably a few other factors that can partly explain the trend towards the "domesticized" nature of R&D partnerships by U.S. companies. Given the absence of a direct effect of publicly-funded programs on R&D partnering in high-tech sectors, these publicly-funded joint R&D activities are, as discussed in the above, not a likely candidate for such an explanation.

Two other factors might, however, have indirectly affected the "domesticized" nature of R&D partnerships of U.S. companies. One factor is the changes in the U.S. antitrust policy that began in the early 1980s and continued through the 1990s. This reduced the post-war hostility of the U.S. federal competition authorities toward R&D collaborations among established firms. The other factor relates to the Uruguay Round, which reduced some of the non-tariff trade barriers in sectors such as telecommunications equipment or pharmaceuticals, that formerly constituted an important motive for international collaboration, and which included a prominent R&D component.

It is clear from the examples cited in the U.S. that both domestic and international policy can have a dramatic affect on paving the way to increased collaboration and partnerships. More importantly, in Canada and specifically in Ontario, policy that encourages the growth of SMEs or draws in multinationals can have a significant effect on knowledge transfer and innovation. Some examples include Canada's SRE&D tax credits and or the development of high tech clusters. We will discuss these in more detail in Section 4.3 below.

4.2 Knowledge Transfer within Firms

Over the last few years there has been an upsurge in interest among scholars on the importance of knowledge management and transfer within firms. An argument usually put forward is that we have gone from an industrial age, in which the most important resource was capital, into an age in which the most critical resource is knowledge. The implication for the firm is that it is increasingly difficult to attain and sustain a competitive advantage through the reallocation of capital and other assets on the balance sheet. Meanwhile, those who have gained a competitive edge over their rivals have increasingly done so through innovative recombination of knowledge already present within the firm or, as we review above, through strategic partnerships. To put it somewhat more dramatically, there is evidence suggesting that the winners in tomorrow's market place will be the masters of knowledge management (see e.g. Nonaka and Takeuchi 1995; Arthur, 1996).

Research on intra-firm knowledge transfer has a long history emanating from studies on the choice of international technology transfer modes (see e.g. Pavitt 1971; Mansfield et al. 1979; Vernon and Davidson 1979). Close scrutiny reveals a focus on a relatively small number of variables. One line of research on the timing of transfer has shown a dramatic increase in transfer speed from product introduction to transfer of technology to subsidiaries (e.g. Mansfield and Romeo 1980; Davidson 1980; 1983). Another line of research on transfer costs has generally found that experience is an important factor (e.g. Teece 1976; 1977; Mansfield et al. 1979). In addition, Zander (1991) and Szulanski (1997) have taken a broader approach to internal knowledge transfer. Zander (1991) found that the tacit-articulated dimension of knowledge had an important impact on the smoothness of transfer. In particular, he found that the transfer of tacit knowledge was more difficult to accomplish than the transfer of more articulated knowledge. Szulanski (1997) focused on the transfer of best practices within firms, and the difficulties experienced in the transfer process. His findings were consistent with Zander's. When analyzing factors causing difficulties in the knowledge transfer process, Szulanski found that the tacit-articulated dimension explained more variance than any other factors, such as motivation.

While the transfer of knowledge between departments or between sister units in the same country is far from trivial, it is clear that the problems associated with transfer will increase with geographical and cultural distance. Indeed, most research conducted on questions of knowledge transfer has been undertaken in an international setting (e.g. Teece 1976; Mansfield and Romeo 1980; Zander 1991). Moreover, the value of knowledge transfer in international firms can be particularly high because foreign markets often provide access to new ideas and stimuli that can be subsequently applied in other countries (Hedlund 1986; Bartlett and Ghoshal 1989; Solvell and Zander 1995). In this section we briefly review some of the research performed focusing on knowledge transfer within multi-national firms (cross borders), within national systems, and through acquisition.

4.2.1 Multinational Firm Divisions

In addition to attaining greater market reach, many Canadian companies are part of multinational enterprises (MNEs) that have extensive global R&D activities and innovative capabilities. Differences in innovation capabilities and the proliferation of knowledge centers at various locations throughout the world has strengthened the incentives for multinationals to strategically place their R&D facilities in locations that best support their activities (Gerybadze and Reger 1999). On one hand, the global dispersion of R&D is driven primarily by a firm's strategy of acquiring new knowledge, new capabilities, and in gaining access to unique human resources (Cantwell 1995; Dunning and Wymbs, 1999, Kuemmerle 1997) found in different locations. On the other hand, the location of these facilities may be quite strategic. For example, Pearce and Papansatassiou (1999) have conducted a survey of the evolution of overseas R&D labs in the U.K. where they identify three different roles for these facilities: support, locally integrated, and internationally interdependent.

The effectiveness of knowledge transfer however, is driven by different mechanisms. In their study of drivers in intra-corporate knowledge transfer efficiency, Gupta and Govindarajan (2000) looked at data from 374 subsidiaries within 75 MNCs headquartered in the U.S., Europe, and Japan. They made two important conclusions: 1) Knowledge outflows from a subsidiary are positively associated with value of the subsidiary's knowledge stock, its motivational disposition to share knowledge, and the richness of transmission channels; and 2) Knowledge inflows into a subsidiary would be positively associated with richness of transmission channels, motivational disposition to acquire knowledge, and the capacity to absorb the incoming knowledge. Both conclusions support the requirement for good organizational and intra-corporate relationships in addition to effective communications channels.

In addition, as a diversified firm expands its divisions into a new host country, the ability to assimilate and transfer knowledge has its own unique set of challenges. For example, Lord and Ranft (2000) examine a series of U.S.-based MNCs and determined that both the nature of local market knowledge itself and differences in organizational structures significantly influence the extent of internal knowledge transfer among divisions. The results suggest that, as firms expand into new international markets, their organizational learning processes differ significantly. Moreover, organizational learning about new host countries appears to be a complex process that varies significantly from firm to firm, due to variations in internal flows of local market knowledge. These variations stem from both the nature of the knowledge itself and from differences in firms' organizational structures. In some firms, each division learns about a new market largely, if not wholly, on its own, whereas in other firms there is a great deal of internal knowledge transfer, resulting in significant shared learning across different divisions.

Lord and Ranft (2000) also determined that both formal and informal aspects of organizational structure appear to be significant determinants of whether, and the extent to which, internal knowledge transfers occur. For example, a formal corporate-level country headquarters appears to positively influence a firm's ability to transfer local knowledge across divisions. Similarly, the active engagement of corporate executives in divisional strategy formulation and implementation will also have a significant effect on knowledge transfers. Some managers in their study noted that they had frequently engaged in a number of corporate-inspired communications and exchanges, including country-specific teams and task forces, explicitly for the purpose of bringing together personnel from different divisions to share their host-country experiences and ideas. Many firms also noted that they had rotated or transferred (either temporarily or permanently) managers who had host country experience to relatively inexperienced divisions, in order to take advantage of their accumulated market knowledge. As Bartlett and Ghoshal (1992) and Hedlund (1994) note, such rich boundary-spanning communications play a critical role in facilitating knowledge flows within the diversified, multinational firm. Alternately, however, other respondents noted that they had never communicated with their counterparts who managed other corporate divisions in the same host country.

In some cases, however, the knowledge needed by foreign entrants expanding into a host country is highly tacit and, therefore, not easy to acquire or transfer (Barkema et al. 1996; Li 1995; Johanson and Vahlne 1977). In such situations, local market knowledge is not “free” and it remains problematic to internally transfer and utilize even after its initial acquisition by one part of the firm. Because local market knowledge cannot be easily acquired without cost, the very difficulty of its acquisition might increase the relative benefits that accrue to those firms which are able to internally transfer it effectively (Andersen, 1993).

Finally, it should be noted that the size of the firm can have a significant impact on its ability to gain access to sophisticated resources that cannot be found elsewhere. For example, Eden et al. (1997) have compared small and medium sized enterprises (SMEs) as technology producers with their larger multinational counterparts (MNEs) and concluded that SMEs face certain constraints, due to small size and inadequate financing that raise their costs of technology production and transfer, relative to the costs for MNEs. SMEs however, have a higher degree of flexibility and can use unconventional methods to create successful mini-nationals in niche markets.

4.2.2 Through Acquisitions

One hybrid mode that has not so far been the focus of knowledge-transfer research is mergers and acquisitions. Nevertheless, a key reason for an acquisition has often been to gain access to knowledge in the acquired company, and to transfer that knowledge to other parts of the firm. In particular, since the speed of competition in many industries has made organic growth seem excessively time-consuming, many managers have come to consider acquisition to be an attractive way to expand a firm's knowledge base quickly.

What many acquiring firms have discovered, however, is that the transfer and utilization of knowledge through acquisitions can be a daunting task. It is contingent on a successful integration of the acquired unit (Haspeslagh and Jemison 1991), and very often the process of integrating the acquired unit fails outright (Jemison and Sitkin 1986).

The literature in this area reveals little, if any, research explicitly directed at this phenomenon. Most relevant is the so-called "process" school, which is concerned with the creation of value through post-acquisition integration (Lindgren 1982; Shrivastava 1986; Haspeslagh and Jemison 1991; Hakanson 1995). Haspeslagh and Jemison (1991), for example, discussed the issue of knowledge transfer, but their focus was on how knowledge transfer may lead to overall value creation, not on the factors facilitating knowledge transfer per se. There has also been some recognition at an aggregate level that resource redeployment (e.g. knowledge transfers) can have an important impact on value creation in acquisitions (Capron, 1996), but of course such studies do not provide much insight into the processes of resource redeployment. Finally, a related body of literature has looked at the acculturation process (Berry, 1983) when two different organizations are brought together. The essential contribution of such studies to the current work is that knowledge transfer between the merging organizations depends on the development of a cooperative relationship.

In their review of knowledge transfer through acquisition, Barkema and Vermeulen (1998) further conclude that the knowledge transfer process in acquisitions is distinctly different from the process under other modes of governance, because of the rapidly-evolving relationship between the two parties. While many of the facilitators of knowledge transfer are likely to be the same (tacitness of knowledge etc.), we can expect their relative importance and the process itself to change significantly over time, as the integration of the acquisition runs its course. In the early stages, knowledge transfer is undertaken in a relatively hierarchical manner (dictated by management), but this then gives way to a more reciprocal process. And over time the type of knowledge being transferred shifts in emphasis from relatively articulate (e.g. patents) to more tacit (know how). The point to make here is simply that the acquisition context gives us a story that is not seen under other modes of governance. The only comparable situation would appear to be in strategic alliances, in which the approach to knowledge-sharing changes as the alliance evolves (e.g. Arino and de la Torre 1998; Doz 1996).

4.3 Firm Collaboration within Canada

There is a fair degree of literature published on inter-firm collaboration within Canada. A significant portion of this work comes through many government reports designed to assess innovation and collaboration (e.g. conference board of Canada's innovation reports). There is also considerable work published in the academic community focusing on inter-firm linkages especially as they relate to industrial (e.g. Grayteck 2004) clusters. Policy pieces also tackle important issues surrounding IP, subsidies and tax incentives (e.g. Hirshorn et al 2000). In general, many of the conclusions drawn from the international literature relating to knowledge transfer between firms are universal and so are also relevant to Canadian firms. The primary focus of this section is therefore to highlight research and issues specific to Canada and Ontario.

Collaboration and Clustering: According to the Conference Board of Canada (2000), inter-firm linkages are quite strong in Canada. For example, one in four manufacturing firms (27.6%) was involved in collaboration for product and/or process innovation during the 1990's. Compared to the size of Canada's economy in the 1990's, the number of strategic alliances that involve Canadian firms is relatively high compared to other OECD countries (See Table 12). However, during the same period, the international exposure through inter-firm collaboration was relatively low. Not surprisingly, the most prevalent international linkages are with US firms considering our proximity and similarity in cultures. For the most part, this can be considered a good thing, especially since many US firms are world leaders. There is risk however, in not exploring and developing other international linkages, especially considering that with globalization, there is a continuing growth in knowledge centers and highly innovative firms around the world.

In terms of a firms preference for collaboration partners, the data in Figure 8 indicate that inter-firm collaborations is more prevalent than the partnering of private sector firms with publicly funded research organizations (universities and federal/provincial research laboratories). The result that firms prefer to collaborate with other firms in their own line of business (e.g. suppliers and customers) is not surprising. The elevated number of inter-firm collaborations is also due in part to that fact that there are a greater number of private firms than publicly funded research institutions in Canada. Inter-firm collaborations are also not restricted to a narrow focus (e.g. scientific research) and as such can be based on a fuller spectrum of activities (e.g. see Table 7).

Although, inter-firm collaborations may be formed to serve a number of different purposes and through a variety of different mechanisms, a significant amount of effort and research has been focused on developing and understanding industrial clusters. With reference to Figure 9, there are many factors responsible for the growth, development and success of clusters. It is now recognized that although ideas, people and money are key factors in the growth of successful companies, the regional economic and competitive advantage associated with clusters will be dependent on additional factors. As such, factors external to the business, but internal to the cluster's economic foundation, are becoming increasingly important for the creation of competitive advantage. Each firm is part of a "cluster" of interrelated firms, suppliers, customers, and service providers, as well as supporting organizations (human resources, R&D, finance, infrastructure, and regulatory environment). Firms within an industrial cluster are in the same – or related – field, and linked by a variety of interdependencies and networks. These include academic networks, common funding resources, a common pool of skilled labor, and industry associations. An industry cluster is a group of companies that benefit from an active set of relationships among themselves to increase individual efficiency and competitiveness.

A key priority of the Government of Canada's innovation and commercialization strategy is to support the development of globally competitive industrial clusters. As such, industrial clusters representing numerous sectors can be found in many regions across Canada. The growth and development of these clusters has attracted much attention in the academic literature, a selection of which has been summarized in Table 13. Although clustering can be found in many industries, there is a definite focus on the life sciences/Biotech/Pharma and hit tech or ICT industries of which a significant number of these clusters are found in British Columbia, Ontario and Quebec. Activity is also increasing in Alberta. From the literature the results tend to support that fact that clusters are instrumental in facilitating knowledge transfer, innovation and economic development. However, many of these reports are also quick to point out various issues associated with clusters formation and growth in their respective sectors and regions that we will discuss in more detail below.

A fairly recent report (Grayteck, 2004) prepared for the ICT and Life Sciences Branches of Industry Canada and the National Research Council focused on the ICT, life sciences and converting technologies across Canada has revealed some fairly interesting observations. A summary of the ICT and Life Sectors by region are provided in Table 14 respectively for reference. From their report, ICT cluster behavior appears strongest in Ottawa and Vancouver where it is fairly well developed. In Toronto, cluster behavior is less developed and can vary significantly throughout the GTA (e.g. more so in Markham and less so in Toronto). In Montreal, ICT cluster activity is underdeveloped and can vary by industry (e.g., it is strongest in the emerging new media area). In the life sciences sectors, the Vancouver and Ottawa clusters are located in smaller municipalities and appear to have achieved a higher profile and cohesion within their respective locations as compared to clusters in Toronto and Montreal. This later observation is due mainly to the fact that clusters in Toronto and Montreal are situated in high industry activity areas and therefore have to compete with several sources for attention. In addition, even though Toronto and Montreal's Life Sciences clusters include pharmaceutical, biotechnology and medical devices capabilities, they cannot be said to be integrated clusters because there are few linkages among the three components. As such, Montreal has diversified capabilities and appears to be the most developed and well rounded cluster overall, resulting in a strong profile. Although Toronto also has diversified capabilities its dynamics are considered largely 'laisser-faire'. Comparison of these centers with Ottawa and Vancouver however is skewed because neither has strong pharma representation. Still, Vancouver appears to be the most dynamic biotechnology related cluster and Ottawa is still at the emerging stage in biotechnology but has a relatively significant medical devices component.

As stated, there is a strong indication from market reviews that industrial clusters play an important role in the overall economic development of Canada. Consequently, there is strong potential to accelerate the development of existing technology clusters where Canada has the potential to develop world-class expertise and to identify emerging clusters with strong growth potential. Specifically, the government can take on roles that include the correction of market failures in investment in technology development, creating infrastructure, financing of risky ventures and developing a regulatory and institutional framework that can facilitate cross-fertilization. For example, a number of these activities have been outlined in Table 15, and although they are specific to the ICT and life sciences sectors they will have broader implications.

While the federal and provincial governments have initiated a variety of programs to fund infrastructure, research and ventures that support cluster developments, these programs often do not achieve there full potential impact. There are several factors that may contribute to there failures, several of which have been outlined in many of the papers cited in Table 13. One of the primary factors for these failures, that may vary regionally, arises from the lack of coordination among federal, provincial, non-profit organizations, and companies. This lack of coordination results in the absence of a long-term vision and strategy for the development of the cluster, and a dilution of the impact of public sector resources. There are insufficient communication and feedback loops between the various public sector institutions established to promote entrepreneurship and the communities of entrepreneurs they serve. This may be attributed to not only the fragmentation of public sector efforts but also to the lack of private sector leadership that can articulate a cluster's needs and vision.

Another issue that may impact cluster formation is related to the degree of fragmentation within a given sector; where the product foci in a given area are diverse there may be little reason for firms to collaborate at certain levels. For example, biotech firms that work exclusively in developing cancer therapeutics may have little interest in working with firms that exclusively develop AIDS/HIV therapies. In these situations, the variety of scientific niches and technologies may limit the opportunities for developing collaborative relationships, technology and information spillovers, and imitation of good practice. However, in the long run, the diversity of areas of expertise may give impetus to innovation resulting from cross-field fertilization.

In fact this 'cross-fertilization' has given rise to what are now commonly referred to as 'convergent' technologies. Converging technologies apply concepts from two or more different fields to create new hybrid technologies that are often more effective or innovative in the way they answer difficult research questions. For example, Figure 10 highlights several new fields of study that apply technologies from the ICT and life sciences in creating novel platforms or technologies that have cross discipline applications. Converging technology areas are found in a full range of new disciplines including bioinformatics, biophotonics, biosensors, nanotechnology, biochips, medical robotics, and medical wireless devices. Often however, these emerging areas will lie beyond the direct interest of traditional pharmaceutical firms and therefore represent a new frontier.

Interestingly, regions that contain strong well developed clusters from different technological sectors provide the basis for the formation of and array of different converging technology clusters. The mix of traditional and new, converging technology clusters should generate regions with strong and diverse arrays of industries, providing a strong base from which economic development can be built. In Canada, however, the number of firms based on convergent technologies and associated clusters are not well developed. In the Grayteck Report (2004), it is believed that the key opportunity is to leverage the strengths of the established ICT clusters in order to grow substantial biotechnology clusters through the use of advanced ICT enabling technologies. While the ICT sector may sense opportunities that would enable cluster renewal, the needs are better known within the biotechnology community; bridging this gap is the challenge.

Finally, in order for a cluster to become truly competitive it must have access to a rich infrastructure present in the local economy that can provide specialized services and resources to support activities at each stage of translating an idea into a commercial product, or a viable self sufficient company. In this regard, access to human capital from scientific and management capability is crucial. With early stage cluster development, within-cluster human mobility has not yet developed to a significant degree where emerging companies may rely on access to skilled workers moving from mature companies. The location of emerging clusters proximal to equivalent sources of labor such as universities or financial centers is therefore desirable. Along these lines, another factor that strengthens clusters and makes them more competitive is a firm sense of community. Successful managers and veteran entrepreneurs can advise and mentor nascent entrepreneurs in the community. As heroes inspire winners, a community should celebrate its winners and their success, thus making them role models.

In Ontario, a relatively new facility known as the Medical and Related Sciences discovery district or the MaRS center was recently opened. MaRS is located in the heart of the University of Toronto research hospital environment and the University of Toronto Campus, with close proximity to the provincial government offices and Toronto's financial district. As such, MaRS promotes itself as a convergence innovation centre dedicated to accelerating the commercialization of new ideas and new technologies by fostering the coming together of capital, science and business.

MaRS was created in 2000 to capitalize on the research and innovation strength of the Province of Ontario, and to position Canada for leadership in the highly competitive global innovation economy. MaRS is focused on building Canada's next generation of technology companies to become global market leaders. MaRS will accomplish this goal by:

- Systematically building the entrepreneurial ecosystem that is the support fabric of young companies.
- Directly intervening and assisting with risk capital, management resources, strategic business tools and access to global markets for a number of emerging companies.
- Developing and maturing Canadian business talent.
- Creating powerful networks that will connect the leadership of Canada's scientific, business and investment communities to their international peers in a meaningful way.

On paper, the MaRS center has all of the ingredients to help increase Toronto's profile as an innovative biotech hub and provides a nice example of a recent initiative in this area. However as a relatively recent phenomenon it will take time to fully evolve and move from a simple real estate model and meeting showcase into a functional integrated cluster.

Incentives and Taxes: In innovation, there are many incentives including both personal and corporate taxes that play a role in attracting new investment and qualified human capital. Corporate taxes are important factors in reducing the overall costs of operating a firm and in making a country an attractive location for MNE's and therefore competitive in the global marketplace. Low levels of personal taxes, along with a high quality of life, attract talented new people from around the world and persuade them to live, work, invest and raise a family in a country. Discussions of these incentives and policies can be found in many sources including government papers (e.g. Conference Board of Canada, 2001) and Policy papers (e.g. Hirshorn et al, 2000).

Tax incentives are employed by governments to offset market failure in allocating resources to long-term and risky investment, such as R&D. They are part of the arsenal of tools that governments have at their disposal to directly stimulate R&D in the private sector. Unlike the direct measures (grants, subsidies, loans and contracts), which usually target the recipient, tax incentives are delivered indirectly through the market decisions of the private sector. Central to Canada's innovation policy is the Scientific Research and Experimental Development (SR&ED) Program, administered by the Canada Customs and Revenue Agency (CCRA). This is Canada's largest federal program that supports industrial R&D, accounting for about 25 per cent of government support. The SR&ED program annually receives more than

11,000 claims for approximately $1.5 billion in tax credits. Some important facts about tax incentives can be summarized as follows:

1. Governments compete to attract R&D investment by increasingly using tax incentives.
2. Investment in R&D is an important channel for transferring knowledge, experience and technology to Canadian firms—and the economy.
3. Canada's R&D tax incentive program is being increasingly viewed as a principal fiscal incentive to R&D investment by both Canadian and foreign investors (Warda, 1998).
4. The Speech from the Throne set a stretch goal for Canada to become fifth in the world in terms of R&D intensity by 2010.

Given this context, it is not surprising that R&D tax incentives have attracted significant attention in recent years and have become an increasingly important mechanism to stimulate R&D in many OECD countries. For example, the Conference Board of Canada (2001) report that the number of OECD countries that offer R&D tax credits jumped from 10 to 16 in 1996. In addition, some countries have taken additional measures, for example, Australia has beefed up its tax concession by offering an additional 175 per cent incentive on incremental R&D expenditure.

In a similar manner, capital gains taxation can have particularly powerful impact on entrepreneurs. By carefully setting their rates, governments can help offset some of they risk they bear when starting a new venture. These individuals are a major driving force for technological breakthroughs, new start-up companies, and the creation of high-paying jobs. To be successful, the entrepreneur needs capital. Fledgling start-ups depend heavily upon equity financing from family, friends and other informal sources. Thus, starting new businesses involves informal investors, venture capital pools and a healthy equity market. All taxable participants are sensitive to after-tax rates of return, which is why the level of capital gains taxation is so important (OECD, 2000). There are two primary reasons for encouraging venture investment and start-ups (Macdonald and Associates, 2001).

- They are critical to the economy, since innovation and job creation derive disproportionately from new start-ups.
- The private market tends to under invest in innovation.

In Canada, the overall average tax burden is close to the OECD average (37 per cent), but is significantly higher than in the United States, as well as Japan and Australia. The Scandinavian countries and France have the highest tax burden, which is not surprising, given their emphasis on social programs. What is surprising is that Finland has made major improvements in its innovation performance in spite of its overall high tax burden.

In stimulating firm growth, sustainability and collaboration, Ontario must offer an attractive R&D, taxation, regulatory, entrepreneurial, and investment environment. These incentives can include specific government programs in addition to generous R&D tax credits, lower corporate income tax rates, tax holidays for foreign researchers, matching foreign VC investments with loans, and refundable tax credits. A recent report released by Farris, Vaughan, Wills & Murphy and Price Waterhouse Coopers (PWC) (2002) provides a good comparison of the incentives available in different provinces. The results are summarized in Table 16. It should be noted that this table is in no means complete as many provinces have introduced numerous other incentive programs (many of which have been described earlier in this paper) to promote innovation in various sectors and regions. Still, the report does indicate that each province tends to take slightly different approaches towards providing incentives to firms, of which Quebec is the most liberal.

IP Policy: Fundamental to the growth and development of any competitive or innovative firm is the ability and right of that firm to protect its own intellectual property. Intellectual property (IP) laws attempt to remedy the market failure in R&D markets by granting property rights that recognize the inventor's exclusive right to make, use or sell an invention. To be effective, these laws must extend to firms operating domestically in a national system or internationally in the global economy. Therefore Canada has an obligation to maintain intellectual property policies that are effective regionally and that are in-line with internationally recognized policies.

Already on the international stage, there has been significant movement. One of the more critical achievements has been through the movement towards an international harmonization of intellectual property regimes captured in the 1991 Uruguay Round Agreement on Trade Related Intellectual Property Rights (TRIPS). This agreement helps set the stage for the preservation of an IP created in one country being protected equally in other jurisdictions. In addition complementary policies that are aimed at preventing countries from creating unfair competitive advantage on the global scale through excessive support of industrial and pre-competitive research have also been developed. For example, in Marrakech, 1994 the WTO "Agreement on Subsidies and Countervailing Measures act was signed. Countries failing to observe the prescribed limits may be subject to disciplinary action. The sector does however make exceptions for some sectors. For example, subsidies remain important in the aerospace sector where firms cannot reasonably compete in the international market without government support. Similarly, almost all OECD countries continue to provide substantial support to R&D activities in the information technology sector.

Domestically, under Canadian law, for example, inventors can apply for a patent that will provide up to 20 years of protection for inventions that meet the tests of novelty, utility and ingenuity. Patents and other intellectual property rights, increase the extent to which benefits of innovation can be appropriated and thus help restore the incentives within the system for private firms to undertake R&D. Although this right is essential, it should be pointed out that it is not always required for firms to be successful. For example, Mansfield (1986) determined that patent protection was judged to be essential for 30% or more of the inventions in only the pharmaceutical and chemical industries. In another three industries (petroleum, machinery, and fabricated metal products), patent protection was considered to have been essential for the introduction of only 10 to 20 percent of inventions. More recently Arundel and Kabla (1998) determined that of 19 European industries, the sales-weighted patent rate for new innovations was found to average 36% for product innovations and 25% for process innovations, again varying widely between sectors.

The development of effective IP policy is not trivial and involves many complex factors. For example, in the case of patents, there is continued debate on what is ideal in term of patent length, patent breadth or scope and the provision of compulsory licensing. A more complex issue involves the strength of patent protection, where overly stringent protection could serve to retard the flow of important knowledge required as a fundamental building block to follow-up innovations. In this regard, Foray (1994) argues that, since innovation now depends largely on the exploitation of existing knowledge, the emphasis should be on promoting the dissemination of new findings so that they can be combined with other information to create new products and processes. His model indicates the need for systems that encourages firms to seek patents, which are preferable to trade secrets in terms of information disclosure, but that reduces the stringency of patent protection and uses provisions such as compulsory licensing to promote knowledge distribution.

In deriving optimal IP policies, one must consider the relative size and impact of a country on the world's technology pool. For example, as Canada is a relatively small player in the global technology pool, it must adopt stronger IP rights in order to effectively develop innovative capabilities needed to absorb foreign produced technologies in its domestic market. This is obvious when one compares Canada with countries such as Korea that has become highly proficient at reverse engineering and is able to acquire advanced technologies at relatively low cost (McFetridge, 1998). Although such limitations can be overcome by developing more aggressive IP policies this must be balanced by Canada's commitment to NAFTA and the TRIPs Agreement. Moreover, stringent policy is not always the answer, this is especially the case where there has been increasing international pressure to extend IP laws or develop new *sui generis* protection to respond to challenges posed by the growth of digital content. For example, Cockburn and Chwelos (2001) point out that proposed U.S. and EU legislation to protect proprietary rights in databases would abandon the general principle of copyright law that facts, *per se*, are not copyrightable. Proposed U.S. legislation would also curtail "fair use" access under copyright which has been important to educational institutions. Since software piracy is already illegal in most countries and firms are developing increasingly effective technological protections, the need for new legal mechanisms is not evident. There is a danger, however, that current pressures could lead to overly restrictive intellectual property laws that restrict information flows and negatively impact on the innovation process. In closing, although much can be done to improve Canada's competitive position in the global economy in terms of IP policy, it should be noted that the incentive to innovate provided by the current intellectual property regime are adequate. In moving forward a balanced approach should be adopted.

Conclusions: It's fair to say, that most of Canada's leading-edge innovation and commercialization originates with small firms created to pursue a specific idea, technology or innovation. If each of these firms is to grow and become the multinationals of the future, Canadian policy must continue to demonstrate a commitment to helping these firms grow and thrive both domestically and internationally. In so doing, it must also help create important linkages between domestic SMEs themselves and their larger counterparts, which often rely on much smaller firms to supply specific innovations. These policies however, should enable and empower private actors to develop new ventures, markets and institutions on their own, rather than through specific direction by the government.

5.0 References

Abramson, H.N, et al. 1997, "Technology Transfer Systems in The United States and Germany: Lessons and Perspectives" Washington DC, National Academy Press, 1997.

Advisory Council on Science and Technology (ACST), 1999. Public Investments in University Research: Reaping the Benefits; Report of the Expert Panel on the Commercialization of University Research, May 4, 1999. http://www.acst-ccst.gca.ca.

Adams, J.D.; Chiang, E.P; and Jensen, J.L. 2003, "The Influence of Federal Laboratory R&D on Industrial Research" The Review of Economics and Statistics, 85, No.4.

Afshari, A. 2005, "The Academic Technology Transfer Landscape in Canada and Quebec in Particular" The 7th National Congress on Government- University- Industry Relations for National Development. pp 1-34.

Agmon, T. and Von Glinow, M. 1991, "Technology Transfer in International Business" Oxford University Press, Oxford, UK.

Agrawal, A. 2001, "University-Industry Knowledge Transfer: Literature Review and Unanswered Questions" International Journal of Management Reviews, 3(4): 285-302.

Aharonson, B.S.; Baum, J.A.C. and Feldman, M.P. 2004, "Industrial Clustering and the Returns to Inventive Activity: Canadian Biotechnology Firms, 1991-2000" Danish Research Unit for Industrial Dynamics (DRUID) Winter conference is Aahlborg, Denmark, January 25, 2004.

Allen, T.J. 1984, "Managing the Flowof Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization" MIT Press, Cambridge, MA.

Allen, R. 2000, "Why can't universities be more like businesses" Chronicle of Higher Education, July 21, B4-5.

Anderson, O. 1993, "On the Internationalization process of firms: A critical analysis" Journal of International Business Studies, 24(2): 209-231.

Anderson M., 1995, "The Role of Collaborative Integration in Industrial Organization: Observations from the Canadian Aerospace Industry" Economic Geography, 71: 55–78.

Andersen P.H., 1999, "Organizing international technological collaboration in subcontractor relationships: an investigation of the knowledge stickiness problem" Research Policy, 28: 625–642.

ARA Consulting Group & Mireille Brochu., 1998 "Approaches of Canadian Universities to the Management and Commercialization of Intellectual Property Diversity and Challenges". AUCC Publications and Resources: http://www.aucc.ca/publications/reports/1998/property_11_26_e.html

Archibugi, D. and Iammarino, S. 2002, "The globalization of technological innovation: definition and evidence" Regional of International Political Economy, 9(1): 98-122.

Argote, L. and Ingram, P. 2000, "Knowledge Transfer: A Basis for Competitive Advantage in Firms" Organizational Behavior and Human Decision Processes, 82: 150-169.

Argyres, N.S. and Liebeskind, J.P. 1996, "Privatizing the intellectual commons: universities and the commercialization of biotechnology" Journal of Economic Behavior and Organization, 35: 427–454.

Arino, A. and de la Torre J. 1998, "Learning from failure: Towards an evolutionary model of collaborative ventures" Organization Science, 9(3): 306-325.

Arthur, W.B. 1996. "Increasing returns and the new world of business" Harvard Business Review, 74(4):100-110.

Arundel, A. and Kabla, I. 1998, "What Percentage of Innovations are Patented? Empirical Estimates for European Firms," Research Policy, 27.

Audretsch, D.B. and Feldman, M.P. 2003, "Small-Firm Strategic Research Partnerships: The Case of Biotechnology" Technology Analysis & Strategic Management, 15: 273-288.

AUTM 1998, "The AUTM Licensing Survey, Fiscal Year 1997" Association of University Technology Managers

AUTM 2000, "The AUTM Licensing Survey, Fiscal Year 1999" Association of University Technology Managers

AUTM 2005, "AUTM Responds to Fortune Article: A Clarification of Key Points", 09/23/2005: www.autm.org

Barkema, H.G.; Bell, J.H.J. and Pennings, J.M. 1996, "Foreign Entry, Cultural Barriers and Learning" Strategic Management Journal, 17: 151-166.

Barkema, H.G. and Vermeulen, F. 1998, "International Expansion through Start up or Acquisition: A Learning Perspective" Academy of Management Journal, 41(1): 7-26.

Barley, S.; Freeman, J. and Hybels, R. 1992, "Strategic Alliances in commercial

biotechnology" In N. Hohria & R Eccles (eds.) Networks and Organizations: Structure, form and action; 311-347. Boston: Harvard Business School Press.
Bartlett, C. and Ghoshal. S. 1989, "Managing across Borders" Boston: Harvard Business School Press.
Baum, J.A.C.; Calabrese, T. and Silverman B.S. 2000, "Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology." Strategic Management Journal, 21 (Special Issue): 267-294.
Beamish, P.W. 1988. "Multinational Joint Ventures in Developing Countries" London: Routledge.
Bell, S. 1996, "University-industry interaction in the Ontario Centres of Excellence" Journal of Higher Education, 67: 322-348.
Bercovitz, J.; Feldman, M.A.; Feller, I.; and Burton, R. 2001, "Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins and Pennsylvania State Universities" The Journal of Technology Transfer, 26: 21-35.
Bercovitz, J. and Feldman, M.A, 2006, "Fishing Upstream: Firm Innovation Strategy and University Research Alliances". In press
Berry, T.W. 1983, "Acculturation: A comparative analysis of alternative forms" In R.J. Samuda & S.L. Woods, editors, Perspectives in immigrant and minority education. Lanham: University Press of America.
Bettis, R.A. and Hitt, M.A. 1995, "The New Competitive Landscape" Strategic Management Journal, 16: 7–19.
Boyer, M.; Robert, J., and Santerre, H. 1998, "Industrial Restructuring in the Knowledge-Based Economy," prepared for "Doing Business in the Knowledge-Based Economy: Facts and Policy Challenges," CIRANO/Industry Canada Conference, Sept. 1998.
Bozeman, B. 2000, "Technology Transfer and Public Policy: A review of research and theory". Research Policy, 29: 627-655.
Bramwell, A.; Nelles, J. and Wolfe, D.A. 2004, "Knowledge, Innovation and Regional Culture In Waterloo's ICT Cluster" Paper presented at the ISRN National Meeting, Simon Fraser at Harbourfront Centre Vancouver, BC, May 12-15, 2004.
Branscomb, L.M. and Keller, J.H., 1998, "Investing in Innovation" MIT Press.
Bremer, H. 1993, "Testimony on the effectiveness of the Bayh-Dole Act." AUTM, vol. V, pp. 27-36.
Bresman, H.; Birkinshaw, J. and Nobel, R. 1999, "Knowledge transfer in international acquisitions" Journal of International Business Studies, 30(3): 439-440.
Britton, J.N.H. 1989, "Innovation Policies for small Firms" Regional Studies, 23: 167–173.
Britton, J.N.H. 2003, "Network structure of an industrial cluster: electronics in Toronto" Environment and Planning A, 35: 983-1006.
Browning, L.D.; Beyer, J.M. and Shetler, J.C. 1995, "Building Cooperation in a Competitive Industry: SEMATECH and the Semiconductor Industry" The Academy of Management Journal, 38(1): 113-151.
Cantwell, J.A., 1995, "The Globalisation of Technology: What Remains of the Product Cycle Model?" Cambridge Journal of Economics, 19(1): 155-174.
Capron, L. 1996, "Mechanism of value creation in horizontal mergers and acquisitions: A test of efficiency, market power and resource-based arguments" Richard Ivey School of Business working paper, 96-23.
Chen, C.J. 2004, "The effects of knowledge attribute, alliance characteristics, and absorptive capacity on knowledge transfer performance" R&D Management, 34: 311-322.
Chen, MJ. and Hambrick, D.C. 1995, "Speed, Stealth, and Selective Attack: How Small Firms Differ from Large Firms in Competitive Behavior" The Academy of Management Journal, 38: 453-482.
Cockburn, I.M. and Chwelos, P. 2001, "Intellectual Property Rights and the Transition to the Knowledge-Based Economy" in: Doing Business in the Knowledge-Based Economy, Industry Canada/Kluwer Academic Publishing, Edited by Lefevbre, Lefevbre and Mohnen. pp 349-390
Cohen, W.M. and Levinthal, D.A. 1990, "Absorptive Capacity: A New Perspective on Learning and Innovation," Administrative Science Quarterly, 35:128-52.
Cohen, W.M.; Nelson, R. and Walsh J. 2002, "Links and Impacts: The Influence of Public Research on Industrial R&D," Management Science, 48(1): 1-23.
Cohen, W.M.; Goto, A.; Nagata, A.; Nelson, R. and Walsh J. 2002, "R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States" Research Policy
Conference Board of Canada 2000, "Collaborating for Innovation" Second Annual Innovation Report: 2000
Conference Board of Canada 2001, "Investing in Innovation" Third Annual Innovation Report: 2001

Conference Board of Canada 2006, “Lessons in Public-Private Research Collaboration: Improving Interactions Between Individuals” Seventh Annual Innovation Report: June 2006.

Cooper, R. 1993, “Winning at New Products: Accelerating the Process from Idea to Launch” (Reading, MA: Addison-Wesley).

Cunningham, J.A.; Martin, G.W.; Coates, L.; Herie, M.A.; Turner, B.J. and Cordingley. J. 2000, “Disseminating a treatment program to outpatient addiction treatment agencies in Ontario: A case study” Science Communication, 22(2): 154-172.

Crowell, W.M. and Greenwood J. C. 2005, "The Law of Unintended Consequences" vs. "The Most Inspired Piece of Legislation in the US in the Last 50 Years" How will history view the Bayh-Dole Act of 1980? An open letter to Fortune Magazine from AUTM and BIO.

Das, S.; Sen, P.K. and Sengupta, S. 1998, “Impact of strategic alliances on firm valuation” Academy of Management Journal, 41: 27-41.

Daghfous, A. 2004, “An empirical investigation of the roles of prior knowledge and learning activities in technology transfer”. Technovation, 24: 939-953.

Davidson, W.H. 1980, “Experience effects in international investment and technology transfer” Ann Arbor: UMI University Press

Davidson, W.H. 1983, “Structure and performance in international technology transfer” Journal of Management Studies, 20(4): 453-466.

Deeds, D.L. and Rothaermel, F.T. 2003, “Honeymoons and liabilities: the relationship between alliance age and performance in research and development alliances” Journal of Product Innovation Management, 20: 468– 484.

Demeritt, D. and Lees, L. 2005, “Research relevance, ‘knowledge transfer’ and the geographies of CASE studentship collaboration” Area, 37: 127-137.

Dodgson M., 1992, “The future for Technological Collaboration” Futures, June, 459–470.

Dodgson M., 1993, “Technological Collaboration in Industry: Strategy policy and internationalization in Innovation” Routledge, London, New York.

Doloreux, D. 2004, “Regional Networks of Small and Medium Sized Enterprises: Evidence from the Metropolitan Area of Ottawa in Canada” European Planning Studies, 12(2): 173-217.

Dorf, R.C. and Worthington, K.K.F. 1989, “Technology transfer: Research to commercial product” Engineering Management International, 5(3): 185-191.

Doutriaux, J. 2003, “University-Industry Linkages and the Development of Knowledge Clusters in Canada” Local Economy, 18(1): 63-79.

Doz, Y.L. 1996, “The Evolution of Cooperation in Strategic Alliances: Initial Conditions or Learning Processes?” Strategic Management Journal, 17: 55-83.

Dunning J.H. and Wymbs, C. 1999, “The geographical sourcing of technology-based assets by multinational enterprises” chapter 10, in Archibugi et al. (Ed), pp. 185-224.

Economist-Opinion, 2002, “Innovations Golden Goose”, The Economist, Dec 12

Eden, L.; Levitas, E. and Martinez, R.J. 1997, “The Production, Transfer and Spillover of Technology: Comparing Large and Small Multinationals as Technology Producers” Small Business Economics, 9(1): 53 – 66.

Eisenhardt, K.M. and Schoonhoven, C.B. 1996, “Resource-based view of strategic alliance formation: strategic and social effects in entrepreneurial firm” Organization Science, 7: 136-150.

ESRC 2004, “The benefits of collaborative research between academic and public/voluntary sector partners” (http://www.esrc.ac.uk/ESRCContent/postgradfunding/CASE-leaflet2.asp) Accessed 10 July 2004

European Commission 2004a, “Science and technology, the key to Europe’s future – guidelines for future European Union policy to support research COM (2004) 353 EU, Brussels

European Commission 2004b, Building our common future: policy challenges and budgetary means of the enlarged Union, 2007–2013 COM (2004) 101 EU, Brussels

Eveland, J. D. 1987, “Diffusion, technology transfer, and implementation” Knowledge, 8(2): 303-22.

Farris, Vaughan, Wills & Murphy and Price Waterhouse Coopers (PWC) 2002, “Promoting growth of the Biotechnology industry in British Columbia”.

Faulkner, W. and Senker, J. 1995, “Knowledge Frontiers: Public Sector Research and Industrial Innovation in Biotechnology, Engineering Ceramics, and Parallel Computing” Clarendon Press, Oxford.

Feldman, M.P. 2000, “Where Science Comes to Life: University Bioscience, Commercial Spin-offs, and Regional Economic Development” Journal of Comparative Policy Analysis: Research and Practice, 2: 345-361.

Feldman, M.P. and Ronzio, C.R. 2001, “Closing the innovative loop: moving from the laboratory to the shop floor in biotechnology manufacturing”

Entrepreneurship & Regional Development, 13: 1-16.
Feldman, M.P; Feller, I.; Bercovitz, J. and Burton, R. 2002, "Equity and the Technology Transfer Strategies of American Research Universities" Management Science, 48: 105-121.
Feldman, M.P. and Kelley, M.R. 2003, "Leveraging Research and Development: Assessing the Impact of the US Advanced Technology Program" Small Business Economics, 20: 153-165.
Feldman, M.P. and Desrochers, P. 2003, "Research Universities and Local Economic Development: Lessons from the History of the Johns Hopkins University" Industry and Innovation, 10: 1-24.
Feldman, M.P. and Desrochers, P. 2004 "Truth for its Own Sake: Academic Culture and Technology transfer at Johns Hopkins University" Minerva, 41: 105-126
Feller, I. 1990, "Universities as engines of R&D-based economic growth: they think they can" Research Policy, 19: 335–348.
Feller, I.; Feldman, M.P.; Bercovitz, J. and Burton, R. 2002, "The State of Practice for University Technology Transfer Activities" Research Management Review, 12: 8-16.
Fisher, D.; Atkinson-Grosjean, J. and House, D. 2001, "Changes in Academy/Industry/State Relations in Canada: The Creation and Development of the Networks of Centres of Excellence" Minerva, 39(3): 299-325.
Florida, R. 1999, 'The Role of the University: Leveraging Talent, Not Technology" Issues in Science and Technology, (Summer, 1999), p. 72.
Florida, R., 2002, The Rise of the Creative Class: And How Its Transforming Work, Leisure, Community and Community and Everyday Life, (New York: Basis Books, 2002)
Foray, D. 1994, "Production and Distribution of Knowledge in the New Systems of Innovation: the Role of Intellectual Property Rights" STI Review, No. 14
Freeman, C. and Hagedoorn, J. 1994, "Catching up or falling behind: patterns in international interfirm partnering" World Development, 22: 771–780.
Friedman, J. and Silberman, J. 2003, "University technology transfer: the impact of organization and environment" Journal of Technology Transfer, 28: 17–30.
Gambardella, A. 1992, "Competitive advantages from in-house scientific research: The US pharmaceutical industry in the 1980s" Research Policy, 21(5): 391-407.
Gertler M.S. and DiGiovanna S., 1997, "In search of the new social economy: collaboration relations between users and producers of advanced manufacturing technologies" Environment and Planning A, 29: 1585–1602.
Gertler, M.S.; Florida, R.; Gates, G. and Vinodrai, T. 2002, "Competing on Creativity: Placing Ontario's Cities in North American Context" A report prepared for the Ontario Ministry of Enterprise, Opportunity and Innovation and the Institute for Competitiveness and Prosperity, (Toronto, 2002).
Gertler, M.S. and Levitte, Y.M. 2005, "Local Nodes in Global Networks: The Geography of Knowledge Flows in Biotechnology Innovation" Industry and Innovation, 12(4): 487–507.
Gerybadze, A, and Reger, G. 1999, "Globalization of R&D: recent changes in the management of innovation in transnational corporations" Research Policy, 28: 251–274.
Gibbons, M. and Johnston, R. 1974, "The Role of Science in Technological Innovation" Research Policy, 3: 220-242.
Glasmeier, A. 1991, "Technological Discontinuities and Flexible Production Networks: The Case of Switzerland and the World Watch Industry" Research Policy, 20: 469-485.
Gomes-Casseres, B., 1996, "The Alliance Revolution: The New Shape of Business Rivalry" Harvard University Press, Cambridge, MA
Gopalakrishnan, S. and Santoro, M.D. 2004, "Distinguishing Between Knowledge Transfer and Technology Transfer Activities: The Role of Key Organizational Factors" IEEE Transactions on Engineering Management, 51: 57-69.
Gould, R.V. 1993, "Collective Action and Network Structure" American Sociological Review, 58(2): 182-196.
Government of Canada 1996, Science and Technology for the New Century: A Federal Strategy (Ottawa: Minister of Supply and Services Canada) 1996.
Government of Canada 1999, Building Momentum: A Report on Federal Science and Technology - 1998 (Ottawa: Industry Canada) 1999.
Grayteck Management; Voyer, R.; Niosi, J.; Materazzi, F, and Makhija, N. 2004. "ICT/Life Sciences Converging Technologies Cluster Study: A Comparative Study of the Information and Communications, Life Sciences, and Converging Next Generation Technology Clusters in Vancouver, Toronto, Montreal and Ottawa" Report Prepared for: ICT and Life Sciences Branches of Industry Canada and the National Research Council. November 25, 2004.
Gulati R., 1998, "Alliances and Network" Strategic Management Journal, 19: 293–317.

Gupta, A.K. and Govindarajan, V. 2000, “Knowledge flows within multinational corporations” Strategic Management Journal, 21(4): 473 – 496.
Hagedoorn, J. 1993, “Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences” Strategic Management Journal, 14: 371-385.
Hagedoorn, J. 1995, “Strategic technology partnering during the 1980s: trends, networks and corporate patterns in non-core technologies” Research Policy, 24: 207–231.
Hagedoorn, J. 2002, “Inter-firm R&D partnerships: an overview of major trends and patterns since 1960” Research Policy, 31: 477–492
Hagedoorn, J.; Link A.N. and Vonortas, N.S. 2000, “Research Partnerships” Research Policy, 29(4-5): 567-586.
Hakanson, L. 1995, “Learning through Acquisitions: Management and Integration of Foreign R&D Laboratories” International Studies of Management & Organization, 25: 121-155.
Hall, B.H. 2005, “Exploring the Patent Explosion” Journal of Technology Transfer, 30(1/2): 35–48.
Hamel, G. 1991, “Competition for Competence and Inter-Partner Learning Within International Strategic Alliances” Strategic Management Journal 12: 83-103.
Hansen, M.T. 1999, “The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge across Organization Subunits” Administrative Science Quarterly, Vol. 44, 1999.
Harrigan, K.R. 1988, “Joint ventures and competitive strategy” Strategic Management Journal, 9: 141-158.
Haspeslagh, P.C. and Jemison, D.B.1991, “Managing acquisitions: Creating value through corporate renewal” New York: The Free Press.
Hearn, G.; Cunningham, S. and Ordonez, D. 2004, “Commercialization of Knowledge in Universities: The Case of the Creative Industries” Prometheus, 22: 189-200.
Hedlund, G. 1986, “The hypermodern MNC-A heterarchy?” Human Resource Management, 25: 9-36.
Hedlund, G. 1994, “A Model of Knowledge Management and the N-Form Corporation” Strategic Management Journal, 15: 73-90.
Heim, C. E. 1988, “Government research establishments, state capacity and distribution of industrial policy in Britain” Reg. Studies, 22: 375-386.
Hirshhorn, R.; Nadeau, S. and Rao, S. 2000, “Innovation in a Knowledge-Based Economy: The Role of Government”. Productivity issues in a Canadian Context – pacific.commerce.ubc.ca.
Holtum, D. 2003, “Review of industrial case” Unpublished report prepared for the EPSRC
Inkpen, A.C. 1992, “Learning and collaboration: An examination of North American - Japanese Joint Ventures” Unpublished doctoral dissertation, The University of Western Ontario.
Inkpen, A. C. 1995, “The Management of International Joint Ventures: An Organizational Learning Perspective” London: Routledge.
Inkpen, A.C. and Crossan, M. 1996, “Believing is seeing: Joint ventures and organizational learning” Journal of Management Studies. 32(5): 595-618.
Inkpen, A.C. and Beamish, P.W. 1997, “Knowledge, Bargaining Power, and the Instability of International Joint Ventures” Academy of Management Review, 22(1): 177-202.
Inkpen, A.C. and Dinur, A. 1998, “Knowledge Management Processes and International Joint Ventures” Organization Science, 9: 454-468.
Irwin, K.S. and Dries, S. 2002, “Research Contracting with Industry: Basic Legal and Contractural Principles” Research Management Review, 12: 17-28.
Jacobson, N.; Butterill, D. and Goering, P. 2004, “Organizational Factors that Influence University-Based Researchers’ Engagement in Knowledge Transfer Activities” Science Communication, 25(4): 246-259.
Jaffe, A.B. and Lerner, J. 2001, “Reinventing Public R&D: Patent Policy and the Commercialization of National Laboratory Technologies” The Rand Journal of Economics, 32: 167-198.
Jemison, D.B. and Sitkin, S. 1986, “Acquisitions: The process can be a problem", Harvard Business Review, 64(2): 107-111.
Jensen, R. and Thursby, M. 2001, “Proofs and prototypes for sale: the tale of university licensing” American Economic Review, 91(1): 240–259.
Johanson, J. and Vahlne, J.E. 1977, “The internationalization process of the firm - A model of knowledge development and increasing foreign market commitments” Journal of International Business Studies 8: 23-32.
Jorda, K. 1999, “Legal Aspects of Licensing of Technologies Developed in Universities and Research Institutions” The Franklin Pierce Intellectual Property Mall, August 1999 www.ipmall.fplc.edu/pubs/speeches/jorda_08_10_99.htm
Kalaignanam, K.; Shankar, V. and Varadarajan, R. (2007), “Asymmetric New Product Development Alliances: Win-Win or Win-Lose Partnerships?” Management Science, in press.

Katz, R. and Tushman, M.L. 1983, "A Longitudinal Study of the Effects of Boundary Spanning Supervision on Turnover and Promotion in Research and Development" The Academy of Management Journal, 26(3): 437-456

Kennedy-Minott, R. 1983, "Technology transfer: An overview" Telecommunications, 17:104-108.

Khanna, T.; Gulati, R. and Nohria, N. 1998, "The Dynamics of Learning Alliances: Competition, Cooperation, and Relative Scope" Strategic Management Journal, 19(3): 193-210.

Killoren, R. 1989, "Institutional conflict of interest" Research Management Review, 3(2): 1-12.

Klevorick, A.; Levin, R.; Nelson, R. and Winter, S. 1995, "On the sources and significance of interindustry differences in technological opportunities" Research Policy, 24: 185–205.

Kogut, B. 1988, "Joint ventures: Theoretical and empirical perspectives" Strategic Management Journal, 9: 319-322.

Kogut, B. and Kim, D.J. 1991, "Technological Platforms and the Sequence of Entry" Working Paper, Reginald H. Jones Center, Wharton School.

Kuemmerle W. 1997, "Building effective R&D capabilities abroad" Harvard Business Review, 75(2): 61-70.

Leaf, C. 2005, "The Law of Unintended Consequences", Fortune, Sept 19, 2005

Lee, Y. 1995, "The academic climate and technological innovation" Final report to the NSF, Research on Science and Technology Program, SBR 9314.

Lee, Y. 1996, "Technology transfer and the research university: a search for the boundaries of university industry collaboration" Research Policy, 25: 843–863.

Lee, Y. and Gaertner, J.W. 1994, "Policy Studies Journal. Technology transfer from university to industry: A large scale experiment with technology development and commercialization" Symposium on Technology Transfer and Public Policy, 22(2): 384.

Lenetsky, M.S. 2002, "Technology Transfer Developments in University-Start Up Interaction: Modeling the Relationships" Research Management Review, 12: 29-40.

Lerner, J. 2005, "The University and the Start-Up: Lessons from the Past Two Decades" The Journal of Technology Transfer, 30: 49-56

Levin, R.; Klevorick, A.; Nelson, R. and Winter, S. 1987, "Appropriating the returns from industrial R&D" Brookings Papers Econ. Activity 3, 783–831.

Levin, S. and Stephan, P. 1992, "Striking the Mother Lode in Science: The Importance of Age, Place and Time" Oxford University Press, April 1992.

Li, J. 1995, "Foreign Entry and Survival; Effects of Strategic Choice on Performance in International Markets" Strategic Management Journal, 16(5): 333-351.

Liebeskind, J.P. 1996, "Knowledge, Strategy and the Theory of the Firm" Strategic Management Journal 17: 93-107.

Lindgren, U. 1982, "Foreign acquisitions: Management of the integration process" Stockholm: Institute of International Business.

Lipsey, R.G. and Carlaw, K. 1998, "A Structuralist Assessment of Technology Policies - Taking Schumpeter Seriously on Policy" Industry Canada Working Paper No. 25, October 1998.

Lord, M.D. and Ranft, A.L. 2000, "Organizational Learning about New International Markets: Exploring the Internal Transfer of Local Market Knowledge" Journal of International Business Studies, Winter 31(4): 573

Lorenzoni, G. and A. Lipparini, 1999, The leveraging of interfirm relationships as a distinctive organizational capability: a longitudinal study, Strategic Management Journal, 20, pp. 317-338.

Lucas, M.J.W. 2005, "Bridging a Cultural Divide: Strengthening Similarities and Managing Differences in University-Industry Relations" Ph.D. Dissertation, (Toronto: University of Toronto, 2005).

Lundvall, B.A. and Johnson, B. 1994, "The Learning Economy," Journal of Industry Studies 1(2): 23-42.

Lundvall, B.A. 2004, "Why the New Economy is a Learning Economy" DRUID Working Paper No. 04-01, (Copenhagen 2004).

Madhok, A. 2006, "Revisiting multinational firms' tolerance for joint ventures: a trust-based approach" Journal of International Business Studies, 37: 30-43.

Madill, J.J.; Haines Jr, J.H. and Riding, A.L. 2004, "Networks and linkages among firms and organizations in the Ottawa-region technology cluster" Entrepreneurship & Regional Development, 16: 351–368.

Makhija, M.V. and Ganesh, U. 1997, "The relationship between control and partner learning in learning related joint ventures" Organization Science, 8(5): 508–527.

Mansfield, E.; Romeo, A. and Wagner. S. 1979, "Foreign trade and US research and development" Review of Economics and Statistics, 61: 49-57.

Mansfield, E. and Romeo. A. 1980, "Technology transfer to overseas subsidiaries by US-based

firms" Quarterly Journal of Economics, 95: 737-750.
Mansfield, E. 1985, "How rapidly does new industrial technology leak out" Journal of Industrial Economics, 34: 217-223.
Mansfield, E. 1986, "Patents and Innovation: An Empirical Study," Management Science, 32: 2.
Marasco, C.A. 2003, "Industrial Postdocs: Engaging Science" Chemical & Engineering News, 81(39): 57-62.
Martin, B. and Irvine, J. 1984, "Foresight in Science: Picking the Winners", (Pinter, London, 1984).
McDonald and Associates 2001, (http://www.macdonaldandassociates.com).
McFetridge, D.G. 1993, "The Canadian System of Industrial Innovation" in R.R. Nelson ed. National Innovation Systems (New York, Oxford University Press, 1993) pp.299-323.
McFetridge, D.G. 1998, "Intellectual Property, Technology Diffusion, and Growth in the Canadian Economy," in R.D. Anderson and N.T. Gallini (eds.) Competition Policy and Intellectual Property Rights in the Knowledge-Based Economy (Calgary: Univ. of Calgary Press).
Malecki, E. and Veldhoen, M.E. 1993, "Networks Activities, Information and Competitiveness in Small Firms" Geografiska Annaler, 75: 131–147.
Malecki, E. and Tootle D.M. 1996, "The Role of Networks in Small Firm Competitiveness. International" Journal of Technology Management, 11(1/2): 43–55.
Malecki, E. 1997, "Technology and Economic Development: The dynamics of local, regional and national competitions" Longman, London.
Merton, R.K. 1957, "Priorities in scientific discovery: a chapter in the sociology of science." American Sociological Review, 22: 635–639.
Michalet C. 1991, "Strategic partnerships and the changing internationalization process" In: Mytelka L. (ed.), Strategic Partnerships: States, Firms, and International Competition. pp. 7 - 34, Frances Pinter, London.
Morgan, K. 1991, "Competition and collaboration in electronics: what are the prospects for Britain?" Environmental and Planning A, 23: 1459–1482.
Morissette, R. 2004, "Relative Wage Patterns among the Highly Educated in a Knowledge-based Economy" (Ottawa: Statistics Canada, 2004).
Morris, Claire. "Creating the knowledge for a better future" The Ottawa Citizen (for AUCC), Sept 29. (2004): A16.
Mowery, D.C.; Oxley, J.E. and Silverman, B.S. 1996, "Strategic alliances and interfirm knowledge transfer" Strategic Management Journal, 17 (Winter special issue): 77-92.
Mowery, D.C.; Oxley, J.E. and Silverman B.S. 1998, "Technological overlap and interfirm cooperation: Implications for the resource-based view of the firm" Research Policy, 27, pp. 507-523.
Mowery, D.C., Nelson, R.R., Sampat, B.N., Ziedonis, A.A., 2001. "The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–Dole act of 1980" Research Policy 30, 99–119.
Mowery, D.C. and Sampat, B.N. 2005, "The Baye-Dole Act of 1980 and University-Industry Technology Transfer: A Model for other OECD Governments?" The Journal of Technology Transfer, 30: 115-127.
Muir, A. 1997, "The technology transfer system". New York: Latham Book Publishing, pp. 24, 37, 38.
Nelson, R.R. 1987, "Understanding technical change as an evolutionary process" (Elsevier Science Pub. Co., Amsterdam, 1987).
Nelson, R.R. and Winter S.G. 1982, "An Evolutionary Theory of Economic Change" (Cambridge, Mass.: Belknap Press, 1982), pp. 76-82.
Nelson, R.R. and Rosenberg, N. 1993, "Technical Innovation and National Systems," in Richard R. Nelson (ed.) National Innovation Systems: A Comparative Analysis, Oxford University Press.
Nonaka, I. and Takeuchi, H. 1995, "The knowledge-creating company" New York: Oxford University Press.
Novis, S. 1993, "Technology transfer: A case study regarding the impact of closer industrial-university relations at Rutgers University Since 1980" Seton Hall.
OECD draft, "Programs to Promote a Knowledge-based Economy: A Summary of Selected Programs in OECD Countries," draft discussion paper
OECD 1992, "Technology and the Economy" (Paris: OECD, 1992)
OECD 1997, University Research in Transition, Directorate for Science, Technology and Industry, DSTI/STP/SUR (97)3/REV2, p. 69.
OECD 1998, OECD, Science, Technology and Industry Outlook 1998 (Paris: OECD, October 1998).
OECD 2000, "The Internationalization of Venture Capital Activity" (Paris: OECD, 2000).
OECD 2005, OECD Science, Technology and Industry Scoreboard 2005 (Paris: Organisation for Economic Co-operation and Development, October 2005).

OST 2002, "Investing in innovation: a strategy for science, engineering, and technology" (HSMO, London, 2002).

Pavitt, K. 1971, "The multinational enterprise and the transfer of technology" In J. H. Dunning, editor, The multinational enterprise. London: George Allen & Unwin.

Pavitt, K. 1991, "What Makes Basic Research Economically Useful?" Research Policy 20: 109-19.

Pearce, R. and Papanastassiou, M. 1999, "Overseas R&D and the strategic evolution of MNEs: evidence from laboratories in the UK" Research Policy, 28(1): 23-41.

Pisano G., Russo M. and Teece D., 1988, "Joint Ventures and Collaborative Arrangements in the Telecommunications Equipment Industry" In: Mowery D. (ed.), International Collaborative Ventures in US Manufacturing. Ballinger, Cambridge, Mass.

Pittaway, L.; Robertson, M.; Munir, K.; Denyer, D. and Neely, A. 2004, "Networking and innovation: a systematic review of the evidence". International Journal of Management Reviews, 5/6 (3&4): 137-168.

Polanyi, M. 1962, "Personal Knowledge: Towards a Post-Critical Philosophy" (New York: Harper and Row, Harper Torchbooks/Academy Library, 1962).

Porter, M.E., 1987. "From competitive advantage to corporate strategy" Harvard Business Review, May–June, 43–59.

Porter M., 1990, "The Competitive Advantage of Nations", New York.

Powell W.W., 1987, "Hybrid organizational Arrangements: New Form or Transitional Development?" California Management Review 30: 67–87.

Powell, W.W. and Owen-Smith. J. 1998, "Commercialism in Universities : Life Sciences Research and its Linkage with Industry." Journal of Policy Analysis and Management, 17(2): 253-277.

Powell, W.W.; Koput, K.W. and Smith-Doerr, L. 1996, "Interorganizational Collaboration And The Locus Of Innovation: Networks Of Learning In Biotechnology" Administrative Science Quarterly, 41: 116-145.

Raco M., 1999, "Competition, Collaboration and the New Industrial Districts: Examining the Institutional Turn in Local Economic Development" Urban Studies, 36(5–6): 951–968.

Rees, K. 2005, "Interregional Collaboration and Innovation in Vancouver's Emerging High-Tech Cluster" Tijdschrift voor Economische en Sociale Geografie, 96(3): 298–312.

Roberts, E.B., 1988, "Managing invention and innovation: what we've learned." Research Technology Management 31: 11–29.

Rogers, E.M. 2002, "The Nature of Technology Transfer". Science Communication, 23: 323-341.

Rood, S.A. 2000, "Government Laboratory Technology Transfer: Process and Impact"
Aldershot, U.K.: Ashgate Publishing Company. pp. 381.

Rosenberg, N. 1990, "Why Do Firms Do Basic Research (with Their Own Money)?" Research Policy 19: 165-74

Rosenberg, N. and Frischtak, C. 1991, In: Rosenberg, N. and Frischtak, C. (eds), International Technology Transfer: Concepts, Measures, and Comparison. New York: Praeg

Rosenfeld S.A., 1996, "Does Cooperation enhance competitiveness? Assessing the impacts of inter-firm Collaboration" Research Policy 25: 247–263.

Rothaermel, F.T. and Deeds, D.L., 2004, Exploration and exploitation alliances in biotechnology: a system of new product development. Strategic Management Journal 25: 201–221.

Saha, A.; Love, H.A. and Schwart, R. 1994, "Adoption of Emerging Technologies Under Output Uncertainty," American Journal of Agricultural Economics, Vol. 76, 1994.

Sako, M. 1992, "Prices, Quality and Trust: Inter-firm Relations in Britain & Japan" New York: Cambridge University Press.

Sako, M. 1994, "Supplier Relationships and Innovation," in Mark Dodgson and Roy Rothwell (eds.), The Handbook of Industrial Innovation, Cheltenham, UK and Brookfield, MA: Elgar.

Schaan, S. and Nemes, B., 2002, Methodological Framework: Decisions Taken and Lessons Learned, Statistics Canada- Survey of Innovation 1999, (88F0006XIE No. 12) June 2002.

Schmiemann, M. and Durvy, J-N. 2003, "New Approaches to Technology Transfer from Publicly Funded Research" The Journal of Technology Transfer, 28: 9-15.

Senker, J. 1995, "Tacit Knowledge and Models of Innovation" Industrial and Corporate Change 4(2): 425-47.

Shane, S. 2004, "Encouraging university entrepreneurship? The effect of the Bayh-Dole Act on university patenting in the United States" Journal of Business Venturing, 19: 127-151.

Shrivastava, P. 1986, "Postmerger integration" Journal of Business Strategy, 7(1): 65-77.

Siegel, D.; Waldman, D.A. and Link, A., 2003, "Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study" National Bureau of Economic Research Working Paper No. 7256, Research Policy 32: 27–48.

Siegel, D.S.; Waldman, D.A.; Atwater, L.E and Link, A.N. 2004, "Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies". Journal of Engineering and Technology Management, 21: 115-142.

Smith H.L.; Dickson S.L. and Smith S., L., 1991, "There are two sides to every story: Innovation and collaboration within networks of large and small firms" Research Policy 20: 457–468

Solvell, O. and Zander, I. 1995, "The dynamic multinational enterprise" International Studies of Management and Organization, 25: (1-2).

Sparks, J. 1985, "The creative connection: University-industry relations" Research Management, Nov.-Dec., pp. 19-21.

Statistics Canada 2006, (http://www40.statcan.ca/l01/cst01/scte04.htm).

Stokes, D. 1997, "Pasteur's Quadrant: Basic Science and Technological Innovation" Brookings Institution Press: Washington, D.C.

Suarez-Villa L. and Karlsson, C., 1996, "The development of Sweden's R & D- intensive electronics industries: exports, outsourcing, and territorial distribution" Environment and Planning A 28: 783–817.

Szulanski, G. 1997, "Exploring internal stickiness: Impediments to the transfer of best practice within the firm" Strategic Management Journal, 17 (Summer special issue): 27-43.

Teece, D.J. 1976, "The multinational corporation and the resource cost of international technology transfer" Cambridge, MA: Ballinger.

Teece, D.J. 1977, "Technology transfer by multinational firms: The resource cost of international technology transfer" Economic Journal, 87: 242-261.

Teece, D.J. 1986, "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy" Research Policy, 15: 285-305.

Teece, D.J. 1992, "Competition, Cooperation and Innovation: Organizational Arrangements for Regimes of Rapid Technological Progress," Journal of Economic Behavior and Organization, 18: 1-25.

Traore, N. 2006, "Networks and Rapid Technological Change: Novel Evidence from the Canadian Biotech Industry" Industry and Innovation, 13(1): 41–68.

Tsai, W. 2001, "Knowledge transfer in intra-organizational networks: effects of network position and absorptive capacity on business unit innovation and performance" Academy of Management Journal, 44(5): 996–1004.

Tushman, M.L. 1977, "Communication across organizational boundaries: Special boundary roles in the innovation process" Administrative Science Quarterly, 22: 587-605.

Varga, A. 2000, "Local Academic Knowledge Transfers and the Concentration of Economic Activity," Journal of Regional Science, 40(2): 289-300.

Vernon, R. and Davidson, W.H. 1979, "Foreign production of technology-intensive products by US-based multinational enterprises" Washington DC: National Science Foundation.

Veugelers, R. 1998, "Collaboration in R&D: An Assessment of Theoretical and Empirical Findings" De Economist, 146: 419-443.

von Hippel, E. 1976, "The Dominant Role of Users in the Scientific Instrument Innovation Process" Research Policy, 5: 212-239.

von Hippel, E. 1988, "The Sources of Innovation" New York: Oxford University Press.

Warda, J. 1998, Taxes and Investment: A Policy Dimension and Improving Canada's SR&ED Tax Incentive Program: Ideas from Industry (Ottawa: The Conference Board of Canada, 1998).

Warda, J. 1999, "Government Research Laboratories: Finding the Right Chemistry for the Future," Conference Board of Canada, Ottawa, Members' Briefing No. 276-99, Nov. 1999.

Westney, D.E. 1988, "Domestic and foreign learning curves in managing international cooperative strategies" In F. Contractor & P. Lorange, editors, Cooperative strategies in international business. San Francisco: New Lexington Press.

Winebrake, J.J. 1992, "A study of technology-transfer mechanisms for federally funded R&D" The Journal of Technology Transfer, 17: 1003-1020.

Wolfe, D.A. 2000, "Networking Among Regions: Ontario and The Four Motors For Europe." European Planning Studies 8(3): 267-284

Wolfe, D.A. and Lucas, M.J.W. 2001, "Investing Knowledge in Universities: Rethinking the Firm's Role in Knowledge Transfer," in John de la Mothe and Dominique Foray, eds Knowledge Management in the Innovation Process: Business Practices and Technology Adoption, (Amsterdam: Kluwer Academic Publishers, 2001), pp. 173-91.

Wolfe, D.A. 2002, "Knowledge, Learning and Social Capital in Ontario's ICT Clusters" Paper prepared for the Annual Meeting of the Canadian

Political Science Association, University of Toronto, Toronto, Ontario, May 29-31, 2002.
Wolfe, D.A., ed., 2003 Clusters Old and New: The Transition to a Knowledge Economy in Canada's Regions, Editor (Montreal and Kingston: McGill-Queens University Press for Queen's School of Policy Studies, 2003)
Wolfe, D.A. and Gertler, M.S. 2004, "Clusters from the Inside and Out: Local Dynamics and Global Linkages," Special Theme Issue on Clusters and Local Economic Development, Urban Studies, 41(5): 1055-77.
Wolfe, D.A. and Lucas, M., eds, 2004 Clusters in a Cold Climate: Innovation Dynamics in a Diverse Economy, Editors (Montreal and Kingston: McGill-Queens University Press for Queen's School of Policy Studies, 2004)
Wolfe, D.A. 2006, "Innovation and Research Funding: The Role of Government Support"
Zander, U. 1991, "Exploiting a technological edge: Voluntary and involuntary dissemination of technology" Stockholm: Institute of International Business.
Zieminski, J. and Warda, J. 1999, Paths to Commercialization: University Collaborative Research, Report No. 261-99 (Ottawa: The Conference Board of Canada, 1999).
Zucker, L.G., and Darby, M.R., 1999, "Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry" Proceedings of the National Academy of Science 93: 12709

6.0 Figures

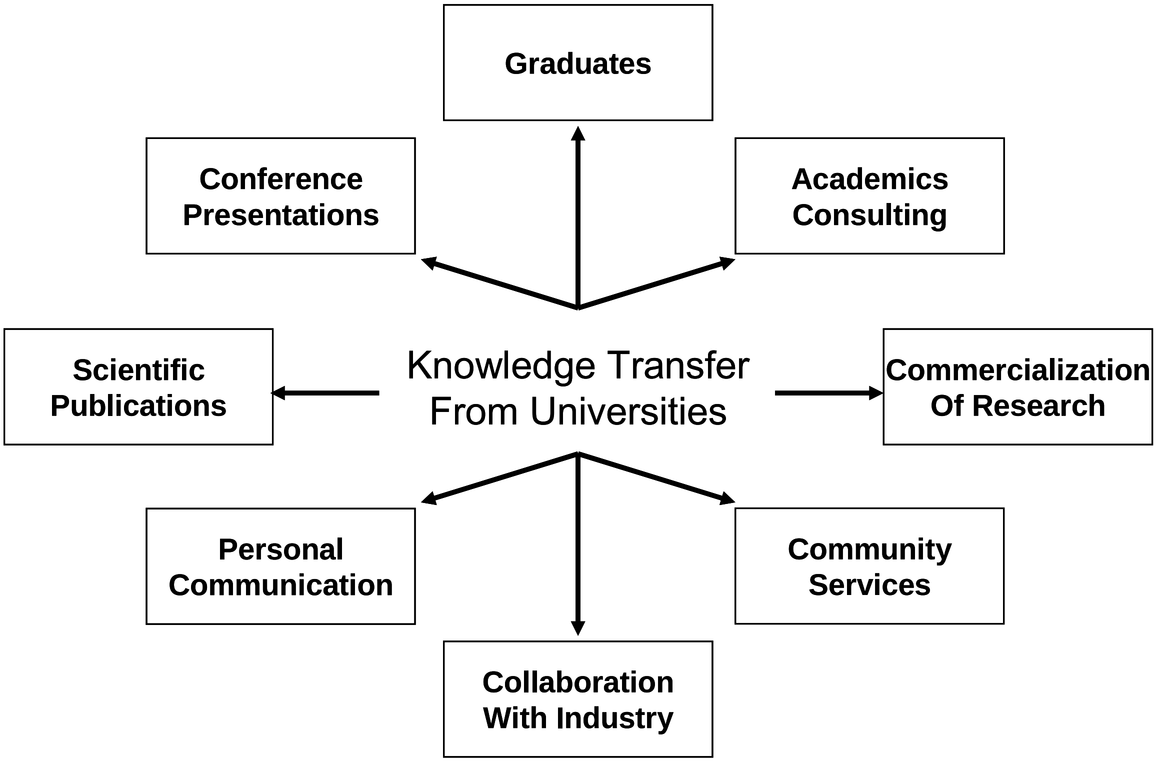


Figure 1 Examples of some knowledge transfer mechanisms from Canadian Universities to the public

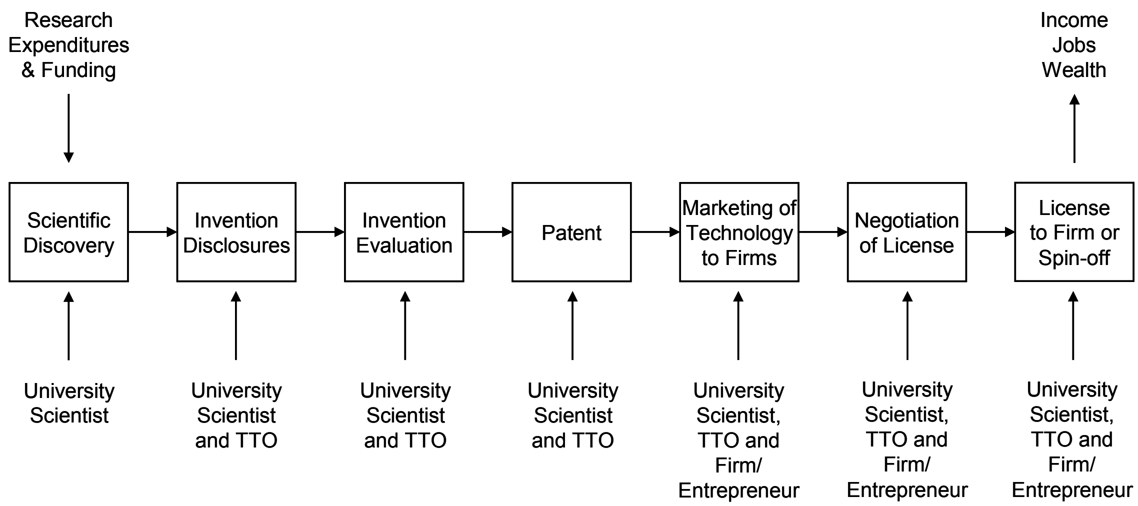


Figure 2 **Theoretical flow of how a technology is transferred from a university to a firm or entrepreneur.**

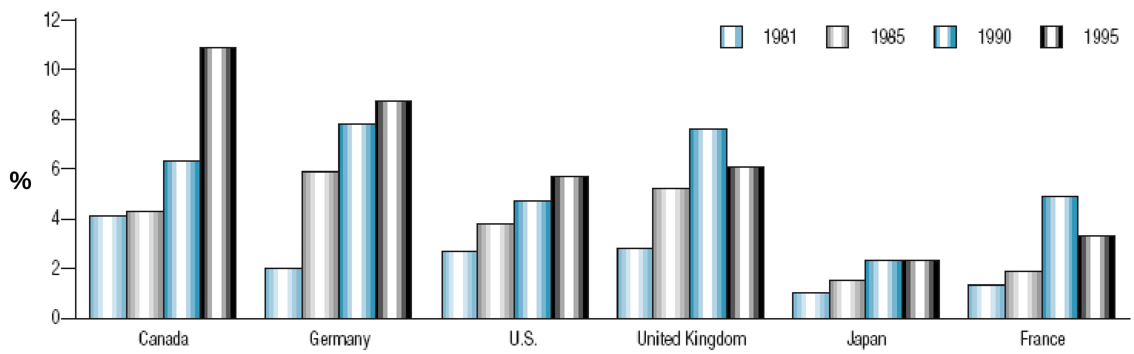


Figure 3 **Private sector funding of University research in Canada v.s. other OECD countries (Conference Board of Canada/Stats Canada)**

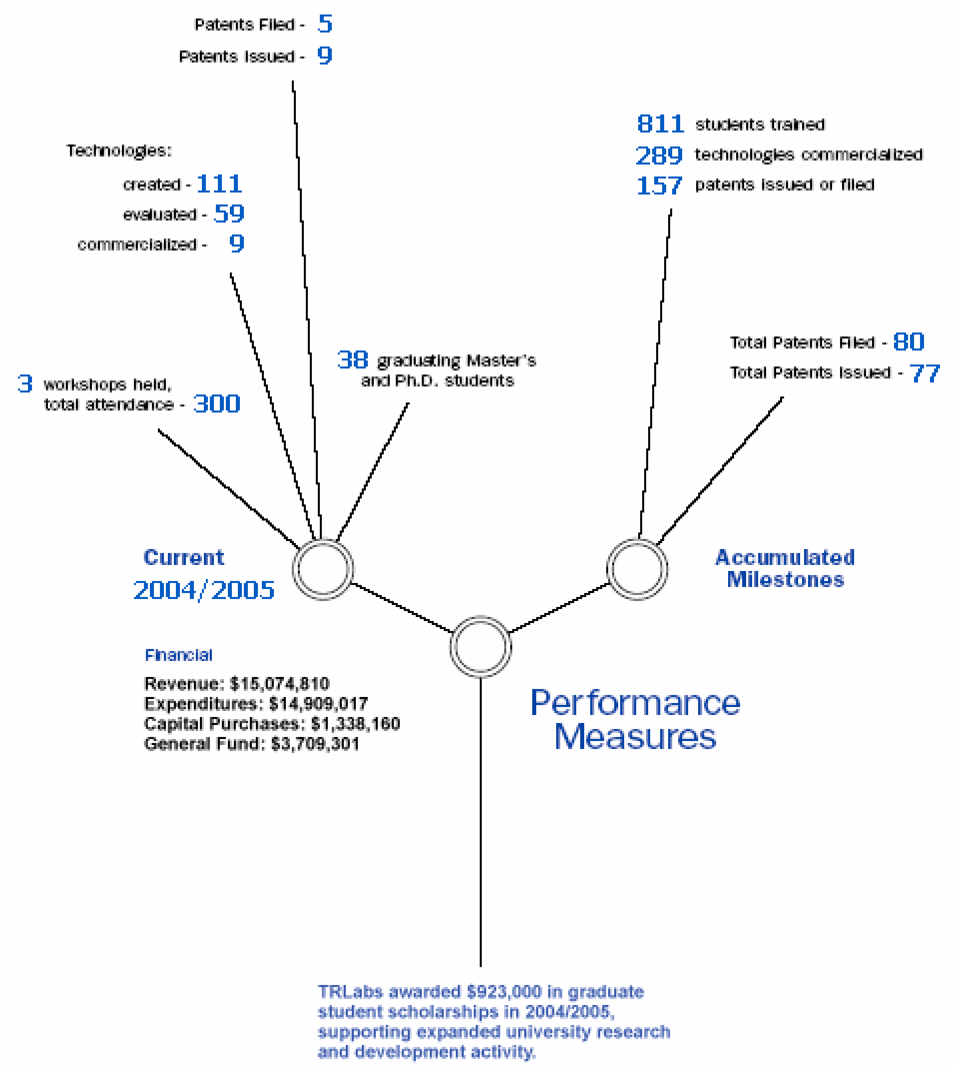


Figure 4 Example of knowledge transfer metric and measurements found in Canada's National Innovations System – TRLabs

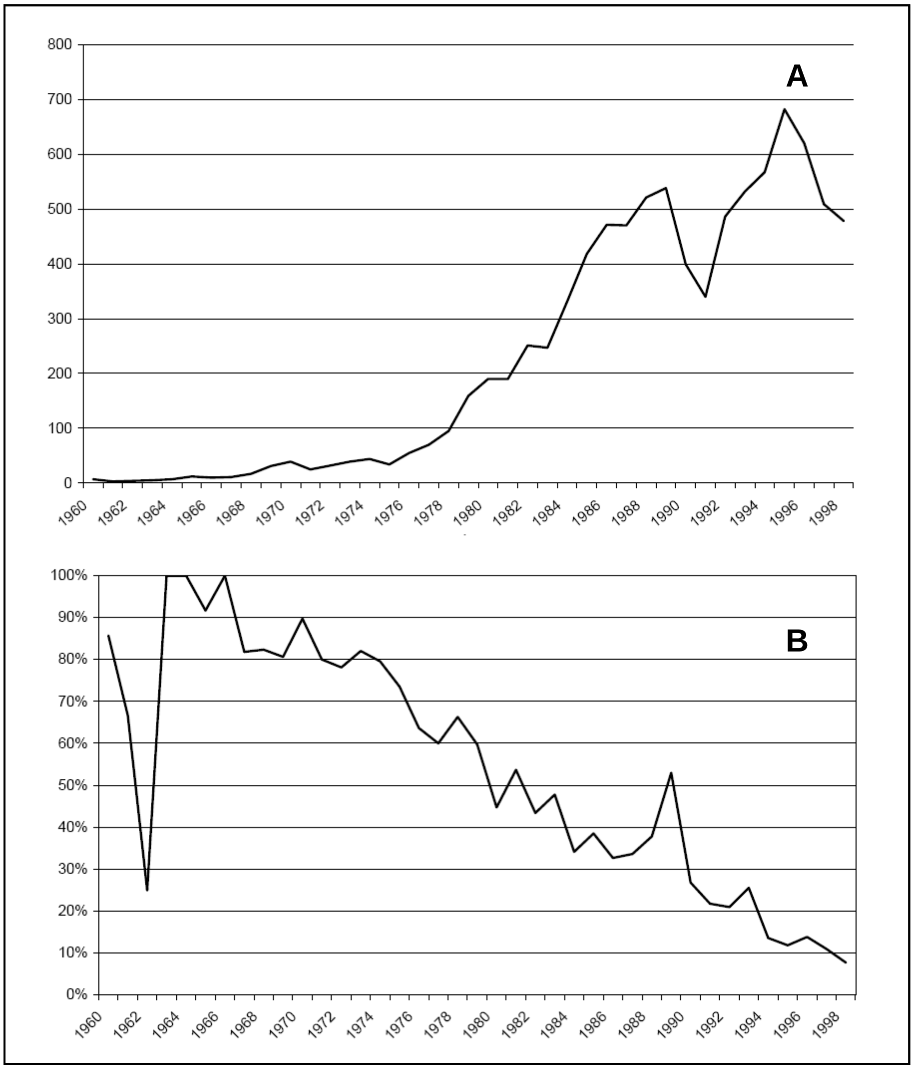


Figure 5 A) The growth of newly established R&D partnerships and B) the share (%) of joint ventures in all newly-established R&D partnerships. All data is taken from Hagendoorn (2002).

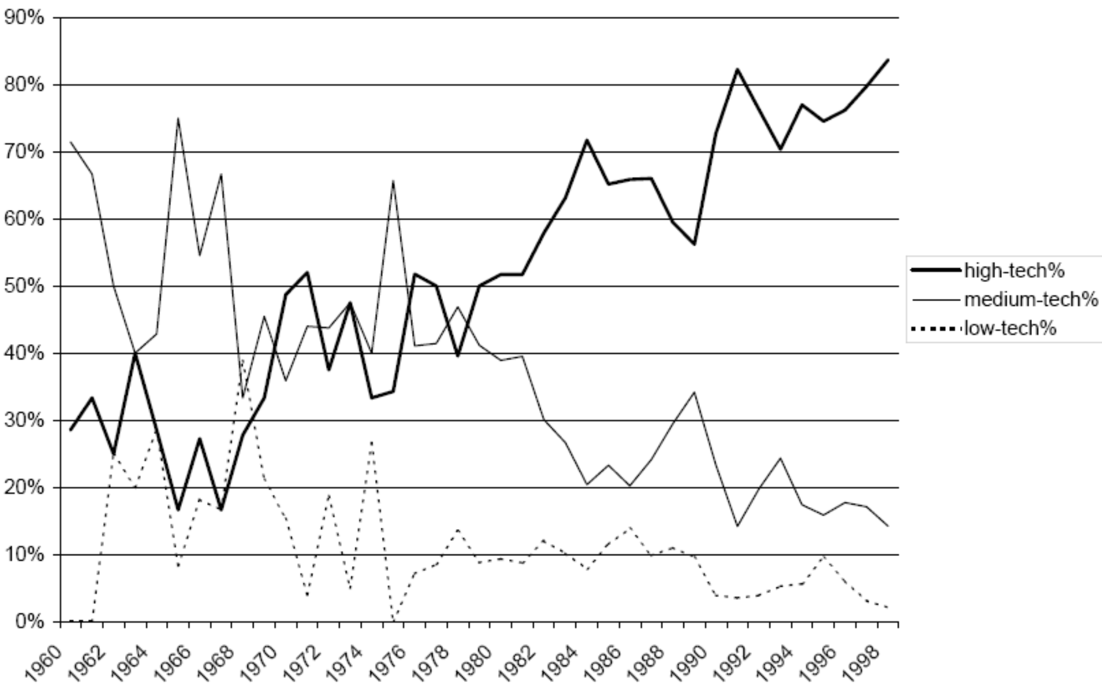


Figure 6 **The share (%) of high-tech, medium-tech and low-tech industries in all newly established R&D partnerships (1960-1998), Hagendoorn (2002).**

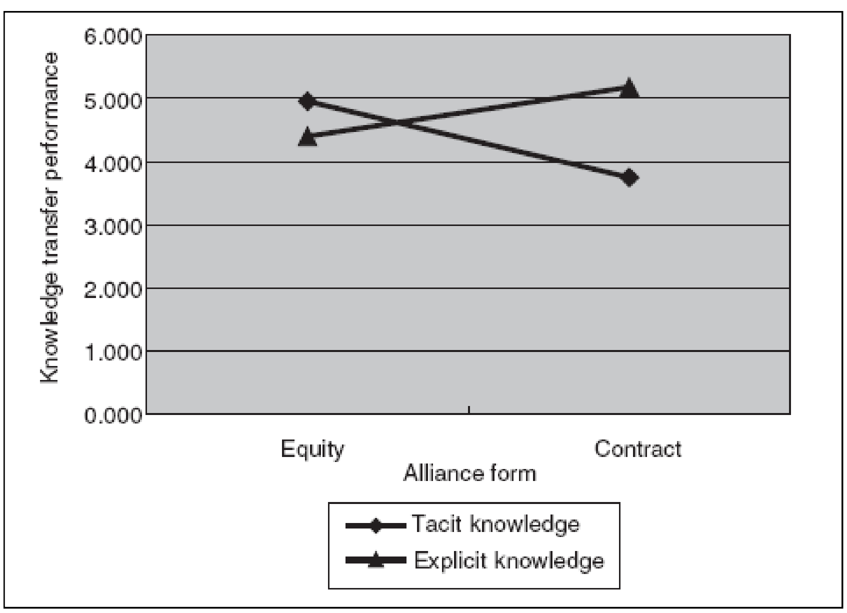


Figure 7 **Interaction effects between knowledge attribute and alliance form (Chen 2004).**

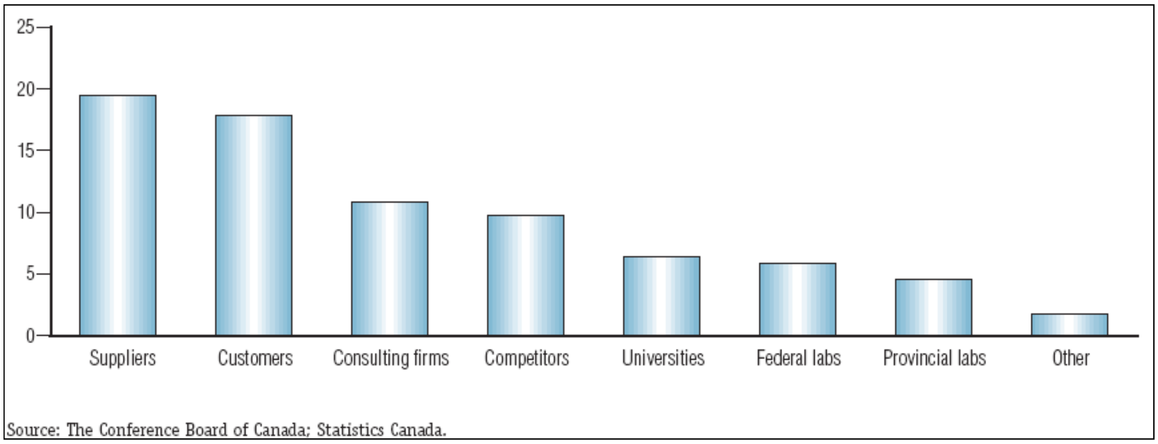


Figure 8 Collaboration preference of Canadian firms in the 1990's is dominated by inter-firm relationships.

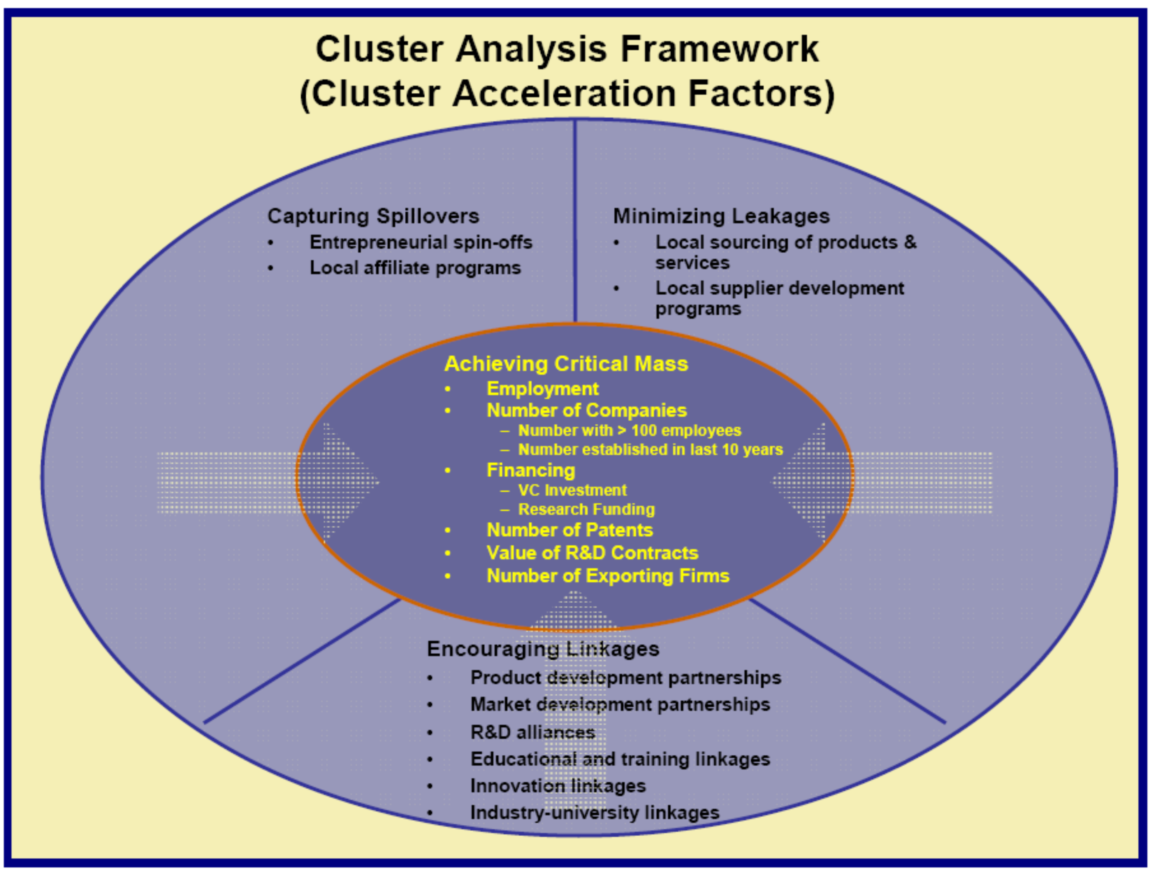


Figure 9 Key drivers involved in building and accelerating cluster capacity for knowledge transfer and competitive advantage (Grayteck, 2004).

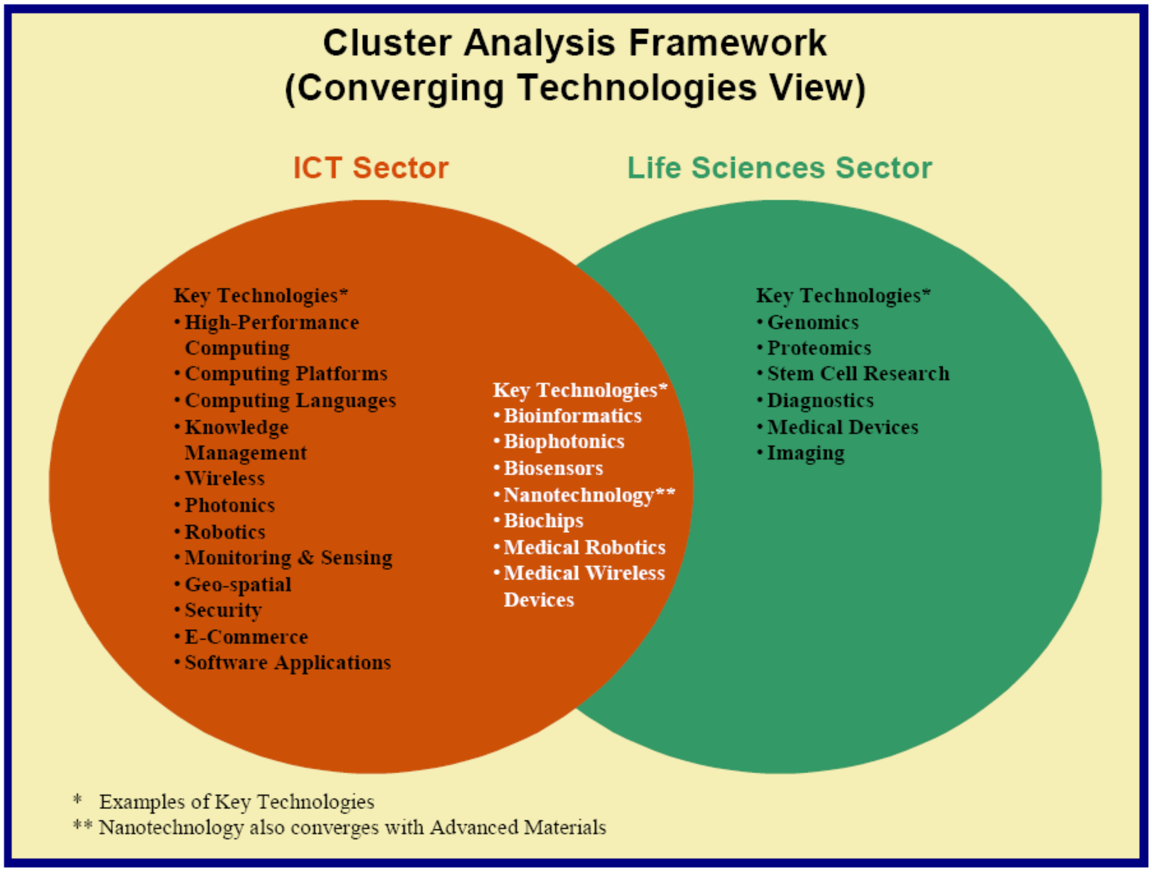


Figure 10 Example of how technologies converge between two separate clusters. Here the presence of diverse technologies within a sector and present in clusters can lead to new, convergent clusters (Grayteck, 2004).

7.0 Tables

Table 1 Key Stakeholders and Their Roles and Motivation in the Transfer of Technology From Universities to the Private Sector

Table 1. Key stakeholders, their roles and representative motives in the transfer of technology from universities to the private sector

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Organizational culture
University scientist	Discovery of new knowledge	Recognition within the scientific community— publications, grants (especially if untenured)	Financial gain and a desire to secure additional research funding (mainly for graduate students and lab equipment)	Scientific
Technology transfer office (TTO)	Works with faculty members and firms/entrepreneurs to structure deals	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm/entrepreneur	Commercializes new technology	Financial gain	Maintain control of proprietary technologies	Organic/entrepreneurial

Table 2 Review of the Key Drivers Affecting University TTO Efficiency

Table 2. Review of the Key Drivers Affecting University TTO Efficiency

Focus	Author	Paper Title	Data Used in Study	Key Findings
Organization, Culture and Location	Friedman & Silberman (2003)	University Technology Transfer: Do Incentives, Management, and Location Matter?	Literature review and analytical models developed from AUTM data	Analysis strongly supports four factors not previously examined in the literature that will enhance university technology transfer: 1) The experience of the university's technology transfer office, 2) Greater rewards for faculty involvement in technology transfer, 3) A clear university mission in support of technology transfer and 4) The location of the university in a region with a concentration of high technology firms.
Communication	Daghfous (2004)	An empirical investigation of the roles of prior knowledge and learning activities in technology transfer	Literature review and analysis based on a survey of 4600 projects undertaken at Penn State.	A significant positive relationship was found between the learning activities performed by the firm during the development and implementation stages of the technology transfer project and the benefits to that firm from the project.
Organizational	Siegel et al (2004)	Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies	Based on 55 structured interviews of 98 UFTT stakeholders associated with five US research universities	Determined that there are numerous impediments to effectiveness in UFTT they are: 1) cultural and informational barriers among the three key stakeholder types (university administrators, academics, and firms/entrepreneurs), 2) TTO staffing and compensation practices, and 3) inadequate rewards for faculty involvement in UFTT. Two somewhat surprising results are that many faculty members have decided to circumvent the formal UFTT process and that involvement in UFTT may actually increase the quantity and quality of basic research.
Organizational Incentives - TTO	Siegel et al (2003)	Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory Study	Quantitative Analysis was Based on 1997 AUTM Report (DEA and SFE), Qualitative Analysis based on 55 interviews of 98 entrepreneurs, scientists, and administrators at five research universities.	Based on our qualitative evidence, we believe that the most critical organizational factors are 1) reward systems for faculty involvement in UITT, 2) compensation and staffing practices in the TTO, and 3) actions taken by administrators to extirpate informational and cultural barriers between universities and firms.
Organizational Form-TTO Managers	Bercovitz et al (2001)	Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins and Pennsylvania State Universities	Case Study from three Universities	The analysis treats the organizational structure (H form, M form, MX form, U form) of the technology-transfer office as an independent variable that accounts, in part, for measured differences in inter-institutional patenting, licensing, and sponsored research activities.
Organization-University Researchers	Jacobson et al (2004)	Organizational Factors that Influence University-Based Researchers' Engagement in Knowledge Transfer Activities	Extensive Literature Review, with a Canadian Focus	Researchers working in Universities report certain structural barriers to engaging in knowledge translation activities. The groups analysis of barriers and solutions suggests that five domains of organizational policy and practice—promotion and tenure, resources and funding, structures, knowledge transfer orientation, and documentation—may be critical to promoting researchers' engagement in knowledge transfer.
Culture	Feldman & Desrochers (2004)	Truth for its Own Sake: Academic Culture and Technology Transfer at Johns Hopkins University	Historical Survey of Johns Hopkins and comparison with current literature.	The institution and its culture largely determines the 'preferred' knowledge transfer mechanism of research to the public.

Table 3 Overview of the IPM Grant Award Recipients (Institutional Cluster and Region)

Table 3. Overview of the IPM Grant Award Recipients (Institutional cluster and Region)

Network Grants

Institutions	Project	Grant
McMaster University University of Guelph University of Waterloo University of Western Ontario University of Windsor Wilfrid Laurier University	IPM Group – Creation of the C4 and the Capacity to Interact With Neighbouring Institutions	$1,725,000
Acadia University Dalhousie University Memorial University of Newfoundland Mount Allison University Mount Saint Vincent University Nova Scotia Agricultural College NSCAD University Saint Mary's University St. Francis-Xavier University St. Thomas University Université de Moncton University College of Cape Breton University of New Brunswick University of Prince Edward Island	IPM Group – Atlantic Research Commercialization Network (ARCN)	$1,545,000
Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain Centre hospitalier de l'Université de Montréal École Polytechnique de Montréal HEC Montréal Hôpital du Sacré-Cœur de Montréal Hôpital Maisonneuve-Rosemont Hôpital Sainte-Justine Institut de cardiologie de Montréal Institut universitaire de gériatrie de Montréal Université de Montréal	IPM Group – Projet VINCI : Valorisation des innovations et du capital intellectuel	$1,380,000
Brandon University CancerCare Manitoba Health Sciences Centre Red River College St. Boniface General Hospital University of Manitoba University of Winnipeg	IPM Group – Manitoba IPM Partnership	$1,200,000
Brock University Lakehead University Laurentian University Nipissing University Ryerson University Trent University University of Ontario Institute of Technology	IPM Group – Ontario Partnership for Innovation & Commercialization	$1,125,000
Mount Sinai Hospital St. Michael's Hospital Sunnybrook & Women's Health Science Centre The Hospital for Sick Children University Health Network University of Toronto	IPM Group – BioDiscovery Toronto	$1,125,000
Camosun College Malaspina University-College North Island College Royal Roads University University of Victoria	IPM Group – Vancouver Island Post-Secondary Educational Institutions Regional Technology Transfer Centre	$930,000
Lady Davis Institute for Medical Research of the Jewish General Hospital McGill University Research Institute of the McGill University Health Centre The Douglas Hospital	IPM Group – Mobilizing and optimizing the performance of the Technology Transfer Network of McGill University through proactive development and incremental activities	$900,000
BC Centre for Disease Control Children's and Women's Health Centre of BC Providence Health Care UBC Okanagan University of British Columbia Vancouver Coastal Health Authority	IPM Group – Enabling & accelerating the transfer of knowledge from UBC, Providence Health Care, BC Centre for Disease Control and UBC Okanagan	$900,000
University of Victoria York University	The Knowledge Broker Model: Knowledge Mobilization for the Social Sciences and Humanities	$665,000
Bloorview MacMillan Children's Center St. Michael's Hospital Sunnybrook and Women's College Research Centre York University	IPM Group – Medical Technologies Research and Commercialization Collaborative	$615,000
Mount Royal College Red Deer College Southern Alberta Institute of Technology University of Calgary University Technologies International Inc.	IPM Group – Southern Alberta Intellectual Property Network (SAIPN)	$582,324
Institut national de la recherche scientifique Université du Québec à Chicoutimi Université du Québec à Trois-Rivières Université Laval	IPM Group – Réseau universitaire en transfert des technologies de l'Est du Québec (RUTTEQ)	$539,200
Algonquin College Carleton University Université du Québec en Outaouais University of Ottawa	IPM Group – Ottawa-Gatineau University-College Regional Innovation Alliance	$504,000
University of Northern British Columbia Westlink Innovation Network Ltd.	IPM Group – The WestLink Technology Bundling Initiative	$450,000
Atlantic Research Commercialization Network (ARCN) Bureaux de liaison entreprises-universités (BLEUs) Ontario Society of Excellence in Technology Transfer (OnSETT) University of British Columbia WestLink Innovation Network	IPM Group – Alliance for Commercialization of Canadian Technology (ACCT)	$80,000

Internship Grants

Institutions	Project	Grant
University of Northern British Columbia WestLink Innovation Network Ltd.	IPM Internship – Addressing the Spectrum	$900,000
Acadia University Cape Breton University Dalhousie University Memorial University of Newfoundland Mount Allison University Mount Saint Vincent University Nova Scotia Agricultural College NSCAD University St. Francis Xavier University St. Mary's University St. Thomas University Université de Moncton University of New Brunswick University of Prince Edward Island	IPM Internship – Springboard Initiative, Interns in Innovation	$576,000
Bishop's University École de technologie supérieure École Polytechnique de Montréal HEC Montréal Institut national de la recherche scientifique McGill University Université de Moncton Université de Montréal Université de Sherbrooke Université du Québec Université du Québec à Montréal Université du Québec à Trois-Rivières Université du Québec, TÉLUQ Université Laval	IPM Internship – Programme de formation en valorisation de technologies (PFVT)	$500,000
Brock University McMaster University University of Guelph University of Waterloo University of Western Ontario University of Windsor Wilfrid Laurier University	IPM Internship – South-western Ontario Internship Program	$400,000
École de technologie supérieure École nationale d'administration publique Institut national de la recherche scientifique Université du Québec Université du Québec à Chicoutimi Université du Québec à Montréal Université du Québec à Rimouski Université du Québec à Trois-Rivières Université du Québec en Abitibi-Témiscamingue Université du Québec en Outaouais	IPM Internship – Réseau ValoRIST : Valorisation de la recherche et de l'innovation sociale et technologique	$365,000
Kingston General Hospital Queen's University Royal Military College of Canada	IPM Internship – Internship Program, PARTEQ Innovations	$131,000

** www.nserc.gc.ca*

Table 4 Overview of the IP Ownership Policies of Select Canadian Universities

Table 4. Overview of the IP Ownership Policies of Select* Canadian Universities

		IP Ownership		
INSTITUTION	**Province**	**Institution****	**Inventor**	**Joint**
University of Ottawa	ON	1		
Ottawa Health Research Inst.	ON	1		
Ottawa Heart Inst. Research Corporation	ON	1		
Carleton University	ON		1	
Queen's University	ON		1	
University of Toronto*	ON			1
University Health Network (PMH, TG, Western)	ON	1		
The Hospital for Sick Children	ON	1		
St Michaels	ON		1	
SunnyBrook	ON	1		
Womens College	ON	1		
Mt Sinai	ON	1		
York University	ON		1	
McMaster University	ON	1		
University of Waterloo	ON		1	
Wilfred Laurier	ON		1	
Univ of Guelph	ON	1		
University of Western Ontario	ON		1	
Memorial Univ of Newfoundland	NF	1		
Acadia University	NS		1	
University of New Brunswick	NB		1	
Ecole De Technologie Superieure	QC		1	
McGill University, MUHC, Douglas Hospital & Jewish Hospital Research Centre	QC			1
University de Montreal	QC	1		
University de Sherbrooke	QC			1
University of Manitoba	MB			1
University of Saskatchewan	SK	1		
University of Calgary	AB		1	
University of Alberta	AB		1	
Simon Fraser University	BC		1	
University of British Columbia	BC	1		
Total		*13*	*11*	*4*

* Designed to provide a 'cross section' with focus on Ontario
** Institution = University or Research Hospital
*** The IP Ownership policies are different than the revenue sharing policies

Table 5 University of Toronto Commercialization and Innovation Indicators*

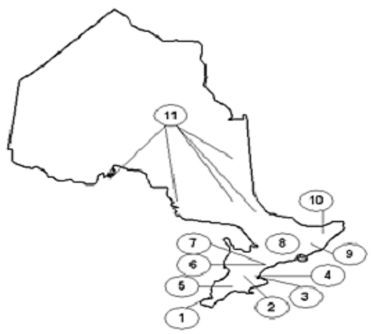
Table 5. University of Toronto Commercialization and Innovation Indicators*

Statistic	Classification	2002-2003	2003-2004	2004-2005
Invention Disclosures	Innovation	138	164	224
Licenses	Commercialization	40	38	28
Active Spin-off Companies**	Commercialization	96	100	103

** Office of the Vice President, Research and Associate Provost 2004-2005 Report, 2005-2006 Plan*
*** Preliminary Number*

Table 6 Ontario's Regional Innovation Networks (RINs)

Table 6. Ontarios Regional Innovation Networks (RINs)*



	Innovation Network	Address
1	Southwestern Ontario Bioproducts Innovation Network (SOBIN)	www.sobin.ca
2	Guelph-Waterloo Partnership in Biotechnology Consortium	www.gwpbiotech.com/
3	Golden Horseshoe Biosciences Network	www.ghbn.org/
4	Western Greater Toronto Area Convergence Centre	www.utm.utoronto.ca
5	London Cluster Consortium	www.ledc.com/home/
6	Biodiscovery Toronto	www.biodiscoverytoronto.ca
7	York Biotech	www.yorkbiotech.ca
8	Greater Peterborough Region DNA Cluster	www.dnapeterborough.ca/
9	Eastern Lake Ontario Regional Innovation Network (ELORIN)	www.kingstonbiotech.com/
10	Ottawa Life Sciences Council (Ottawa and Eastern Ontario)	www.olsc.ca/
11	Northern Ontario Biotechnology Initiative Consortium (NOBI)	www.thunderbay.ca/

**http://www.mri.gov.on.ca/english/programs/RIN-Program.asp*

Table 7 Differentiating Reasons for the Firm's Involvement in Collaboration with a Particular Type of Partner

Table 7. Differentiating Reasons for the Firm's Involvement in Collaboration with a Particular Type of Partner*

Type of Partner	Cost Sharing	Risk Spreading	Accessing R&D	Prototype Development	Scale-up	Expertise	New Markets	Distribution Channels
Competitors	Y	Y					Y	
Clients	Y	Y		Y	Y		Y	Y
Suppliers				Y	Y	Y		
Consulting Firms		Y	Y		Y	Y		Y
Federal Labs	Y		Y					
Provincial Labs							Y	
Universities	Y		Y			Y		

** The Conference Board of Canada, based on Statistics Canada, Survey of Innovation 1999*

Table 8 Drivers of University-Industry Collaboration

Table 8. Drivers of University-Industry Collaboration

Key Advantages to Industry	**Key Success Factors**
• Provides access to leading-edge experise	• Relevance of the research to both university and company
• Provides access to proven talent (professors) and new talent (students)	• Existence of champions on both sides
• Validates the industry project in scientific terms	• Emphasis on teamwork, couples with effective project management
• Gives opportunity to spread financial risks through the potential for shared funding	• Complementarity of expertise
• Allows for savings on the cost of doing research	• Clear understanding of aims and objectives of the program and the expectations of various parties, setting of milestones and specific deliverables
• Provides access to infrastructure, equipment, facilities and administrative and organizational support	• Clarity of policies to deal with intellectual property, conflict of interest, confidentiality and coverage of indirect costs
Key Advantages to Universities	**Key Problem Factors**
• Brings additional research funding into the university from industrial collaborators, sale of research results, and royalties from the sale of commercialized products using tehcnologies licensed out by the university (ie provides receptor)	• Lack of communication between industry and university about their mutual needs
• Increases the chance of the research's commercial application	• Incentive stystems in universities not geared to create motivation for researchers to work with industry
• Enables universities and industry researchers to intereact and learn from each other	• Research in universities not geared to fast-changing priorities of industry
	• Disagreements over the ownership of intellectual property

** Conference Board of Canada*

Table 9 Overview of the NRC Mandate (NRC Act) and Areas of Research and Industry Support

Table 9. Overview of the NRC Mandate (NRC Act) and Areas of Research and Industry Support

Mandate		Areas of Research and Industry Support	
1	Undertaking, assisting or promoting scientific and industrial research in different fields of importance to Canada	**Aerospace**	1 research institute, one technology centre
2	Establishing, operating and maintaining a national science library	**Biotechnology**	6 research institutes
3	Publishing and selling or otherwise distributing such scientific and technical information as the Council deems necessary	**Engineering and Construction**	3 research institutes, 3 technology centres
4	Investigating standards and methods of measurement	**Fundamental Sciences**	3 research institutes
5	Working on the standardization and certification of scientific and technical apparatus and instruments and materials used or usable by Canadian industry	**Industry Support**	One institute, one national program
6	Operating and administering any astronomical observatories established or maintained by the Government of Canada	**Information and Communications Technologies**	2 research institutes
7	Administering NRC's research and development activities, including grants and contributions used to support a number of international activities	**Manufacturing**	4 research institutes, one technology centre
8	Providing vital scientific and technological services to the research and industrial communities. This mandate is discharged to a great extent through the operation of the NRC Industrial Research Assistance Program, the NRC Canada Institute for Scientific and Technical Information and the Canadian Technology Network.		

Table 10 List of Major Provincial Initiatives Created by the Ontario Government to Stimulate Innovation and Knowledge Transfer

Table 10. List of Major Provincial Initiatives Created by the Ontario Government to Stimulate Innovation and Knowledge Transfer

Initiative	Description
The Ontario Research and Development Challenge Fund (Challenge Fund)	The ORDCF is designed to promote research excellence by increasing the R&D capacity of Ontario universities and other research institutions through private and public partnerships. The Challenge Fund will help to ensure that Ontario's universities are able to compete for funding from the Canada Foundation for Innovation on a timely basis. This new program will result in a total of $3 billion of R&D in our universities and other research institutions over the next 10 years.
The Ontario Innovation Trust	Established in 1999 by the Ontario government and endowed with more than $1 billion, invests in research infrastructure - research facilities, equipment and technology - at the province's universities, colleges, hospitals and research institutes. To date, the trust's committed investments total more than $636 million, supporting 728 research projects, involving more than 1,500 researchers and scientists.
The Ontario Research Performance Fund	Established in 2001, the $30 million Fund supports indirect research costs, such as technology transfer operations, libraries, computer networks and research administration-at Ontario's universities, colleges and research institutions.
Ontario Research Commercialization Program	The Ontario Research Commercialization Program (ORCP) is a key component of the government's Research and Commercialization Strategy. The overall goal of the new, three year, $27 million program is to increase Ontario's innovation capacity
Ontario Centres of Excellence	The Government of Ontario established the Ontario Centres of Excellence (OCE) program to strengthen research linkages between academia and industry. OCE's networks help to bridge the gap between research and the marketplace -- bringing universities, industry and government together to help in the application of new science and technology to successful business endeavors.
Ontario Cancer Research Network (OCRN)	The Ontario government has committed $100 million over the next five years to the Ontario Cancer Research Network (OCRN) to accelerate research on promising new cancer therapies, bringing new and innovative treatments to patients sooner.
Ontario Research and Innovation Optical Network (ORION)	The Ontario Research and Innovation Optical Network (ORION) is a $32.3 million Government of Ontario initiative to create a province-wide, high-speed, fibre optic based advanced research network. As of July 2005, 22 regional centres within the ORION network connected 65 institutions across Ontario
Biotechnology Cluster Innovation Program (BCIP)	The Biotechnology Cluster Innovation Program (BCIP) is a key component of the Ministry's Biotechnology Strategy, which aims to make the province one of the top three biotech centres in North America. The goal of the $30 million Biotechnology Cluster Innovation Program is to accelerate the development of Ontario's biotechnology clusters by supporting commercialization infrastructure projects such as research parks and other initiatives that promote entrepreneurship and innovation.
The Ontario Fuel Cell Innovation Program (OFCIP)	The Ontario Fuel Cell Innovation Program (OFCIP) is a discretionary funding program ($500,000 per project) administered by the Ministry of Research and Innovation that focuses on the commercialization of fuel cells and fuel cell-related technologies with an emphasis on moving products to the manufacturing stage
Ontario Regional Innovation Network Program (ORINP)	Ontario is implementing a commercialization framework based on a system of "regional innovation networks." These are multi-stakeholder, regional development organizations established with Provincial funding that support partnerships among business, institutions and local governments to promote innovation
The Premier's Research Excellence Awards	The Premier's Research Excellence Awards is investing $75 million over 10 years to help world-class researchers at universities, colleges, hospitals and research institutes attract talented people to their research teams. To date, PREA has awarded prizes to 303 researchers for a total of $30.3 million.
The Premier's Platinum Awards	This $10 million, six-year program provides two $1 million awards annually to reward the best senior researchers and help universities attract and keep top research talent.

Table 11 Motivation and Issues Associated with Firm-Firm Collaboration

Table 11. Motivation and Issues Associated with Firm-Firm Collaboration*

Key Motives for Allying	Key Problems with Allying
• Sharing of Costs/Risks	• Start-up investments
• Access to partner's know-ho/markets/products	• negotiating costs, invenstment in infrastructure, foregone partnerships
• Efficiency enhancements	
• economies of Scale in production/distribution/R&D	• Coordination and agency costs of running the cooperation
• synergy effects from sharing complementary know-how	• Assymetric information
• Competitive Considerations	• assessment of partner's input (a priori valuation and ex post evaluation)
• monitor/control partners's technolgoy/markets/products	
• influence other alliacne activities (pre-emption, followers)	• Control of information flows between partners
• influence competitive structure	
• Government Policy (industrial, trade and competition policy)	
• e.g. subsidies for cooperation, local content and anti-trust	

** Veugelers 1998*

Table 12 Strategic Alliances: Canada and Selected OECD Countries (1990-1999)

Table 12. Strategic Alliances: Canada and Selected OECD Countries (1990-1999)*

	Total Number of Alliances/Deals	Number of Alliances/Deals per $1B GDP	International Alliances/Deals (% of all Deals)	Share of International Alliances with US Partner as a share of Total International Alliances
United Stat	37,548	4.5	48.3	–
Japan	9,417	3.1	83.7	56.6
Canada	**4,269**	**5.7**	**66.2**	**64.9**
Australia	2,550	6.2	68.9	33.0
United King	5,565	4.3	83.0	44.1
Germany	3,877	2.1	84.8	31.8
France	2,828	2.2	89.6	33.0
Italy	1,430	1.1	86.4	32.3
Finland	450	4.0	84.9	–

** The Conference Board of Canada, based on Statistics Canada, Survey of Innovation 1999*

Table 13 An Overview of Canadian Network and Cluster Research by Region and Sector

Table 13. An Overview of Canadian Network and Cluster Research by Region and Sector

Paper Title	Author	Region	Sector	Key Findings
Interregional Collaboration and Innovation in Vancouver's Emerging Hight Tech Cluster	K. Rees	BC-Vancouver	ICT	Indepth research reveals that interregional collaboration provides firms with vital access to basic research, production expertise and finances that are locally scarce. Most collaborative links are found to be national or international rather than local, although considerable variation is evident between the two industries.
Networks and Rapid Technological Change: Novel Evidence from the Canadian Biotech Industry	N. Traore	Ontario-general	Biotech	Results show that even though networking is a common practice among biotech firms, most of them would rather keep this activity to a minimum. In addition, participation in these networks is found to vary according to the firm's size, stage of development and its sector of activity.
Knowledge, Learning and Social Capital in Ontario's ICT Clusters	D. A. Wolfe	Ontario-general	ICT	One of the key insights of this analysis is the importance of building social capital and trust among the relevant groups and individuals within a cluster. However, trust among economic actors in a local or regional economy is a difficult process that requires a constant dialogue between the relevant parties so that interests and perceptions can be better brought into alignment. As two of the cases studied here suggest, talk and confidence are more likely to succeed when they occur in a setting that is geographically localized and that small, repeated low cost experiments can generate interactive learning between parties in a shared environment.
Knowledge, Innovation and Regional Culture In Waterloo's ICT Cluster	A. Bramwell, J. Nelles & D.A. Wolfe	Ontario-Waterloo	ICT	We suggest that local economic growth in the KW case is a result of the interaction between location, institutions and culture. Where purely locational factors – based on demanding local customers, suppliers and competitors – cannot fully explain the Waterloo cluster, local institutions and cultural characteristics provide the glue to retain and sustain innovative and high tech firms.
Network Structure of an Industrial Cluster: Electronics in Toronto	J.N.H. Britton	Ontario-Toronto	Electronics	Inter-regional and local collaboration vary in importance as a result of scale-dependent resource differences between firms and in response to choices associated with foreign rather than domestic ownership. The results support the rejection of simple models of clusters and learning regions in which internal connections are privileged over inter-regional and international transactions operating either between or within firms
Networks and linkages among firms and organizations in the Ottawa-region technology cluster	J.J. Madill, G.H. Haines & A.L. Riding	Ontario-Ottawa	ICT	Previous work argues that technology firms need to be relatively more adept at developing external relationships in order to be successful than do nontechnology based companies. This work, however, finds that technology firms exhibit fewer linkages than non-technology based companies do within the Ottawa cluster. The research suggests that the vitality of the Ottawa cluster could be further enhanced through the promotion of additional networking and linkages among regional firms. A key implication for management practice is that CEOs of technology-based firms should work towards establishing and maintaining additional valued relationships
Regional Networks of Small and Medium Sized Enterprises: Evidence from the Metropolitan Area of Ottawa in Canada	D. Doloreux	Ontario-Ottawa	SME	The results revealed SMEs rely as much on external networks of customers and suppliers, as they do on ones based in their own region, and that these are considerably more important, than other potential sources of ideas, to the innovation process within the firm
Industrial Clustering and the Returns to Inventive Activity: Canadian Biotechnology Firms, 1991-2000	B.S. Aharonson, J.A.C. Baum & M.P. Feldman	Canada	Biotech	We find clustered firms are eight times more innovative than geographically remote firms, with largest effects for firms located in clusters strong in their own specialization. For firms located in a cluster strong in their specialization we also find that R&D productivity is enhanced by a firm's own R&D alliances and also by the R&D alliances of other colocated firms.
Local Nodes in Global Networks: The Geography of Knowledge Flows in Biotechnology Innovation	M.S. Gertler & Y.M. Levitte	Canada	Biotech	Our findings highlight the importance of inhouse technological capability and absorptive capacity as determinants of successful innovation in biotechnology firms. Furthermore, our results document the precise ways in which knowledge circulates, in both embodied and disembodied forms, both locally and globally. We also highlight the role of formal intellectual property transactions (domestic and international) in promoting knowledge flows. Although we document the importance of global networks in our findings, our results also reveal the value of local networks and specific forms of embedding. Local relational linkages are especially important when raising capital—and the expertise that comes with it—to support innovation.

Table 14 Factors That Help Accelerate the Development of Clusters in Various Industries

Table 14. Comparison of ICT and Life Sciences Cluster Statistics by Region

Cluster Acceleration Factors			ICT Clusters	
	Vancouver	Toronto	Montreal	Ottawa
Achieving Critical Mass	~5600 companies	~9000 companies	>2500 companies	~1500 companies
	~ 56,000 FTE's	185,000 FTE's	~110,000 employees	~64,000 employees
	Few MNE's	Dominated by MNE's	Many MNE's	Many MNE's
	Many new entrants	Many new entrants	Some new entrants	Many new entrants
	R&D contracts: little evidence	R&D contracts: little evidence	R&D contracts: some evidence	R&D contracts: little evidence
	Poor financing			
	Exporting firms: not available	Exporting firms: not available	Exporting firms: not available	Exporting firms: not available
	Patents: strong, particularly wireless	Patents: not clear	Patents: not clear but declining	Patents: not clear
Capturing Spillovers	Spin-offs (mainly from Universities)	Spin-offs (mainly from firms)	Spin-offs (mainly from firms)	Spin-offs (mainly from firms & research labs)
Minimizing Leakages	Local sourcing: some (e.g., wireless)	Local sourcing: some	Local sourcing: mainly manufacturing	Local sourcing: some (e.g., via Breconridge)
	Local supplier development programs: not evident			
Encouraging Linkages	Strong in wireless	Not generally evident	Not generally evident	Mainly in telecom and photonics areas
	Strong between universities and spin-offs	Some universitycorporate, corporatecorporate, and corporate supplier linkages	Links between biotech firms and universities and other public labs	Some university corporate, and corporate customer linkages
			Life Sciences Clusters	
Achieving Critical Mass	~90 companies	~400 companies	>270 companies	>100 companies
	> 1,900 FTE's	> 30,000 FTE's	>21,000 FTE's	> 3,500 FTE's
	1,400 FTE's in public institutions	A few large indigenous firm	A few large indigenous firm	1 large indigenous firm
	A few large indigenous firm	Several MNEs	Some MNE's	Few MNEs
	Mostly SMEs <100 employees	Many SMEs <100 employees	Many SMEs <100 employees	Many SMEs <100 employees
Capturing Spillovers	Spin-offs (mainly from Universities)	Spin-offs (mainly from Universities and Firms)	Spin-offs (mainly from Universities and Firms)	Spin-offs (mainly from Universities)
Minimizing Leakages	Need to develop supplier base	Diversified supplier base	Diversified supplier base	Need to develop supplier base
Encouraging Linkages	No pharma presence	Few linkages among pharma, biotech and medical devices firms	Few linkages among pharma, biotech and medical devices firms	No pharma presence
	Links between universities and biotech firms	Links between biotech firms and universities	Links between biotech firms and universities and other public labs	1 large indigenous medical devices firm with no local linkages
				Links between universities and govt. labs and biotech firms

* Grayteck, 2004

Table 15 Factors That Will Help Accelerate the Development of Clusters in Various Industries

Table 15. Factors That Help Accelerate the Development of Clusters in Various Industries*

ICT Sector	Life Sciences Sector
• Encourage entrepreneurs, particularly serial entrepreneurs, to grow successful companies over time rather than selling out at the earliest opportunity;	• Encourage contacts between the life sciences clusters and other high-technology clusters.
• Provide incentives to venture capitalists (VCs) to make long term commitments to investing in companies from start-up through subsequent growth stages;	This will require conferences and projects so that players in various clusters can become more familiar with each other;
• Increase the pool of executive management talent capable of growing such companies (e.g., increase the support for management and business skills training through the education system; provide incentives to successful entrepreneurs to become serial entrepreneurs; encourage the recruiting/repatriation of high profile executives from abroad)	• Encourage the development of the local supplier base;
• Encourage the procurement of locally developed products and help to promote such products in international markets; and	• Set in place demonstration projects within the hospitals to encourage demand pull;
• Use government policy and procurement levers to encourage multi-nationals to increase their long-term commitment to Canada.	• Stimulate alliances between pharmaceutical and biotechnology firms;
	• Develop a commercialization strategy aimed at growing existing • Encourage the consolidation of small biotechnology firms

** Grayteck 2004*

Table 16 A Basic List of Government Incentives by Province

Table 16. A Basic List of Government Incentives by Province*

	Location of Firm		
	British Columbia	**Ontario**	**Quebec**
		R&D Incentives	
R&D Tax Credits	10% refundable and/or non-refundable for expenditures that qualify for federal R&D tax credits	Ontario Innovation Tax Credit – 10% refundable to all companies performing R&D in Ontario	1) 40% refundable credit to taxpayers who contract with universities, public research centers, or biotechnology research institute.
			2) 40% tax credit on pre-competitive research expenditures by arm's length approved research.
Other	Product development fund: grant up to 75% of eligible costs		Companies with less than $25 million in assets can claim additional 15% credit on the increase of R&D expenditures.
		Tax holidays, exemptions and other incentives	
Provincial corporate income tax	13.50%	11.00%	8.90%
Provincial capital tax rate	0.00%	0.30%	0.64%
Tax holiday for foreign researchers	NA	NA	5 years for researchers specializing in pure or applied science.
Other	1) Exemption from provincial social tax on logging, mining and energy sectors production machinery and equipment	1) ONTTI: 100% tax deductible for income and capital tax of IP	1) FAIRE: financial assistance to cover start-up costs such as leasehold improvements for laboratories and rent.
		2) 2% M&P credit & exemption from retail sales tax on R&D manufacturing equipment	2) 125% deduction of M&P and data processing equipment, software and intangible assets
		3) Capital tax exemption for all ordinary corporations of $5 million	3) 5 year tax holiday for new corporations in health services
		Infrastructure incentives	
Investment in manufacturing & processing	NA	R&D Challenge Fund generating $3 billion over 10 year period	NA
Other (e.g.)	1)BIRC Corporation: $6 million capital funding.	1) BCC Fund: $20 million to boost competitiveness	FAIRE Program
	2)BCKA Fund: $217 million to boost R&D – cancer research center	2) Innovation Trust	
		Labour cost incentives	
Refundable training	Up to 60% of gross wages for max 24 weeks in science or technical positions	10%-15% of wages of students	1) 40% of wages of students
			2) 40% of the increase in certain business at a proposed site

* Grayteck, 2004

Appendix 1. The Fortier Report

The Expert Panel on the Commercialization of University Research was created in October 1998 by the Advisory Council on Science and Technology (ACST). The Panel's mandate was to provide independent, expert advice on options to maximize the social and economic benefits to Canada from the public investment in university research. The Panel completed its work in May 1999. Its report Public Investments in University Research: Reaping the Benefit is available on to the public, in which the ACST has recommended that the federal government implement the recommendations of the Expert Panel:

a) Develop a university IP policy framework
In order for researchers to qualify for federal research funding and universities to qualify for commercialization support, universities (and their affiliated research hospitals and research centers) should be required to adapt their IP policies. The Fortier Reports guidelines included the following items:

1. All IP with commercial potential (excluding books and journal articles) that was supported in whole or in part with federal funding must be promptly disclosed by the researcher to the university. Researchers who do not comply will be denied access to future federal research funding.
2. All IP with commercial potential (excluding books and journal articles) that was supported in whole or in part with federal funding must be disclosed annually by the university to the federal government, provided that such information is not subject to the Access to Information Act.
3. All IP created from research that was supported in any part by federal funding is owned either by the university or by the researcher(s) who created it. In those universities where the ownership of such IP resides with the researcher(s), the IP must be assigned to the University for possible commercialization.
4. Universities (and their affiliated organizations) must make reasonable efforts to commercialize IP that they have found to have innovative potential.
5. Universities can assign IP back to the creator under the following conditions: when the university has decided not to pursue commercialization; when the university has been unsuccessful in commercializing the discovery within a reasonable time frame; or when the university and the IP creator both agree that the creator can maximize benefits without undue conflict of interest.
6. Universities (and their affiliated organizations) must provide incentives to encourage their faculty, staff and students engaged in research to create IP. These incentives must include appropriate sharing of net benefits from successful commercial undertakings whether in the form of equity or licensing income. These incentives must also include appropriate recognition of innovative researchers in tenure and promotion policies.
7. Universities (and their affiliated organizations) will encourage the participation of small and medium-sized enterprises and, where appropriate, support the creation of spin-off companies in commercializing publicly funded research. Small businesses, including local spin-off companies, will be given priority to license innovations, dependent on finding appropriate businesses and equitable terms.

b) Strengthen universities' commercialization capacity
The Fortier Report suggested that the federal government should invest new and additional resources to strengthen the commercialization capacity of universities in an amount equal to 5% of its investment in university research.

c) Develop the commercialization skills base
It was suggested that with the new funding, universities should train people with the necessary skills required to increase the number of successful innovations created from the results of university research.

d) Establish competitive business conditions
A wholesale review of Canadian tax policy was also recommended in order to ensure that it does not impede and, where possible, supports research-based innovation.

e) Fuel the innovation pipeline
It was recommended that investment in university research should be increased to a great extent. In particular, the lack of specific funding for indirect costs of research was underlined.

1. Phone: 706-542-0581, Email: mfeldman@uga.edu