University Intellectual Property Policies And University-Industry Technology Transfer In Canada

by

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Abstract

This research investigates the relationship between those incentives for faculty support of university-industry technology transfer that are governed by university intellectual property policies and technology transfer outcomes at Canadian universities.

Empirical research, chiefly conducted in the United States, has explored the link between the incentives that are governed by IP policies and various outcomes and found that financial incentives are correlated with a variety of outcomes. This research extends the literature by exploring the same underlying relationship, in Canada, where IP policies also determine ownership and control of the development of the IP; some universities retain control over the development and other universities let the ownership and control vest with the inventors.

The research question was pursued by conducting three studies, each of which provided a different perspective. The first study seeks to explain cross-institutional patterns in the numbers of patents held by Canadian universities using variables that represent the financial incentives and control offered to faculty inventors by the universities' policies. The second study investigated the impact of a policy change at the University of Toronto, using interrupted time series analysis techniques. The third study investigated the experiences of faculty inventors at the University of Waterloo through in-depth interviews and thematic analysis of the resulting qualitative data.

The first, cross-sectional study failed to generate statistically significant results. In the second, longitudinal study, the change from a "university-owns" to an "inventor-owns" policy appeared to have significantly and substantially increased the number of invention disclosures submitted to the University of Toronto by its faculty members. The third, qualitative study suggests that faculty members interpret the incentives governed by intellectual property policies and that this interpretation is shaped by group norms, academic leadership, university culture and the inventors' experiences with technology transfer support organizations. Therefore, Studies 2 and 3 indicate that university intellectual property policies are effective levers with which to stimulate university-industry technology transfer and thus deserve further study. The importance of university factors in Study 3 implies that intellectual property policies must fit with their organizational contexts in order to be productive.

This research also has important policy implications. Many governments have been attempting to emulate the American Bayh-Dole Act by introducing or changing national regulations affecting university IP policies. This research suggests that these national regulations may actually depress researcher support for technology transfer and thus the amount of activity at those institutions that would benefit from an alternate policy. In effect, standardization of university IP policies through national regulations may deprive university administrators of an effective lever for encouraging technology transfer on their campuses. This inference will be the focus of further research which will broaden the work documented in this dissertation by exploring the relationship between university IP policies, university-industry technology transfer, and university factors, including culture, across a wider range of universities.

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I would also like to offer my thanks to the expert academic entrepreneurs who shared their valuable time and expertise by participating in my interview study, and to the technology managers who provided both data from and insights into technology transfer processes at a variety of institutions. Their contributions were vital to the development of the thesis.

Dedication

This work is dedicated to my family and, especially, to my parents, John and Odila Hoye. Without your loving support and unswerving confidence in my abilities, this work would not have been possible.

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Chapter 1
Introduction

The commercialization of university research has become a hot topic over the last ten years. Commercialization is the process by which inventions, or new technologies, become innovations, or market-ready products and services. As a result, commercialization activities offer the potential to improve the quality of life by facilitating industry access by industry to new knowledge created in the university, leading to the availability of improved products and services. There is also evidence that the commercialization of university research can contribute to regional and national economic growth, and international competitive advantage. These economic outcomes are highly desirable for policy makers, in part because they represent a relatively direct benefit arising from public investments in university research, which can be used in justifying these expenditures.

The potential to create sustainable economic advantage is particularly important in Canada where the universities are the second largest performers of research and development (Thompson, 2005, p. 24). Canadian universities perform one third of all research and development in Canada; for every dollar spent on research performed by industry in Canada, $0.65 is spent on doing research in Canadian universities (Thompson, 2005). Furthermore, the importance of university research is probably going to grow as Canada tries to close the “innovation gap” between itself and other major industrialized nations (Gu & Whewell, 1999). In 2003, Canadian business expenditures on R&D represented only 1.0% of GDP, much less than the U.S.’s 1.8% or the OECD average of 1.5% (Expert Panel on Commercialization, 2006). Furthermore, the World Economic Forum ranked Canadian businesses 27^{th} in the world in terms of their propensity to compete based on unique products and processes (World Economic Forum, 2005 as cited in Expert Panel on Commercialization, 2006). This “innovation gap” is a continuing challenge made more difficult by the relative scarcity of policy levers beyond the provision of tax credits for scientific research and development (for an overview of tax credits in this context, see Audretsch et al., 2002). In these circumstances, governments are quite likely to continue to encourage higher levels of university technology transfer activity, as a component of an overall policy program to increase the amount of R&D integrated into Canadian products and services and in the hopes of realizing more economic benefits from public investments in university research.

Internationally, the most notable policy move in support of technology transfer is the Bayh-Dole Act, enacted in the United States in 1980. It streamlined university-industry technology transfer of technologies arising from research that had been funded by the U.S. federal granting councils and agencies. Prior to Bayh-Dole, each agency maintained its own policies and processes regarding commercialization activities and a complex set of bilateral agreements between individual universities and government agencies governed university technology transfer. The Bayh-Dole Act transferred ownership of all intellectual property arising from publicly-funded research to the universities and required, in exchange, that the universities commercialize any promising technologies. Therefore, the act increased the incentives for university involvement in technology transfer and made it easier for universities to manage the commercialization of publicly-funded research. The act’s requirements also created increased capacity for technology transfer across the U.S. because many universities opened technology transfer offices (TTOs) or their equivalent; the number of TTOs grew from 25 in 1980 to over 200 by 1995 (Mowery & Sampat, 2001a).

There are two common misunderstandings of the Bayh-Dole Act. First, since the act supersedes university policies, it is sometimes described as creating a uniform policy for all universities. However, the act only pertains to publicly-funded inventions so university policies still apply to all other inventions. For example, at the University of Wisconsin-Stout, inventors still own any intellectual property arising from non-publicly funded research (University of Wisconsin-Stout, 2000). Secondly, the act is often simply described as a switch to university ownership of intellectual property. This description fails to acknowledge that, prior to the Bayh-Dole Act, many government agencies permitted universities to commercialize inventions; these permissions were provided through bilateral agreements between universities and government agencies. This description can also be misinterpreted as a shift away from the "inventor-ownership" policies common in many other countries. In fact, "university-ownership" was the dominant model for university intellectual property policies in the United States prior to the Bayh-Dole Act (Bowers & Leon, 1994).

The Bayh-Dole Act of 1980 is often credited with a very significant role in encouraging universities to embrace technology transfer activities and thus with the creation of significant economic benefits. For example, The Economist has declared, "More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance" ("Innovation's golden goose", 2002, p. 3). Several studies that investigated the impact of the Bayh-Dole Act provided evidence of this relationship, noting an increase in the propensity of universities to file patents starting in 1981 (e.g. Jensen & Thursby, 2001; Shane, 2004b). However, other studies argue strongly that this is a misattribution, pointing to other changes to the U.S. university milieu during the 1970s and 1980s, including the role of the Research Corporation in developing organizational capabilities to support technology transfer at the universities (Mowery & Sampat, 2001a), and the increasing propensity of private universities in the U.S. to become involved in patenting and licensing over the 1970s (Mowery & Sampat, 2001b). Rai and Henderson (2003) note that developments in the field of biotechnology have narrowed the gap between fundamental research and commercial applications and that these changes, together with the broadening of patent rights by the U.S. legal system, appear to have stimulated patenting activity in biotechnology[1]. These arguments are further strengthened by the trends in the number of patents per dollar of research expenditures at the universities; the time series of this measure displays an upward trend that is stable starting in the early 1970s (Mowery et al., 2004). As a result, Mowery and Sampat (2005) caution policy-makers that the impact of the policy decisions embodied by the Bayh-Dole Act need to be considered within the context of the U.S. national innovation system and that adoption of similar policies may not have similar results in another context.

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[1] Kortum and Lerner (1999) demonstrated that the changes noted by Rai and Henderson (2003) do not account for the rise in domestic patenting in the U.S. Instead, they suggest that the trend is a result of changes to the management of research and the aggressive exploitation of the patent system by new and less established patentees but they do not explain the behaviour of the new entrants (1999). Rai and Henderson's arguments are provided here as rationales for the more aggressive pursuit of patents by these new entrants including universities.

In spite of these critiques, the Bayh-Dole Act is often cited as part of the rationale when nations move to “university-ownership” policies. Denmark, Germany, Austria, Ireland, Spain and Korea are examples of countries that cited the U.S. act in their recent decisions to adopt “university-ownership” policies, replacing policies that allowed ownership of university-developed technologies to vest with the inventors (Association of University Technology Managers, 2006a; Mowery & Sampat, 2005). Japan has introduced even broader changes in moving towards the current U.S. model of university-industry technology transfer. Through the Industrial Revitalization Act, Japan has privatized its national universities so that they can have the legal status required to apply for patents and the universities have been granted the ownership of all inventions developed with university resources through the November 2002 report of the Ministry of Education’s IPR working group. Prior to the Industrial Revitalization Act, ownership rested with individual researchers but the researchers had to navigate complex government procedures to gain permissions for commercialization activities (Collins & Wakoh, 2000; Watts, 2000).

Canada is not immune to this international trend. The most significant policy document published on this topic in the past decade also cites the Bayh-Dole Act as a reason for policy change. The Prime Minister’s Expert Panel on the Commercialization of University Research recommended that universities should retain title to inventions resulting from publicly funded research. This recommendation was supported by the assertion that “the proposed IP policy framework will inspire a transformational shift in culture within Canadian universities, as happened in the U.S. with the passage of the Bayh-Dole Act in 1980” (1999, p. 28).

1.1 Research Statement

Clearly, there is enormous political interest in promoting university-industry technology transfer. Ideally, the relevant policy-makers would have access to copious research into university-industry technology transfer. Unfortunately, little appears to be known about several of the key relationships in this area. For example, many of the proposed federal policy changes would influence or override university intellectual property policies. These university policies are the target of the proposed changes because they are widely expected to be a significant lever in changing the university researcher’s involvement with technology transfer activities and because they are one of the few aspects of the university environment which can be easily changed by administrators. However, little research has been done in this area and the impact of these policies upon technology transfer, like licensing and the formation of spin-off companies, is not clear; in particular, it is not known whether or not university ownership of the intellectual property rights to inventions arising from university research has an important effect on the commercialization of these inventions. In spite of increasing amounts of activity in the past five to ten years, research on the topic of technology transfer is still quite embryonic (Shane, 2004a), and very little empirical work has been done to assess the importance of various factors in determining the amount of this technology transfer activity across institutions or nations. The research reported in this thesis was designed to help answer these important policy questions by conducting empirical research in response to the following research question:

> What, if any, relationships exist between intellectual property policies and university-industry technology transfer, through licensing and the formation of spin-off companies, in Canada?

The research goals are to provide timely information and analysis to university and government policy makers both in Canada and abroad, and to contribute to the emerging field of technology transfer research.

1.2 The Canadian Context

Three aspects of the Canadian university system make it a good one in which to study the relationship between university intellectual property (IP) policy and university-industry technology licensing. First, the vast majority of the post-secondary institutions are public universities that share the same mandate and are maintained by relatively consistent funding systems. Second, the public universities appear to be embracing the challenge of commercializing university research. Third, they exhibit a wide diversity of IP policies.

In Canada, almost all the universities are public institutions. These universities vary from small liberal arts universities with less than three thousand students to large, multi-location institutions offering a wide range of undergraduate, graduate and professional degrees to over fifty thousand students. However, all Canadian universities share the same three mandates: education, research, and community service. The public universities not only provide access to the majority of degree granting programs (The Association of Universities and Colleges of Canada, 2005) but also perform approximately one third of the nation's research (Thompson, 2005). These institutions are governed by and receive most of their operational funding through the provincial governments. The federal government provides funds for operating costs indirectly by providing transfer payments to the provinces and provides funds for research expenses directly, primarily through the three federal research-granting councils. As a result, both university funding levels and the relative importance of different sources of university funding vary less from institution to institution in Canada than in the U.S. (Boychuk, 2000). This consistency reduces the risk that an analysis of the levels of technology transfer activity across the universities will be contaminated by factors external to the universities.

There is evidence that Canada is also undergoing the 'second revolution' described by Etzkowitz (1998) and increasingly supporting technology transfer activities. In 1980, very few Canadian universities had offices dedicated to supporting intellectual property management and the commercialization of university research (Expert Panel on the Commercialization of University Research, 1999). By 2003, 78% of universities were actively managing IP, and 68% of them through a central office dedicated to this activity (Read, 2005). From 1997 to 2003, respondents to the Statistics Canada Surveys of Intellectual Property Commercialization in the Higher Education Sector reported increases of 123% and 138% in the number of active licences held by the universities and university spin-off companies, respectively (Bordt & Read, 1999; Read, 2005). This evidence suggests that there is enough activity in Canada that it will be possible to look for relationships between the level of activity and intellectual property policy variables.

In spite of these similarities, Canadian universities exhibit a wide variety of IP policies. The federal government does not regulate the rights and responsibilities of inventors and universities with respect to technology transfer (Atkinson-Grosjean, 2002), so universities can hold policies that differ widely. In 2003, technology managers at 61 of the 121 Canadian universities, which were included in the Statistics Canada survey, reported that their university affords researchers either full or joint ownership of any IP arising from their research (Read, 2005). This stands in stark comparison with a number of other countries. For example, in the United States, all but three universities retain the rights to IP developed by their faculty (Bowers & Leon, 1994). Therefore, a Canadian investigation of the influence of IP policies on university-industry licensing is expected to be of international interest.

Chapter 2
Background and Literature Review

This chapter is organized into two sections. The first section provides a brief description of intellectual property (IP), IP policies, and technology transfer, in the context of the commercialization of university research. This discussion of technology transfer includes a brief review of the regional and national impact of technology transfer. The second section reviews the literature that investigates the relationship between university IP policies and university-industry technology transfer.

2.1 Intellectual Property, Policies, and Technology Transfer

2.1.1 Intellectual Property

Intellectual property (IP) protection is key to technology transfer because it addresses the inherent conflict between academe's expectations of open publishing of academic work and their industrial partners' need to preserve competitive advantage, which in many industries is accomplished by preserving trade secrets. IP protections are designed to stimulate innovation by granting the entities responsible for the invention of a novel product, process or design or the discovery of a material or new plant hybrid a time-limited monopoly to benefit from their work in exchange for the open publication of a description of the work (Harvard University, 1999). This time-limited monopoly represents a competitive advantage that can be legally transferred through licensing agreements or sale of the IP. Therefore, IP protection can create a competitive advantage that is not dependent on secrecy. With IP protection, researchers can publish their research and still provide industrial partners with the incentive to commercialize their inventions (Conceição et al., 1998).

There are many different forms of IP protection. As shown in Table 1, the different forms of technology-related intellectual property protection used by Canadian universities and research hospitals include patents, copyright registration, new plant registration, and the registration of industrial designs. All of these forms of IP protection provide a successful applicant with legal rights to determine who can and can not use the invention for some predetermined length of time.

Patents appear to be the most commonly employed form of IP protection. It is clear from Table 1 that patenting is the dominant form of technology-related IP protection currently in use in Canada. The number of disclosures protected by patents is more than 20 times the number of disclosures protected by copyright. Most universities exclusively use patents to protect IP. A review of the Statistics Canada surveys demonstrates that this has been true since 1998 (Bordt & Read, 1999; Read, 2000, 2003, 2005). The absence of any other form of IP protection in a major survey of American TTOs suggests that this is also the case in the United States (Association of University Technology Managers, 2004).

Since the objective of this research is to provide results of practical significance, where this research must focus on only one form of IP protection, it will focus on patents, the dominant form of

IP protection. The main limitation of this approach is an inability to account for software inventions, which are often protected by copyrights instead of patents, and this bias may influence cross-comparisons of institutions.

Table 1. Different Forms of Technology-Related Intellectual Property Protections Employed by Canadian Universities and Research Hospitals between 1999 and 2003 (Adapted from Read, 2005, p. 24).

IP Protection	*IP Type*	*Institutions Reporting this IP Protection in the Last 5 Years*		*Number of Intellectual Properties*	
		Number of Institutions	*Percentage of Respondents*	*Disclosed to Institution*	*IP Protection Initiated by Institution*
Patent	Inventions	62	51	1133	527
Copyright Registration	Software, Databases	25	21	48	12
Registration	Industrial Designs	5	4	0	0
Registration (Canada), Patent (U.S.)	New Plant Varieties	7	6	Not Available	Not Available

2.1.2 Policies Governing the Commercialization of University Research

The policies governing university research define the rights and responsibilities of the members of the university with respect to the protection and commercialization of IP arising from university research. The definition of rights and responsibilities often includes clauses that define the permitted technology transfer activities, the processes that support technology transfer, and the sharing of the benefits of these activities.

The policies that govern the commercialization of university research are usually designed and held by universities and national governments. Some countries have federal policies that govern the commercialization of university research and these policies usually overrule any university IP policies. For example, U.S. universities and colleges own and have an obligation to commercialize IP arising from government-funded university research regardless of the university policy (Mowery et al., 2004). Canada does not have a federal policy governing the commercialization of university research, so the only policies governing technology transfer in Canada are the IP policies of the universities (Atkinson-Grosjean, 2002).

In Canada, many universities have different policies for different members of the university. Most have policies that pertain to faculty members (Read, 2005). Some have different policies, and some appear to have no policies at all, that apply to other members of the university, including staff and students.

For the most part, the incentives offered to faculty members are not also offered to other staff members at the university. Many university IP policies contain clauses that provide the university with ownership of inventions developed as a component of “assigned tasks.” These clauses apply to most of the work done by staff members and so the incentives offered to faculty are generally not offered to staff.

Many of the Canadian policies that apply to faculty do not also apply to students. Among the 23 Canadian universities that reported receiving invention disclosures from students in the 2001 Statistics Canada survey, at least six universities had policies for faculty but no policies for students, and at least another four had different policies for faculty and students (Read, 2003). Comments by the respondents to the survey noted that some institutions have policies for graduate students but not for undergraduate students (Read, 2003). For example, the University of Saskatchewan does not appear to have a policy for undergraduates and the policy for graduate students, while similar to the policy for faculty members, also includes additional restrictions on publication delays (University of Saskatchewan, 1996).

Since the policies treat different members of the university differently, this analysis will focus on university faculty members and their involvement in technology transfer. This is unlikely to bias the results significantly because faculty members are expected to account for most technology transfer activity. University staff members tend not to be involved in university research to the same extent as faculty and students and are, therefore, unlikely to account for a significant number of inventions. Interviews with technology managers at the University of Waterloo and M.I.T. suggest that even though students are important producers of commercializable inventions and can have an important role in economic development by taking new ideas with them into industry, they tend not to be directly involved in technology transfer activities as defined in this thesis (Morrison, 1995). This is consistent with the small percentage of universities that reported receiving invention disclosures from students in 2001 (Read, 2003). Therefore, it is reasonable to assume that faculty members account for most technology transfer activity originating from publicly-funded research.

2.1.3 Technology Transfer

The phrase ‘technology transfer’ has been used to denote a very wide range of activities. Part of the ambiguity associated with the phrase stems from the term ‘technology’. This word is often used to denote products, processes and configurations of products or processes that are intimately related with applied science (Betz, 1995; Bozeman, 2000). However, as Sahal observed, these products, processes and configurations are not useful without knowledge of their applications (Sahal, 1981). Therefore, for the remainder of the paper the term technology will be used to describe not only the device, process or configuration but also the knowledge of the construct’s applications, and invention will be used to refer to new technology.

The technology transfer literature describes the movement of applied scientific knowledge between institutions of various sorts. Common themes include firm to firm interactions, international technology transfer, particularly between the first and third world, and the commercialization of university research (Bozeman, 2000). In this thesis, technology transfer refers exclusively to the commercialization of university research through the licensing of IP and through spin-off company formation.

These mechanisms for technology transfer are not the only important mechanisms. Analysis of the data collected by the Carnegie-Mellon Survey on Industrial R&D indicated that the key channels through which information is transferred from university research to industry include academic papers, conferences and meetings, informal exchanges, and consulting (Cohen et al., 2002). Agrawal and Henderson's investigation of knowledge flows indicated that MIT's industry partners view faculty consulting, academic publications, collaborative research, the recruitment of graduate students and the co-supervision of graduate students as more important knowledge transfer channels than patenting and licensing (2002). Furthermore, several of these mechanisms, including academic publication, openly disseminate new knowledge and thus create public goods (Gu & Whewell, 1999).

Licensing and spin-off formation were chosen as the focus of this research because, among of the various knowledge channels, they are most directly affected by university IP policies. The other forms of knowledge transfer have little connection to university IP policies. University IP policies rarely have clauses governing faculty consulting activities. The university policy that most pertains to faculty consulting activities in Canada is a requirement for faculty members to report consulting activities; however, administrators at these universities noted that the policy was not enforceable (Read, 2000). Therefore, there is unlikely to be a strong relationship between any university policies and faculty consulting activities. Some universities have policies that pertain to contract research but generally contract research is negotiated on a case-by-case basis (Read, 2000). The other channels, like co-supervision of graduate students and academic publishing, have little if any connection with IP policies. Therefore, this investigation of the effects of university IP policies will be limited to their effect on licensing and spin-off formation.

Licensing and spin-off formation are also of special interest because, unlike many of the other activities, they require additional investments. The resources provided to university TTOs are primarily used to staff TTOs and to pay legal fees incurred in the patenting and licensing of university technologies. The Statistics Canada survey of Canadian universities, research hospitals and research institutions revealed that TTOs spent $36.4 million in 2003, of which 47% was spent on employee salaries and benefits on the equivalent of 255 full-time employees, 29% was spent on patent and regular legal expenses, 4% was spent on litigation, and 21% was spent on other operational expenses (Read, 2005). Among these institutions, universities probably accounted for the majority of the expenditures. In 2003, TTOs at 27 Canadian universities were staffed by the equivalent of 215 full-time employees, 105 of whom were primarily employed in technology transfer activities, including licensee solicitation, technology valuation, marketing of technology, licence agreement drafting and negotiation, and spin-off efforts (Association of University Technology Managers, 2004). These universities spent $8.0 million on legal fees (Association of University Technology Managers, 2004). Since the universities appear to employ about 80% of the technology managers in Canada and account for about 80% of the spending on legal fees, it is likely that the total cost of TTOs in Canadian universities is approximately 80% of the total spending, or approximately $29.0 million, in 2003.

The next two subsections will briefly describe the two identified technology transfer mechanisms, licensing and spin-off formation, and the subsequent subsection will describe the impact of these forms of technology transfer in Canada.

2.1.3.1 Licensing

Licences are contracts that allow the licensee to make use of the licensor's IP by using or selling some product or process. The contract can limit the right of use to certain fields of use or to use in a particular territory. Licences can also include options to acquire further improvements on the existing technology that arise from further university research, sublicensing rights, and assistance with the development of the technology through contract research and faculty consulting (Jones, 2004). In exchange, the university receives financial compensation. Common components of a licensing agreement at the University of California at San Francisco include a signing fee, an annual maintenance fee, royalties, and additional payments based on milestones, such as the acquisition of FDA approval (Boswell & Sauer, 1998). Licensing executives estimated that the licensor should usually receive financial compensation worth between one quarter and one third of the product sales or savings generated by the use of the innovation (Boswell & Sauer, 1998). However, the value of the innovation also depends on a variety of factors including whether or not the licence is exclusive, the strength of the IP protection, the existence of competitive technology (Boswell & Sauer, 1998), and the amount of risk involved in the commercialization, which is highly influenced by the stage of development of the technology (Jones, 2004). As a result, the staff responsible for overseeing technology transfers at universities, also called university technology managers, are told to expect royalty rates as low as 0.5% for non-exclusive licences of bio-technology that provides a benefit only in combination with other innovations, or as high as 40% for exclusive licences of market-ready software (Jones, 2004).

Measures used to track licensing activities at universities include the number of new licences created per year, the number of active licences, the number of licences resulting in revenues, and the total licensing revenues per institution size (Association of University Technology Managers, 2004; Read, 2005). Recent surveys also make additional distinctions between, for example, exclusive and non-exclusive licences and whether or not the industry partner is a small or medium-sized enterprise (Association of University Technology Managers, 2004; Read, 2005).

The significant challenge when using these measures in quantitative analyses is the skewness of many variables, especially licensing revenues. Empirical research has demonstrated that private returns from individual technological innovations are quite skewed (Scherer & Harhoff, 2000). The same is true of the income universities derive from the licensing of intellectual property. Not all IP is licensed and licences appear to have a positively skewed distribution with a majority of licences resulting in little or no financial return to the university and a minority of licences yielding significant, and sometimes spectacular, income for the university (Gregory & Sheahen, 1991). As noted earlier, Canadian universities also demonstrate positively-skewed income from licensing intellectual property. The positive skewness of the income distribution means that great care needs to be taken when using this measure in cross-comparisons of universities.

Another concern with the use of these measures is the bias towards "university-owner" institutions. Both the AUTM and the Statistics Canada data are provided by university TTOs. As a result, the data do not capture the licensing activities of university researchers when the licences do not involve the university TTO. Some university technology managers have complained about technology escaping "out the back door," which is evidence that this occasionally occurs at even "university-owner" institutions (Blumenstyk, 2002). Therefore, it is plausible that these measures fail to include a substantial amount of activity at "inventor-owner" universities.

2.1.3.2 Spin-off companies

Spin-off companies are defined in a number of different ways in the literature and by the organizations that track university-industry interactions. In the literature, there is often a focus on new technology-based firms but some definitions include all ventures started by members of a university, either immediately or within a certain time period after leaving the university (Stankiewicz, 1994). The Association of University Technology Managers defines spin-offs as those firms formed to license technology from a university (Association of University Technology Managers, 2004). Statistics Canada recognizes as spin-off companies those companies formed with the help of university TTOs for one or more of the following reasons: to license the institution's technology, to fund research at the institution in order to develop technology that will be licensed by the company or to provide a service that was originally offered through the institution's department or unit (example providing laboratory services of some kind) (Read, 2000). The Industrial Research Assistance Program (IRAP), a branch of the National Research Council of Canada, recognizes as spin-off companies those technology companies that are started by university faculty with or without the assistance of a TTO (Read, 2000). In order to remain consistent with the focus on the relationship between intellectual property policies and the transfer of technology from the university, this research will focus on only those firms formed in order to develop and commercialize new technology developed at a university. Some of these spin-off companies will license technology from the university; therefore, the two transfer mechanisms of interest are not mutually exclusive.

Measures used to track spin-off companies include counts of new spin-offs, counts of active spin-offs, the amount of equity in spin-offs held by universities, and university revenues from cashed-in equity (Association of University Technology Managers, 2004; Read, 2005). The principal problem with many of the measures tracked by the Association of University Technology Managers or Statistics Canada is that the data do not include spin-offs formed without the assistance of a TTO. IRAP, which does track these companies, listed 741 Canadian spin-off companies formed by 1999 and Statistics Canada reported only 471 (Read, 2000). The 57% difference in spin-off counts strongly suggests that the AUTM and Statistics Canada numbers may be significant underestimates of the formation of university spin-off companies at "inventor-owner" universities.

2.1.4 Impact of Technology Transfer

This section reviews the literature pertaining to the impact of university technology transfer, in terms of the following four desirable outcomes: 1) improved quality of life through the incorporation of new technology into goods, services, and industrial practices; 2) national economic development, 3) regional economic development, and 4) the provision of an additional stream of revenues in support of universities and university research.

2.1.4.1 Improved Quality of Life

No estimate of the impact of university-industry technology transfer on quality of life was found. However, it is possible to demonstrate the impact on the quality of life by reviewing examples of university technologies that have been made available to society through technology transfer. Many readers will be familiar with high-profile university spin-off companies, including MDS Sciex, QLT, Open Text, Dalsa, and Angiotech Pharmaceuticals. However, the impact on quality of life is even broader than that implied by these high-profile cases in biotechnology and information technology. The following table includes Canadian examples pertaining to medicine, agriculture, information technology, manufacturing, and the environment that demonstrate that there are also a set of lower-profile companies that also have an impact on many aspects of quality of life. This suggests that technology transfer has a broad impact on quality of life and more depth than just that implied by high-profile spin-off companies.

Table 2. Examples of Technologies Transferred from Canadian Universities.

Technology Transfer	*Technology Description*	*Evidence of Use*
LMS Medical Systems, a Montreal start-up company, was formed to commercialize this technology, which was developed by an interdisciplinary group at McGill (Hamilton, 1997).	Decision support system using current results of large-scale trials to provide guidance for obstetricians and nurses on expected labour times and thus to reduce incidence of both unnecessary Caesarean sections and birth-related brain injuries (LMS Medical Systems, 2005). The costs of the technology is expected to be offset by the reduced costs of malpractice insurance for obstetrics (LMS Medical Systems, 2006a).	LMS had product-based revenues of $1.58M in fiscal year 2006 (LMS Medical Systems, 2006b), and their clients include the Calgary Health Region in Alberta, Hôpital du Sacré-Coeur de Montréal and CHU Sainte-Justine in Montréal, and 7 U.S. hospitals (LMS Medical Systems, 2006a).
Western Ag Innovations, a Saskatoon start-up, licensed this technology from the University of Saskatchewan (Association of University Technology Managers, 2006d).	A comprehensive soil test device that mimics plant roots to gauge nutrient uptake from the soil. When used jointly with advanced crop nutrition planning software crop yields can be increased by 20 percent which more than off-sets the cost of the technology (Association of University Technology Managers, 2006d).	This technology is used as the basis for decisions regarding fertilizer use on over 1.5 million acres of farmland in western Canada for 17 cereal, oil seed, pulse, and forage crops (Western Ag Innovations Inc., 2006).

Table 2 continued.

Technology Transfer	*Technology Description*	*Evidence of Use*
Q1 Labs Inc., a privately funded Delaware corporation with offices in California and New Brunswick, was founded to commercialize a computer program, developed at the University of New Brunswick (Association of University Technology Managers, 2003).	The program can visually represent a computer network of any size, which facilitates the monitoring of networks and the management of potential internal and external threats and misuse (Association of University Technology Managers, 2003).	Q1 Labs' customers include the U.S. government, state and municipal government agencies, universities, financial institutions, energy firms, service providers, and healthcare providers (Q1 Labs, 2005). For example, Harvard University has described Q1 as their main network anomaly control system (Brown, 2006).
CVD Diamond Corp., of London, Ontario, was founded to exploit a new method for manufacturing diamond-coated industrial tools developed at the University of Western Ontario (Association of University Technology Managers, 2006c).	The new manufacturing process produces tools that last at least 20% longer than other state-of-the-art diamond-coated tools and 10 to 20 times longer than tungsten carbide tools (Association of University Technology Managers, 2006c).	By early 2006, CVD had 50 corporate clients, and sales had been growing steadily by approximately 25% for several years (Brennan, 2006).
New groundwater remediation technologies, collectively known as permeable reactive barriers, or PRBs, have been developed at the University of Waterloo and have been patented and licensed to industry (Association of University Technology Managers, 2006b).	When installed in the path of the contaminated groundwater, PRBs remove contaminants as groundwater flows through them (Association of University Technology Managers, 2006b). Not only are the filters very effective, they also cost less than the competing technologies, which require pumping the groundwater to the surface for treatment (Association of University Technology Managers, 2006b).	The PRB designed to filter out heavy metal contaminants has been field-tested at five sites in Canada and the United States (Association of University Technology Managers, 2006b). Thus far, twelve commercial entities have licensed the technology, including several in Canada, five in the United States and several in the European Union (Association of University Technology Managers, 2006b).

The examples provided in the preceding table include four instances in which a technology was further developed and made available by spin-off companies and one instance in which the technology was licensed to a number of industrial partners. It is unlikely that these technologies would have been made available without the resources for technology development acquired through the technology transfer process. Based on the general trend with university technologies, it is likely that each of these technologies was quite embryonic when the inventors first sought to commercialize them (2001). In the creation of each spin-off company, resources were acquired and organized around the further development of the technology. Relevant resources include human resources, in the form of individuals with the requisite business knowledge and skills, and the financial resources required to further develop the product, engage in product trials, acquire the requisite regulatory approvals, and so on. Even in the case of the PRB, a technology with sufficient interest for the associated industry that it was licensed to multiple receptor organizations, the role of technology transfer was important. Industrial partners were only interested in adopting the technology after data were collected from expensive field trials (Inwood, 2006), in part because of the need to demonstrate the effectiveness of the technology to regulatory bodies (Association of University Technology Managers, 2006b). These examples provide evidence that technology transfer activities facilitate the provision of improved goods and services and, as a result, improve the quality of life in Canada and elsewhere.

The only indicators of the magnitude of this effect that could be located are simple patent and technology counts. By 2003, Canadian universities held at least 1,756 active licences representing the transfer of at least 722 inventions (Read, 2005).

2.1.4.2 National Economic Development

The organization of resources around the development and provision of improved goods and services has also been linked to economic benefits including national economic growth. Estimates of the economic impact of university technology transfer usually assess the impact of licensing and spin-offs separately.

In 1995, the AUTM economic impact committee investigated the economic impact of the licensing of university technology in Canada and the U.S. Using the AUTM survey data on licensing revenues, they estimated that university technologies accounted for U.S.$20.6 billion in product sales in 1996 (Gu & Whewell, 1999). Following Pressman et al.'s argument that the economic impact should also include pre-production investment[2] (1995), the committee also found that university technologies accounted for a further U.S.$4.2 billion in 1996, which translated into a total economic impact of $24.8 billion per year, supporting an estimated 212,500 jobs (Gu & Whewell, 1999). Gu and Whewell estimated the economic impact of Canadian university technologies by allocating the above estimates in proportion to the ratio of gross licence income in Canada and the U.S. (Gu & Whewell, 1999). They estimated that the total economic impact of the Canadian university-industry licensing was U.S.$500 million per year, supporting approximately 4,000 jobs (Gu & Whewell, 1999). These estimates rely on assumption that the ratios of GDP and job creation to gross licence income are the

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[2] Pre-production is the phase of commercialization in which the manufacturing processes and techniques required to produce the product are developed.

same in Canada and the U.S. More recent estimates of the economic impact of university licensing were not located. However, the application of the above estimation technique would result in an increased assessment of the economic impact because gross licensing revenues increased from Cdn$16.1 million to Cdn$36.5 million, an increase of 127%, between 1996 and 2003 (Association of University Technology Managers, 1997, 2004). If the previous ratios continued to hold, the total economic impact of Canadian university licensing in 2003 would have been U.S.$1.1 billion per year, supporting 9,100 jobs.

The economic impact of spin-offs has also been assessed using product sales and employment information. An NSERC investigation of the 107 spin-offs formed to commercialize university research that had been funded by NSERC, found that these companies accounted for about Cdn$1 billion of product sales, and employed more than 5,000 Canadians (Gu & Whewell, 1999). Vincett (2005) calculated the return on investment of government research spending by estimating the present value of past and projected spin-off revenues. The spin-offs that have developed from Canadian university research in physics had an impact-to-total-funding ratio of 1.26, which combined with multipliers related to the recirculation of money in the economy suggested that "the total economic impact is nearly four time the original outlay" (2005).

The main drawback to these estimation techniques of the economic value of university licensing and spin-off formation is that they allocate all of the economic benefits arising from the development of university technologies to the technology that leaves the university, often in a very early stage of development (2001). This allocation probably underestimates the importance of other resources required to develop the invention, which can include inventions from other sources, and thus overstates the economic value of the university activities. Furthermore, these assessments only look at the outcomes of university-industry technology transfer. An opportunity-cost analysis of their benefits would need to "take into account foregone opportunities, especially alternative uses for scientific and technical resources" (Bozeman, 2000). No such analyses could be located, probably because of the difficulty in estimating the "counter-factual," a hypothetical situation in which scientific and technical resources are otherwise employed (Bozeman, 2000). Again, this criticism suggests that existing estimates of economic impact overstate the value of university-industry technology transfer.

While it is clear that more work needs to be done in providing reliable estimates of the impact of university-industry technology transfer, the current best estimates suggest that these activities have a substantial positive effect on the economy.

2.1.4.3 Regional Economic Development

There is also an emerging literature on the multi-faceted benefits that universities bring to their surrounding regions. This literature includes estimates of the total economic benefits realized by a regions containing universities, where the economic impact can include the effects of knowledge spillovers to local firms or the regional impact of the creation of university spin-off companies (e.g. Martin, 1998, 2004; Pricewaterhouse Cooper, 2001).

The possibility that university research can stimulate economic growth in their surrounding regions is of great interest for governments because it implies that the economic benefits of investments in university research can be captured within the country. The impressive success of a few high-profile, high-technology clusters suggest that the economic benefits can be substantial. For example, the development of Silicon Valley is credited in part to Stanford University. Miner et al. (Miner et al., 2001) and Armstrong (2001)are very skeptical of the extent to which the economic growth demonstrated by these "totemic" sites of the new economy are realizable in other contexts (2001, p. 525). To a large extent, this question can only be addressed by further research.

To date, the emerging literature has demonstrated some links between universities and regional development that extend beyond Armstrong's totemic sites. In a survey of 1000 American academics, most faculty members reported that their universities were actively engaged in regional economic development (Lee, 1996). An investigation of university-industry interactions in the bio-technology sector in the U.S. and Europe, found that these interactions were rooted in regional clusters (Owen-Smith et al., 2002). Agrawal and Cockburn (2003) found strong evidence of the co-location of upstream academic research and downstream industrial R&D suggesting the presence of knowledge spill-overs. Siegel, Westhead, and Wright (2003) discovered higher research productivity among firms located in university research parks in the U.K. In France, Monjon and Waelbroeck (2003) found evidence that knowledge spillovers from universities increased the innovativeness of firms in the university's region that were less intensively engaged in R&D.

Overall, recent studies suggest that there is a role for universities in regional economic development but that that role, in most cases, is likely to be less extravagant than the role depicted by Stanford and the Silicon Valley.

2.1.4.4 Revenues for University Research

As universities have grown in number and in size they have become increasingly reliant on external funding from governments and industry. Especially in periods of declining governmental or industry funding, university administrators are expected to be interested in the potential to generate additional resources through technology transfer. For example, Raine and Beukman (2002) attribute growing interest in university-industry interactions in New Zealand to declining public funding of tertiary education.

Even though a focus on technology transfer is relatively new to Canadian universities, technology transfer appears to be generating a small stream of funds for the Canadian university system. In the AUTM survey for 2003 (2004), Canadian universities reported total revenues of $36.5 million resulting from technology transfer activities and $7.4 million of sponsored research tied to licences and spin-offs. Based on the earlier estimate that the universities incurred costs of approximately $29 million in pursuit of technology transfer activities, this implies that altogether Canadian universities realized $14.9 million in research and operational funding from their technology transfer activities in 2003.

The principal problem with estimating returns for individual universities based on national totals is that technology transfer income appears to have a positively-skewed distribution. In the U.S., most licences result in little or no financial return to the university and only a small minority of licences provide significant, and sometimes spectacular, returns (Gregory & Sheahen, 1991; Parker & Zilberman, 1993). The skewness of these returns prompted Feller (1990) to declare that for many universities, investing in technology transfer with the expectation of generating appreciable net revenues is equivalent to buying a lottery ticket.

Returns from technology transfer activities also appear to follow a skewed distribution in Canada. The Canadian university that receives the most licence income, about $10M per annum, receives the vast majority of its licence revenue from a single technology that is widely licensed (Clayman, 2004). Furthermore, this university receives about ten times more annual revenue than the next highest-earning university (Clayman, 2004). Given the small size of the revenue stream and the skewness of the distribution of the returns, it would probably be more realistic for universities to aim for modest returns in order to reduce the costs of their investments in technology transfer rather than to expect spectacular returns.

2.1.5 Summary

This section introduces and specifies the variables under study: 1) university intellectual property policies governing faculty members, especially as they pertain to patents; and 2) university technology transfer, where it is defined as the patenting and licensing of university technologies and the creation of university spin-off companies. The final subsection establishes that university technology transfer has the potential to contribute to quality of life, regional and national economic development, and to do so at low cost to the universities. The literature cautions that spectacular occurrences, such as cases in which universities realize significant returns from a technology transfer or contribute to economic growth on the scale of Silicon Valley, are infrequent. However, there remains a great deal of scope to entertain more cautiously optimistic expectations for the realization of economic and social returns from university research. This possibility is sufficiently important to warrant further research.

2.2 University IP Policies and Technology Transfer

This section builds on the introduction of the variables of interest by investigating the technology transfer literature pertaining to the relationship between IP policies and university-industry technology transfer. First, an overview of the technology transfer literature is provided as context. The next subsection discusses empirical studies of the relationship between IP policies and technology transfer. The last subsection summarizes the state of the literature.

2.2.1 Overview of the Literature

Agrawal (2001) describes the university-industry technology transfer literature as having four distinct research areas, which study: 1) firm characteristics; 2) channels of knowledge transfer; 3) geography, in terms of localized spillovers; and, 4) university characteristics. The literature concerned with firm characteristics explores the characteristics of firms and partnerships that allow firms to make use of scientific knowledge that is generated outside the firm (e.g. van den Berghe, 2001). The literature concerned with channels of knowledge investigates the characteristics of different knowledge transfer mechanisms, including publications, licensing, spin-off company formation, research contracts, joint ventures, consulting, informal meetings, recruiting, and personal exchanges (e.g. Hoye et al., 2006).

The localized spillover research stream explores the relationship between the 'stickiness' of tacit knowledge and the geographical proximity between the creator and the recipient of the tacit knowledge and thus focuses on relationships between universities and clusters of innovative activity (e.g. Xu, 2003). The fourth research stream, 'university characteristics,' focuses on university issues, including incentive structures for professors and university policies. Since this research is investigating the relationship between policies that determine incentive structures and university outcomes, it falls squarely within this last category. Therefore, the following literature review will focus predominately on the empirical work that has been published in this research stream. The review will examine studies that describe the role of faculty inventors in technology transfer and the empirical evidence of a relationship between university IP policies and university-industry technology transfer.

2.2.2 The Role of Faculty Inventors

This section reviews the role of faculty inventors in technology transfer activities because since this role is key to understanding the importance of incentives for faculty support of technology transfer. IP policies are assumed to influence technology transfer outcomes through their effect on faculty inventor behaviour. Therefore, the strength and nature of the relationship between IP policies and technology transfer outcomes will depend on the strength and nature of the relationship between faculty behaviour and technology transfer outcomes. This section reviews the evidence that faculty inventors are important actors in technology transfer: that their involvement may be critical for success in some cases and a barrier to success in others.

2.2.2.1 Evidence that faculty inventor involvement is critical to success

Studies conducted in the U.S. where universities own IP, suggest that faculty inventors have a critical role in the identification of commercializable technologies and disclosure of these technologies to TTOs and in other supporting roles.

Most industry liaison offices rely on researchers to identify commercializable inventions and, in many cases, technology transfers will not proceed if the researchers do not want to pursue the commercialization of their inventions (Jensen et al., 2003; Read, 2000; Siegel, Waldman et al., 2003; Stevens & Bagby, 1999). Thursby and Kemp (2002) discovered, in interviews with technology managers, that the technology managers believe that less than 50% of all commercializable technologies are disclosed to their offices. Thursby, Jensen and Thursby's survey of university technology managers revealed that directors of TTOs believe that some highly-productive faculty members are unwilling to disclose inventions and that this is a significant barrier to the commercialization of technology at their universities (2001).

There is also evidence that faculty inventors have an important role in the identification of possible licensees for university technology. Jansen and Dillon (1999) found that faculty inventors were the most likely to identify the licensor of a university technology; they identified the licensor in 56% of cases, whereas TTO staff, licensing companies, research sponsors were responsible for 19%, 10%, 7% of the cases, respectively. Ramakrishnan, Chen and Balakrishnan (2005) analyzed the origins of 283 licences completed by the U.S. National Institutes for Health (NIH) and found that inventor contacts were responsible for 38% of the leads that led to licensing. Thursby, Jensen and Thursby's survey of university technology managers found evidence that the personal contacts of faculty inventors are the primary source of marketing leads in the licensing of university inventions (2001). This finding was further supported by Thursby and Thursby's complementary survey of industry receptors of technology transfer (2001). Siegel et al. (2003) noted the importance of faculty "buy-in" to university-industry technology transfer, after 55 interviews with 98 entrepreneurs, scientists, and administrators at five research-intensive universities in the U.S.. They observed that faculty are important not only in terms of the disclosure of potentially commercializable technologies, but also the marketing of the technology because "they are usually in a good position to identify potential licensees and because their technical expertise often makes them a natural partner for firms that wish to commercialize the technology" (Siegel, Waldman et al., 2003, p.29). This latter finding suggests that faculty inventors also have a role in supporting the further development of commercialization technologies.

Three studies have provided evidence that inventors have a significant role in the subsequent development of university technologies. In Thursby, Jensen and Thursby's survey of technology managers, TTO staff indicated that the commercialization of 71% of licensed inventions required inventor cooperation (2001). Agrawal (2006) demonstrated, using a dataset of 124 licence agreements associated with inventions from MIT, that licensing strategies that directly engaged the inventor in the commercialization process increased the likelihood and degree of commercialization success. Hoye, Pries, Guild and Roe's survey of Canadian and American technology managers indicated that faculty inventor involvement in a wide range of technology transfer activities generally has a positive effect on the probability of achieving a successful transfer of the technology, for those technologies developed through the TTO (2006). The technology transfer activities assessed in the survey included invention disclosure, evaluation of the invention, marketing, prototype development and licensing or spin-off formation (2006).

The need for faculty inventors' continued involvement beyond disclosure may be a function of the need for tacit knowledge transfer, the stage of development of the technology and the 'appropriability' of the technology, where appropriability refers to the extent to which an innovating firm can capture economic benefits through the commercialization of the technology (von Hippel, 1982). Bozeman (2000) and Agrawal (2006) have both argued that the successful transfer of technology often depends on the concomitant transfer of tacit knowledge regarding the development and use of the technology. Tacit knowledge is knowledge that is difficult to codify and thus it is most effectively transferred using rich communication channels such as face-to-face communication. Colyvas et al. (2002) explored the importance of tacit knowledge transfer through their review of eleven case studies of inventions at Stanford and Columbia University. They suggest that the need for tacit knowledge transfer and hence faculty inventor support for technology transfer is linked to the stage of development of the technology; embryonic and early stage technologies require direct interaction between academic inventors and company scientists (Colyvas et al., 2002). This is an important finding because many university technologies are at very early stage of development. Thursby, Jensen and Thursby's (2001) survey found that the majority of inventions were at the proof of concept or prototype stage with further development needed; only 12.3% were ready for commercial use (2001). Shane (2002) used royalty, sponsorship and invention data from M.I.T. to investigate the commercialization of 1397 patents. He found evidence that highly-appropriable technologies were most effectively commercialized via licensing to non-inventors in either new or established firms; the inventions that were difficult to patent were most likely to be commercialized when the university licensed the technology to the inventor, in effect permitting them to develop it independently (2002).

Overall, these studies suggest that researcher support can be very important for technology transfer, that this support can require a role in many technology transfer activities. However, the usefulness of their involvement may depend on aspects of the technology or the transfer situation, including the need for tacit knowledge transfer, the stage of development of the technology and the appropriability of the technology.

2.2.2.2 Evidence that faculty inventor involvement is a barrier to success

In response to the survey by Hoye et al. (2006), a number of technology managers elaborated on their responses to the survey's Likert-type items with observations about the role of faculty inventors. Some of these comments suggested that it was possible for faculty inventors to be over-involved in technology transfer, especially the licensing of university technologies. The following comments are illustrative of the range of responses.

> Faculty inventors initiate our TT process and their level of involvement can functionally expedite or cripple progress. But over-involvement or under-involvement can lead to either of these extreme outcomes.
>
> I'm not sure if this [item] meant to ask whether faculty/inventors solely negotiate licences OR assist in helping TTO/VC/business mgrs negotiate licences? If solely, then disaster. If assist, then positive (I assumed this).
>
> Their participation beyond their input in identifying and initial interaction with a potential licensee is not a strong determinant of success in [technology transfer] via licensing.
>
> Faculty must be excited about the technology transfer process but be very clear that their role is to support the technology transfer process.
>
> Inventors who respond to patent attorneys are generally responsive in other areas as well, and there this is a reasonable predictor of successful commercialization. Be responsive, stay involved. Leave business issues to business people. Great if inventors identify potential licencees & solicit government funding.

These comments suggest that high levels of involvement may be detrimental to the success of technology transfer activities. Those that offer a rationale or refer to specific activities seem to suggest that inventors are a liability in negotiations and in other 'business' activities.

These technology managers are not alone in questioning the extent to which faculty inventors can pursue technology transfer activities efficiently and effectively. Researchers have also posited that faculty inventors may not have the requisite skills, experience or motivation to manage business activities (Bower, 2003; Meyer, 2003). Meyer (2003) reviewed four case histories of spin-offs led by faculty inventors and observed that, in some cases, the founders of the spin-off firms are seeking avenues with which to develop their research, rather than seeking to build a high-growth, high-technology firm. This is consistent with Otto's suggestion that researchers tend to focus on their product and its underlying technology rather than customer benefits, market needs and opportunities (1999). Bower observes:

> It is a difficult challenge for academic founders with little prior market knowledge and linkages, and no previous experience of professional investors and their requirements, to select the applications and business models which will support successful venture creation (2003, p. 97).

In summary, faculty inventors' involvement in technology transfer activities may be a liability if they take on managerial roles in licensing or spin-offs without first developing an understanding of the market and a support network. However, the earlier section demonstrated that faculty inventors often have a significant role in a wide range technology transfer activities. Their involvement can permit access to valuable resources, including their tacit knowledge of the technology, the research skills that they could direct towards further development of the technology, and their contacts with possible licensees.

Since faculty inventor support for technology transfer is an important factor in technology transfer outcomes, there is considerable interest in providing effective incentives in support of this behaviour. Unlike employees in industry, researchers can not be compelled to select or pursue projects that do not interest them and researcher support of technology transfer can be quite variable (Etzkowitz, 1998). Therefore, the next section reviews the literature regarding the relationship between incentives for faculty involvement in technology transfer and technology transfer outcomes.

2.2.3 University IP Policies and Technology Transfer

Recent work, mainly in the U.S., has identified the financial incentives for faculty involvement in technology transfer that are established by university IP policies as an important determinant of technology transfer outcomes. These studies used quantitative, qualitative and mixed methodologies. The following subsections discuss this empirical work, grouped by the type of methodology employed.

2.2.3.1 Quantitative Studies

Four quantitative studies have demonstrated a relationship between the faculty member's share of revenues arising from technology transfer and university technology transfer outcomes. These studies, summarized in Table 3, used regression analysis, recursive systems modeling and stochastic frontier analysis to assess the impact of the financial incentives in the context of models that included other organizational variables. This section reviews each of the four studies, in alphabetical order by author's last name, and then discusses their strengths and weaknesses as a group.

2.2.3.1.1 Study 1

DiGregorio and Shane (2003) demonstrate a negative relationship between the inventor's shares of licensing revenues at a university and the number of spin-off companies associated with that university, using panel data representing five fiscal years of activity at a set of U.S. universities. To compensate for the large numbers of zeroes in the count data of spin-off companies started per university per year and to address the possibility of auto-correlation across years, they chose to use negative binomial models in generalized estimating equations (2003). Thirteen models are presented; a main model and twelve others with which they demonstrate that their initial results are robust to changes, including the omission of the universities that had no spin-off activity, and the use of different random-effects generators to account for unobserved differences between the universities (2003). Across all 13 models, the intellectual eminence of the university, as determined by the Gourman graduate school score, had a significant and positive effect, the inventor's share of the revenues had a significant and negative effect, and the university's demonstrated willingness to take equity shares in spin-offs rather than requiring royalties had a significant and positive effect (2003). The authors suggest that lower royalty rates may be an incentive to undertake the additional work required for venture creation over licensing to an established firm when their shares of licensing revenues are low (2003). They also observe that universities that are willing to take equity in lieu of royalties are less likely to create cash flow problems for their spin-offs and can be seen as providing a more supportive environment (2003).

Table 3. Quantitative Studies of the Relationship between IP and Technology Transfer (Modeled after Phan & Siegel, 2006).

Author(s)	*Data*	*Methods*	*Key Findings*
DiGregorio and Shane (2003)	AUTM	Regression analysis	Ability of university and inventors to take equity instead of royalties is a key determinant of the number of spin-offs
Friedman and Silberman (2003)	AUTM, NSF, NRC, Milken Institute 'Tech-Pole' Data	Regression analysis and recursive system modeling	Higher royalty shares for faculty members are associated with greater licensing income
Link and Siegel (2005)	AUTM, NSF, U.S. Census Data	Stochastic frontier analysis	Higher royalty shares for faculty members are associated with larger numbers of licences and greater licensing income
Lockett and Wright (2005)	Quantitative survey of U.K. TTOs	Regression analysis	Universities allocating a higher percentage of royalty payments to faculty tend to have more spin-offs

2.2.3.1.2 Study 2

Friedman and Silberman (2003), employed a technique introduced by Carlsson and Fridh (2002), in which the impact of cross-correlations between explanatory variables are mitigated by modeling technology transfer as a sequence of events. Systems equations were designed that model two stages in the technology transfer process, one leading to invention disclosure and another going from invention disclosure to final outcomes (2003). Invention disclosures at each university were assumed to be dependent on faculty quality, the number science departments at the university that offered Ph.D. programs, and the amount of research funding provided to the university by the federal government and industry (2003). The technology transfer outputs were assumed to depend on the estimates for invention disclosures generated by the first systems equation, the income provided to the inventor, a number of environmental factors including the concentration of high-technology industry in the university's region, the age of the TTO and a dummy variable representing whether or not the TTO provides the university community with a statistical report of its activities (2003). The first systems equation successfully predicted the annual invention disclosures at the universities over fiscal years 1997-1999 (R^2=.80) (2003). All of the independent variables were found to be significant at the .05 level, at least (2003). The second systems equation was used to model five different outcomes for each university in Fiscal Year 1999: the number of licences generating income; the number of licences with equity; the cumulative number of active licences; the number of spin-off companies; and, the amount of licence income received (2003). All of the explanatory variables were significant in at least one of the models, with the exception of the variables distinguishing between types of universities (private, land-grant, medical school) (2003). The inventor's share of licensing revenues was only a significant factor in the model of licence income, and only when the estimate of invention disclosures was dropped from the model (2003). This finding suggests that inventor's shares of revenues are a predictor but that they may covary with some or all of the variables used as determinants of the number of invention disclosures in this model. Friedman and Silberman suggest that the inventor's share of licensing revenues has the most impact on licensing revenues, as opposed to the other measures that were used, because successful licensing requires the continued involvement of the faculty inventor.

Friedman and Silberman's findings are weakened by the skewness of the response variable licensing income. The authors attributed the lack of explanatory power (R^2=.23) of the model in which the inventor's share of revenues was found to be significant to the skewed distribution of the response variable (2003). Skewed response variables can lead to violations of the assumption underlying regression analysis that the residuals will have a normal distribution. The authors did not provide evidence that the skewness of the response variable did not violate this assumption, which makes it impossible for readers to assess the validity of the observed relationship (2003).

2.2.3.1.3 Study 3

Link and Siegel (2005) evade problems with the skewness of the response variables by modeling licensing outcomes using stochastic frontier equations. This modeling technique represents organizational productivity measures using two sets of variables. The first set, called production function parameters, includes all significant inputs for the process which is used to estimate the highest productivity possible for each organization. In the Link and Siegel (2005) model, the maximum possible licensing activity at each university is hypothesized to be a function of the invention disclosures, the number of TTO staff, and the amount of legal expenditures. The second set of variables, called the determinants of relative inefficiency, is used to explain differences between each organization's actual productivity figures and the maximum productivity levels estimated using the first set of variables. Link and Siegel (2005) use six variables to model the differences between the actual licensing performance of each university and the estimate of the maximum possible activity. The six variables were: 1) a dummy variable indicating whether or not the university had a hospital; 2) the average annual industry R&D intensity in the university's state; 3) the average annual real output growth in the university's state; 4) the age of the TTO; 5) a dummy variable set to one if the university has a centralized TTO and set to zero if the TTO is decentralized; and, 6) the inventor's share of technology transfer revenues (2005). The stochastic frontier equations were used to model the number of licensing agreements and the amount of licensing revenue produced by each university, on average over fiscal years 1991-1998. In both cases, the production functions were found to be stable regardless of whether or not the determinants of relative inefficiency were included and, in at least one of the cases, all of the production function determinants were significant at the .05 level (2005). Only three of the six determinants of relative inefficiency were found to be significant: 1) average annual industry R&D intensity in the university's state; 2) the age of the TTO; and, 3) the inventor's share of technology transfer revenues (2005). Among these predictors the financial incentives for involvement in technology transfer had the largest effect on both the average number of licensing agreements and the average annual income of the universities that were investigated; Link and Siegel conclude, "university administrators should view faculty as economic agents. Changing incentives will change behaviour" (2005, p. 179).

Stochastic frontier analysis is capable of modeling skewed response variables. However, the strength of the findings is strongly linked to the extent to which the production function captures all of the critical inputs for productivity. Link and Siegel's choice of production function variables was motivated by earlier empirical studies which represent the current state of the art (2005). However, given the nascent state of the literature, only further research will be able to vindicate their model and thus their findings.

2.2.3.1.4 Study 4

Lockett and Wright (2005) extend the other studies by investigating the relationship between the researchers' share of technology transfer revenues and spin-off formation in the U.K. Their respondent variables (the number of spin-offs per year per university and the number of equity investments in university spin-offs by external inventors per year per university) both demonstrate skewed distributions (2005). To accommodate these distributions, the authors tested their hypotheses using both negative binomial and Poisson regression techniques (2005). The model included two constructs, 'Business Development Capability' and 'Incentives and Rewards,' that were assessed using the Likert-type items in the author's own survey (2005). 'Business Development Capability' relates to the extent to which the university has a clear process for developing spin-off companies (2005). 'Incentives and Rewards' relates to the incentives and rewards for involvement by university staff[3] in spin-off formation (2005). The full model included eight other explanatory variables: 1) total research expenditures by the university; 2) expenditures by the university on external IP advice; 3) TTO staffing counts; 4) the age of the TTO; 5) 6) whether or not the university has a medical school; 7) whether or not the university has a science park; and, 8) the R&D intensity of the region (2005). The model was strongly significant when tested using negative binomial regression techniques and when tested using Poisson regression techniques. Three of the ten variables were found to be significant at the .10 level under both tests: 1) expenditures by the university on external IP advice; 2) 'Business Development Capability'; and, 3) the researcher's share of revenues arising from technology transfer (2005). The researcher's share of technology transfer revenues was not significant at a .05 level; therefore, the models provide only weak evidence that revenue sharing is a factor (2005). In discussing the link between revenue sharing and spin-off activity, the authors observe that universities seeking to support technology transfer may be more likely to provide higher shares of licensing revenues to their inventors and that this "may form part of the array of signals to the academic that the university is seeking to encourage technology transfer" and thus lead to increased spin-off activity (2005, p. 1048).

2.2.3.1.5 Discussion

Together, the four quantitative studies provide some evidence that the financial incentives determined by IP policies have an effect on technology transfer outcomes. The studies model the university researcher as an economic agent, who is directly influenced by the costs and financial benefits of

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[3] It is not clear from the context whether the authors are referring to TTO staff members and/or faculty members.

multiple courses of action. Although the formal economic models of individual decision-making can include non-financial variables, these models limited themselves to financial aspects of the decision-making. The way in which the 'economic agent' model of motivation was used in these studies, implies that the authors assume that the agents are knowledgeable about their choices and make rational choices to maximize their personal financial gain. No research could be located that directly investigated the decision-making processes of university inventors and the only research regarding faculty inventors awareness of IP and IP policies found that faculty members at Monash University were generally uninformed (Monotti, 2000). This finding suggests that the economic agent theory focused only on financial benefit, as implied by these studies, may not provide an adequate description of faculty inventor's motivations for engaging in technology transfer.

One of the ways to counterbalance the current shallowness of the theory in the field and the high reliance on a single data set demonstrated by the quantitative research is to explore the mixed methods and qualitative research pertaining to the relationship between university IP policies and technology transfer.

2.2.3.2 Qualitative and Mixed Methods Studies

Qualitative and mixed methods research can be used to elicit information from actors and stakeholders and, as a result, these methods are often used in emerging areas of research to suggest which factors are most likely to be important and why. As a result, these methods can be important in establishing theory in emerging areas.

This section discusses three studies: two employed a purely qualitative methodology and another used a mix of interview content analysis and regression analysis. The studies, summarized in Table 4, will be reviewed separately in chronological order and then discussed together.

Table 4. Qualitative and Mixed Methods Studies (Modeled after Phan & Siegel, 2006).

Author(s)	*Data*	*Methods*	*Key Findings*
Renault (2006)	Author's survey, interviews with faculty members at 12 universities in the U.S. south-east author's survey, AUTM, NSF	Logistic regression, content analysis	Institutional policies, including royalty distribution, are important determinants of support for technology transfer activities and other university-industry interactions; faculty attitudes to the role of the university are correlated with involvement in technology transfer activities
Siegel, Waldman, Atwater and Link (2004)	Interviews with U.S. technology transfer stakeholders	Qualitative analysis as defined by Miles and Huberman (1994)	Financial incentives for technology transfer are important for encouraging faculty support of licensing activities and may influence the ability to attract faculty who are active in licensing
Stevens and Bagby (1999)	Interviews with technology managers at experienced and active TTOs	Unidentified qualitative process	Incentive systems are needed to reward inventors and relevant participating units (i.e. colleges, departments)

2.2.3.2.1 Study 1

Stevens and Bagby (1999) were among the first researchers who sought to identify significant factors related to technology transfer activities in U.S. universities. Their study made an effort to obtain information representative of best practices by restricting the study to TTOs with a long history and a high level of activity. As a result, the results of their qualitative study are primarily descriptive. For example, they observe that licensing fees are usually distributed between the inventor, the inventor's department, college, or research department, central administrative units and/or the TTO (1999). In their conclusions, they state that incentive systems are needed to reward inventors but no rationale is provided and it isn't known to what extent this statement reflects the content of the interviews they conducted (1999).

The authors note in the article that they provided little information regarding the methodology to conform to the truncated format required by the journal (1999). Unfortunately, this makes it very difficult to interpret the study. For example, it isn't clear how many participants were interviewed or at how many universities. Nor did the authors explain how they reduced and synthesized that data for publication. As result, their claim that incentive systems are important can only be treated as weak evidence of an effect.

2.2.3.2.2 Study 2

Siegel, Waldman, Atwater and Link (2004) conducted 55 structured interviews with 98 stakeholders, including TTO directors, university administrators who oversaw TTOs, academic scientists and managers or entrepreneurs based at firms in university science parks (2004). The participants were all members of a convenience sample of research-intensive universities in North Carolina and Arizona, the states in which the authors reside (2004). The authors argue that the sample is more likely to be representative of a wide range of U.S. universities than a study that restricts its focus to higher-profile institutes, which are recognized as leaders with respect to technology transfer (2004). The interviews were structured using a list of open-ended prompts derived from the literature that were largely common across stakeholder groups (2004). The data analysis was conducted following Miles and Huberman's three stage approach and all of the comments were independently categorized by at least two of the researchers to minimize the impact of individual bias (2004).

The study identified four themes and assessed the differences between stakeholder groups with respect to the themes: 1) the outcomes for technology transfer that they recognize and the significance they attribute to those outcomes; 2) the aspects of relationships and networks that they described as important; 3) the barriers to technology transfer that they identified; and, 4) their suggestions for improvements (2004). Many participants across the stakeholder groups identified inadequate rewards for faculty inventors as a barrier to effective technology transfer, and suggested increasing rewards for inventors in order to improve technology transfer (2004). Academic scientists and university administrators mainly focused on the lack of rewards for technology transfer in the promotion and tenure process and some scientists indicated that they felt their shares of the revenues from technology transfer were too small.

This study provides relatively strong evidence that incentives, including financial incentives, are likely to be important factors in explaining institutional differences in technology transfer performance. It is clear from the descriptions that the qualitative analysis was conducted scrupulously. The only aspect of the study that seems to deviate from accepted practice is the authors choice to interview multiple stakeholders together. Depending on the ways in which they were grouped this may have suppressed valuable information. For example, a technology manager is unlikely to report weak support for technology transfer on the part of the university's administration if the administrator to whom he or she reports is also in the room.

The study also provides insight into the ways in which incentives may account for differences in technology transfer performance across universities. In their discussion of incentives, the authors provided the following excerpt from an interview with a department chair:

> At my former university, faculty members received 60% of the money from a licence, while here it is 30%. This disparity has not been helpful, in terms of our ability to recruit and retain faculty members who are active in this area (2004, p. 135).

This observation suggests that IP policies that offer desirable incentives can improve a university's technology transfer performance in three ways: 1) by inducing faculty members to support technology transfer; 2) by attracting and helping to retain faculty members who are engaged in technology transfer activities; and, 3) through some combination of the first two methods. If this could be demonstrated to be the case, it would have important policy implications. If the effect of incentives were primarily achieved through a redistribution of researchers across universities, it would imply that changing incentives are likely to have little effect on the aggregate level of activity across a university system, unless the incentives spur shifts across national boundaries.

2.2.3.2.3 Study 3

Renault (2006) designed and administered a survey to assess faculty member's attitudes towards the role of the university and the relationship between these attitudes and faculty members experience with collaboration with industry and patenting, and their interest in forming a spin-off (2006). The survey was completed over the web by 59 professors, which generated a 14% response rate (2006). In addition, surveys were completed in interviews with 39 professors (2006). The interviews were transcribed and used to investigate the differences between the professors when they were grouped according to the survey results for their attitudes or behaviours (2006). The quantitative data were used to model the behaviours reported by the professors as a function of their: 1) attitude to technology transfer; 2) university's attitude to technology transfer; 3) department's attitude to technology transfer; 4) tenure status; 5) publications; 6) field of study (ie. engineering vs. life sciences); 7) years in academe; 8) share of technology transfer revenues; 9) TTO's propensity to submit provisional applications rather than patents, and; 10) TTO's propensity to patent without first identifying a licensee (2006).

Only a few of the factors explored in the study proved to be significant. Faculty members attitudes, their share of technology transfer revenues, and the number of publications produced by a faculty member were all significant at the .05 level in at least one model (2006). Individual attitudes were a significant predictor of all three behaviours, revenue shares were significant in predicting both patenting behaviour and interest in spin-off formation, and publication counts were significant in the context of patenting (2006). Renault also found qualitative differences between comments made by the participants with low, medium, and high levels of interest in and acceptance for technology transfer activities and provides examples that illustrate the differences (2006).

Renault's study is somewhat difficult to assess. Like the paper by Stevens and Bagby (1999) , her paper does not provide any information about how the interviews were conducted or the data analyzed (2006). This undermines the value of both the quantitative and the qualitative findings because half of the surveys were completed in the context of an interview (2006). Otherwise, her study design would have provided a good example of the strength of mixed methods; her qualitative results could be interpreted as evidence that her attitudinal survey has the face validity and thus strengthened her findings (2006).

2.2.3.2.4 Summary

All three of the papers reviewed in this section provide some evidence that incentives are an important factor in technology transfer outcomes. The progression of the three papers suggests that research in this area is moving away from descriptive work towards theory building. Siegel et al. (2004) demonstrated the power of qualitative research to suggest alternate explanations for phenomena by identifying faculty hiring and retention as a mechanism by which IP policies may influence technology transfer activity at a university. Renault (2006) contributes to theory building by demonstrating that faculty attitudes also have an effect on behaviour. This finding suggests that individual faculty members respond differently to their environment and thus may be contribute to a more sophisticated model of faculty inventor's motivation to engage in technology transfer than the economic agent model implicit in the quantitative models.

2.3 Summary

As can be expected in an emerging and multi-disciplinary research area, the studies are principally based on similar prior empirical work and not grounded in theory. This lack of theoretical grounding means that there is not enough information to infer a causal relationship, even in the cases where there is strong quantitative evidence of a relationship. Consider for example, the contradictory rationales provided by two of the four studies. DiGregorio and Shane (2003) suggested that lower shares of licensing revenues may encourage inventors to form spin-offs instead of licensing to explain the negative relationship they observed between shares of licensing revenues and spin-off formation. Lockett and Wright suggested higher shares of licensing revenues may stimulate spin-off formation by communicating the university's interest and support for technology transfer to university inventors (2005). In the absence of a theoretical framework, the only way to explore these competing rationales is through further empirical study and by continuing to seek connections with established theory outside of this substantive area of study.

There is also a need for the use of more diverse sources of data. In part as a consequence of the volume of work done in the U.S., most quantitative studies rely on the Association of University Technology Managers (AUTM) annual survey as their sole source of technology transfer data. This is significant because the AUTM survey data are self-reported, not audited, and given the increase in publicity surrounding the results, especially in the business press (e.g. Clifton, 2005; , "Innovation's golden goose", 2002), the individuals aggregating the statistics may experience pressure to modify their reporting strategies to present their institutions in the best possible light. As a result, the AUTM data may not be sufficiently valid and reliable to be the basis of academic work.

There is a need for some of this empirical work to occur in countries other than the U.S. The studies are consistent with the larger technology transfer literature in that most of the work was conducted in the U.S. This means that the literature may be overly attuned to factors specific to the current situation in the U.S. and may not address factors important outside the U.S. For example, inventor-ownership of IP is unlikely to be identified as a factor in the U.S. because it exists at so few institutions and, as a result of the Bayh-Dole Act, the inventor ownership policy would only pertain to the small percentage of research conducted without the use of any governmental funds or resources. Therefore, it is not possible to determine from U.S. studies whether or not inventor-ownership is significantly different from university-ownership of IP or in what ways. This is an example of the need for empirical work that investigates the importance of IP policies in other countries and, in particular, the need to explore the significance of the incentives provided by university IP policies in the context of a country like Canada in which there are examples of significantly different university policies governing technology transfer activities.

Chapter 3
Methodology

A recent review and critique of the academic entrepreneurship literature calls future work to employ mixed methods research (O'Shea et al., 2004). The rationale provided is that quantitative research is important in the identification and verification of substantial and generalizable effects but it alone is not capable of accessing “the complexity and richness of the dynamics of academic entrepreneurship” in order to “uncover how academics make sense of their decisions” (2004, p. 24). This research is responsive to these needs; it seeks to gain a better understanding of the research problem by converging both quantitative and qualitative data. Three studies were used to accomplish this purpose. Study 1 assesses the impact of university intellectual property policies upon technology transfer outcomes for Canadian universities. Study 2 assesses the impact of changes to intellectual property policies at the University of Toronto. Study 3 explores, through in-depth interviews, the perceptions of experienced academic entrepreneurs at the University of Waterloo. The benefit of the use of mixed methods design is that each study provides a different perspective on the research question and therefore the studies should provide a richer description of the phenomenon than would be available through only one method.

This chapter first discusses the use of mixed methods and its advantages and disadvantages for this particular research. Then a detailed description is provided of the methods used in the three studies.

3.1 Mixed Methods Research

The three studies in this research use different methods. Studies 1 and 2 involve the analysis of quantitative data using cross-sectional analysis of aggregate-level data and interrupted time series analysis of longitudinal data, respectively. Study 3 involves the qualitative analysis of “in-depth” interviews with experienced academic entrepreneurs (Seidman, 1998). As discussed in Chapter 2, qualitative analysis of interview data and quantitative analysis of secondary data, including time series and survey data, have both been used in the study of university-industry technology transfer. However, they have rarely been used in the course of the same research project as complementary sources of evidence.

This use of multiple research methods in the course of a research project is referred to as ‘triangulation’ (Denzin, 1959). This term uses the navigation strategy of using multiple reference points to determine an object’s exact position as a metaphor for the manner in which the use of different research methodologies allows researchers to describe the phenomenon of interest with more validity (Smith, 1975). Each individual method is known to have particular strengths and weaknesses. In mixed methods research, the methods are expected to complement each other such that the weaknesses of each individual method or data source are mitigated by the strengths of the other methods and data sources and the overall study gains validity and reliability (Jick, 1979).

In this research, the three studies complement each other in terms of the richness of the information they provide and the reliability of the overall research. The statistical methods employed in Studies 1 and 2 provide a reliable assessment of the significance and magnitude of effects associated with policy differences. This information is critical when assessing possible policy interventions and in determining the importance of further research in this area. However, these quantitative studies can not identify why the policies are associated with the observed effects. Study 3 uses a more subjective qualitative analysis to develop a richer understanding of the link between university IP policies and university researcher support for technology transfer activities. The analysis of this rich information provides the basis for a theory of the relationship which informs the interpretation of the quantitative analysis and is expected to form the basis of future research. In interpreting this theoretical foundation jointly with the results of more reliable statistical analysis, the overall research results gain reliability and depth.

The studies also complement each other in a manner that enhances the validity of the overall research. Internal validity depends on the extent to which the study eliminates rival causes of the observed relationships (Drucker-Godard et al., 2001). Longitudinal research designs, like Study 2, are most strongly able to demonstrate causal relationships by permitting analysis of the temporal relationships between presumed cause and effect. However, the difficulty in obtaining usable time series of data spanning a policy intervention resulted in an institutional sample size of one, which limited the study's external validity or generalizability. By contrast, Study 1 employed a cross-sectional design, which offers little ability to assess causal relationships and so has little to contribute to the question of internal validity; however, it investigated a large sample population and so contributed to the external validity or generalizablility of the overall research.

In summary, the three studies build upon each other so that the complementary strengths of the methods result in inferences based upon both objective but shallow quantitative data and a rich description of the phenomenon. Used jointly, the three methods provide better reliability and validity than any one design used singly.

3.2 Study 1

The purpose of this study was to assess quantitatively whether or not there is statistical evidence across Canadian universities of a relationship between university IP policies and university researcher support for technology transfer. This section describes the data used to assess the relationship of interest and the methods used in the analysis, and the procedures used to obtain the data.

3.2.1 Sample

There are 98 degree-granting institutions in Canada (Association of University Technology Managers, 2004). The study was limited to the 48 degree-granting Canadian universities that are included in the Maclean's magazine annual university survey for two reasons. Firstly, many of the 98 degree-granting institutions recognized by The Association of Universities and Colleges are affiliates of the major universities (Association of University Technology Managers, 2004). For example, the University of St. Michael's College and the University of Trinity College are affiliates of the University of Toronto. These affiliates often rely on the larger institutions for a number of functions including technology transfer support services (Bordt & Read, 1999). Therefore, their inclusion would serve no purpose. Secondly, limiting the study to those universities evaluated by Maclean's means that the magazine's categorization of the universities can be used as a measure of the research intensity of the universities.

IP Policies were obtained for 37 of the 48 universities; the other eleven universities either did not have a policy at the time they were collected or did not make their policy available. The resulting sample includes a broad range of Canadian universities and includes most of the research-intensive universities in Canada. The 37 universities include 13 of the 16 'Medical-doctoral' universities, 9 of the 13 'Comprehensive' universities, and 15 of the 21 'Primarily undergraduate' institutions ("The Rankings", 1999). Thirty of the 37 universities also appear on the RE$EARCH Infosource listing of the 50 Canadian universities that receive the most research income (RE$EARCH Infosource, 2005). The main limitation of this sample was the underrepresentation of Québec universities. As shown in Appendix A, most of the universities that are included on the RE$EARCH Infosource list but not included in this study are located in Québec.

3.2.2 Data

3.2.2.1 Canadian University IP Policies

After the IP policies were collected, a set of variables was developed to capture differences in the types and amounts of incentives provided by the policies. The review of the policies revealed that universities appear to offer their researchers two primary forms of incentives for commercializing their inventions: shares of revenues and autonomy.

Two different arrangements for sharing licensing revenues are described in most Canadian intellectual property policies. One sharing arrangement is used if the university develops the intellectual property and is responsible for the costs of developing the IP. The other sharing arrangement applies when the inventor commercializes the IP independently, an option that is sometimes available.

Usually universities that develop the IP will share any revenues after the direct costs of developing the IP have been repaid. The proportion of these revenues that is provided to the researcher is either stipulated in the intellectual property policy or negotiated on a case-by-case basis. Instead of stipulating a single proportion, some universities pay different percentages depending on the amount of revenue the licence provides. Typically, these universities provide the researcher a large percentage of the revenues until some threshold is reached, at which point the researcher's share of all future revenues falls to a lower percentage.

Some universities require their researchers to share licensing revenues with the school when the researcher develops the IP independently. When the university requires revenue sharing, the researcher is usually expected to provide the universities with a certain percentage of the revenues after the direct costs of developing the IP are repaid. For example, at the University of Alberta, researchers who choose to commercialize inventions independently of the university are required to provide the university with one third of the net proceeds of the commercialization of the investment (University of Alberta, 1991). By contrast, at the University of Waterloo, inventors who choose to commercialize their inventions without the support of the university's Technology Transfer and Licensing Office, are under no contractual obligation to share the proceeds of their activities with the university (University of Waterloo, 1997).

Many universities also make some provision to provide, out of the university's share of the returns from the commercialization of university inventions, research funding to future projects in the same technological area, or to the inventor's research group, department, or faculty. While these funding arrangements could be perceived as important incentives by university researchers, they are not good candidates for a cross-university comparison because the funds are directed to many different subgroups and the benefit to the researchers involved in the commercialization attempt is sometimes unclear.

The literature indicates that researchers desire autonomy in the context of university-industry technology transfer. Campell and Slaughter sought to identify possible sources of conflict arising from technology transfer activities (Campbell & Slaughter, 1999). Their survey of faculty and administrators at U.S. universities suggests that "faculty favoured ways to retain their autonomy, whereas administrators were supportive of greater oversight" with respect to technology transfer" (1999, p. 343). Segal (1986) suggests that Cambridge's inventor-ownership IP policy has been a factor in the development of a high-technology cluster in Cambridge, England. Therefore, policies that provide the researcher with more control over the technology transfer activities are expected to act as incentives.

Some universities require researchers to provide the university with a 'right of first offer'. In this case, any researcher interested in commercializing an invention must describe the invention to university administrators in a formal 'invention disclosure'. If the university representative decides that the invention seems promising, the university will develop the IP and attempt to commercialize it. Other "inventor-owner" universities allow the researcher to choose between developing the IP independently and allowing the university to develop the IP. Since policies that do not reserve a right of first offer increase the researcher's control over the technology transfer activity, they are expected to act as an incentive and thus result in higher levels of technology transfer activity.

Three measures were used to represent each policy: one measure that assessed the degree to which the policy provides the researcher with autonomy and two measures that evaluated the financial incentives provided by the policy.

Right of First Offer: This measure was used to evaluate the control that the policies provide to researchers. It distinguishes between universities at which the university reserves the right of first offer and those at which inventors determine whether or not the university is involved in the commercialization of their inventions.

Share of Revenues When University Commercializes Invention: The percentage of net income provided to the researcher, when the university commercializes the innovation, was recorded.

Share of Revenues When Inventor Commercializes Invention: The percentage of net income retained by the researcher, when the researcher commercializes the innovation, was recorded.

There were three circumstances where it is not possible to record a single percentage for the researchers' share of revenues: 1) the percentage provided to the researcher is not specified in advance but negotiated on a case-by-base basis, 2) the university does not support technology transfer activities by developing IP, and 3) the revenue sharing agreement is structured using thresholds, above which the researcher's share of the revenue changes.

The data that describes the intellectual property policies of the sample of Canadian universities are included in Appendix A and described in Section 4.1.

3.2.2.2 University Research Intensity

The research intensity of the universities is expected to influence the level of technology transfer activity supported by each university by affecting the availability of patentable technology. Therefore, the universities' research intensity was used as a control variable in assessing the relationship between university intellectual property policies and university-industry technology transfer.

University research intensity was represented using the Maclean's categorization system for Canadian universities. This system represents universities as members of one of three groups that Maclean's describes as follows:

> The Medical Doctoral universities are those with a broad range of PhD programs and research, as well as medical schools. The Comprehensive universities are those with a significant amount of research activity and a wide range of programs at the undergraduate and graduate levels, including professional degrees. The Primarily Undergraduate universities are those largely focused on undergraduate education, with relatively few graduate programs. ("Reading the Rankings", 1999)

This grouping appears to capture several correlated aspects of scientific research intensity. The data gathered by the universities for use by Maclean's magazine were investigated to verify that there is a relationship between the Maclean's university typology and research intensity, measured by the number of faculty members actively engaged in research of the type funded by the Natural Science and Engineering Research Council of Canada (NSERC) and Canadian Institute of Health Research (CIHR) research, the number of grants received and amount the research money available to the faculty in support of their research. As shown in the following table, there is evidence of a relationship between the university classification and all three measures of university research intensity.

Table 5. Maclean's Classifications and University Research Intensity.

University Classification	*Average Amount of NSERC & CIHR Research Grant Money Received ($M)*	*Average Number of Researchers Eligible for NSERC & CIHR Grants*	*Average Number of NSERC & CIHR Grants Received*
Medical-Doctoral (*n*=14)	54.0	662	912
Comprehensive (n=10)	12.2	262	304
Primarily Undergraduate (n=17)	1.3	75	47

Source: Association of Universities and Colleges of Canada (AUCC) database of data generated by participants in the 2003 Maclean's Magazine survey.

3.2.2.3 Technology Transfer Outcomes

While there are no canonical measures for the success of technology transfer initiatives, simple counts of patents, licences, and spin-off companies (Brett et al., 1991; Expert Panel on the Commercialization of University Research, 1999), ratios of these counts (Gregory & Sheahen, 1991) and revenues associated with licensing and spin-off activities are often used as indicators (Brett et al., 1991; Expert Panel on the Commercialization of University Research, 1999). Since the purpose of this study was to determine how university policy is related to university technology transfer through faculty support, the measure of technology transfer should be most dependent on actions within the university. For this reason, measures like patent counts are more appropriate than licensing revenues, which also depend on external factors such as the existence of receptor capacity, and the state of the market. The number of Canadian or U.S. patents currently held by a university is a publicly available measure. The Statistics Canada surveys indicated that the majority of the patents obtained by Canadian universities are U.S. patents. Therefore, the number of U.S. patents currently held by a Canadian university was used as the measure of technology licensing activity.

The search for U.S. patents held by the 48 Canadian universities of interest identified a total of 1290 U.S. patents currently held by Canadian universities. The Statistics Canada 1999 survey reported that 81 Canadian universities held 635 U.S. patents by 1998 and 84 Canadian universities held 948 U.S. patents by 1999 (Bordt & Read, 1999). The difference between the 1999 patent count provided by Statistics Canada and the patent count provided by this study may be a function of the time that elapsed between the completion of the Statistics Canada study and the start of this study. The data were collected in late 2000 resulting in a time difference of about a year. Alternatively, patents developed by the research hospitals associated with Canadian universities may have appeared in the patent counts in this study and artificially increased the results for the universities affiliated with research hospitals.

3.2.3 Procedures

The data used in this study were collected in October and November of 2000, principally from online sources. This section describes the data gathering procedures for the IP policies and U.S. patent counts.

Most Canadian universities post their policy statements on their web pages. Therefore, the IP policies were gathered by searching university websites for the relevant policy. When no policy was found, the university's TTO was contacted to request a copy of the policy. Policies were obtained for 37 of the 48 universities. Three universities indicated that they did not have an IP policy, seven more universities had no IP policy posted on their web site and failed to respond to a request for the policy, and in one case only an incomplete copy of the policy was obtained.

U.S. patent counts were obtained through university-specific searches of the Delphion Intellectual Property Network online searchable patent database. For each university a search was conducted for all U.S. patents with the university name listed as the assignee. The resulting patent counts are presented in Appendix B. Unfortunately, this search method will not identify patents that are independently developed by university faculty members. Therefore, there is a high probability that the patenting activities at inventor-owner institutions were underestimated compared to patenting activities at university-owner institutions. This bias could not be addressed by requesting information directly from Canadian universities or by using existing surveys like the AUTM Annual Survey because most universities fail to track independently-developed technologies in a systematic fashion. This outcome variable also fails to capture inventions that are best protected with other forms of IP protection, like software. This flaw may bias the results if the amount of technology transfer activity associated with the commercialization of unpatentable inventions varies across universities differently than technology transfer activities associated with the commercialization of patentable inventions. It is unlikely that this bias will have a significant impact on the overall assessment because, as discussed in section 2.1.1, patenting is by far the dominant form of IP protection in Canada.

The results of the analysis of the relationship between the policy variables and the count of U.S. patents are documented in Chapter 4.

3.3 Study 2

The purpose of this study was to assess quantitatively whether or not university IP policies have a statistically significant and substantial impact on university researcher support for technology transfer by evaluating the impact of university IP policy interventions. This section describes the data used to assess the impact of policy interventions and the methods used in the analysis.

3.3.1 Sample

Interrupted time series analyses require a time series spanning the intervention and during which no other significant changes occurred. This meant that the policy intervention must have occurred at least a decade earlier than this study was conducted and that the university had started actively supporting and tracking technology transfer substantially before the policy shift.

Six universities were identified that had had changes of policy during the time period of interest: Queen's University, Ryerson University, the University of Alberta, the University of Calgary, the University of Toronto, and the University of Western Ontario. Of these six institutions, only the University of Toronto had a viable data set. Queen's University was not appropriate for further study because PARTEQ Research and Development Innovations, a non-profit corporation dedicated to technology transfer activities, started serving the university only a couple of years before the policy change (Queen's University, 2000). Any attempt to assess the impact of the policy intervention is likely to be confounded by the effects of the founding of PARTEQ. Ryerson's policy was effectively changed in September, 2003, when a binding agreement with the faculty association overruled the existing policy, at least as it pertained to faculty. While it will be interesting to observe the impact of their unusual arrangement in which the university and faculty members share ownership of all innovations commercialized with the support of the university, too few data are available to do a time series analysis (Ryerson University, 1990). The University of Alberta's policy was last updated in 1991. While technology transfer measures were collected prior to 1992, TEC Edmonton did not provide the data because they were collected prior to the establishment of TEC Edmonton and thus their reliability could not be verified (Freeman, 2006). The University of Calgary updated its policy in 1988 and 1992, but the limited data collected in the years before these interventions cannot be compared against the technology transfer measures from the period after the policy change because technology transfer support services were only made available in 1989 (Association of University Technology Managers, 2004). The University of Western Ontario did not begin to provide technology transfer support services to the entire campus prior to 1995/1996 and no data were collected in a systematic fashion prior to 1993/1994 (Walzak, 2006). Therefore, data were not available to examine the impact of the 1983 policy change from a "university-owns" to an "inventor-owns" policy at the University of Western Ontario. The University of Toronto TTO had tracked invention disclosures since 1975, which meant that a data set was available to assess the impact of the 1990 policy change from a "university-owns" to an "inventor-owns" university. Since the University of Toronto is the only university that offered a viable data set, it is the focus of this study.

3.3.2 Data

Invention disclosures are the formal disclosure of a potentially commercializable invention made by an inventor to a university. The annual counts of invention disclosures at the University of Toronto were the focus of this study for two reasons. Firstly, under both the old and new policies, faculty members have been required to submit an invention disclosure to the university at the start of any commercialization process. Therefore, the university's counts of invention disclosures track the activity at the university including any independently-developed technologies. Secondly, unlike patents, licences, and spin-offs, invention disclosures are created shortly after the faculty members decide to commercialize a technology and do not rely heavily on the availability of commercialization resources, such as investment capital, funds for prototype development and intellectual property protection, and business expertise. As a result, the number of invention disclosures reported at a university is more closely linked to researcher support for technology transfer than the other outcome variables that are currently tracked, such as licence revenue and returns from the realization of spin-off equity. The main limitation of this choice of measure is the lack of a direct link to any of the desired outcomes for technology transfer, including improvements to goods and services stemming from the use the innovation or economic benefits in the region or the nation that result from the commercialization.

3.3.3 Procedures

The data were obtained directly from the University of Toronto TTO. A meeting was held with technology managers in the office to determine whether or not this study is an appropriate use of the data, prior to the release of the data. To verify the validity of the data further and to obtain information on the historical context of the policy shift, Office of Research Ethics approval was obtained for interviews with technology managers and a university technology manager, who worked at the University of Toronto TTO during the time period of interest, was interviewed.

According to this university technology manager, there were two important changes to invention disclosure management that were not directly related to the policy change. Prior to the policy change, no early consulting was done to determine whether university research was ready to be disclosed. After the policy change, university researchers would be advised not to disclose in a number of circumstances, including cases where the technology had not yet been reduced to practice. This change is expected to make tests of the policy change more conservative because it will result in an underestimate of the number of instances, after the policy change, in which university researchers sought to make a disclosure. The second change in the management of invention disclosures was a streamlining of the disclosure form itself, which reduced it in length from about eight pages to two pages, shortly after the policy change. This change could be expected to increase the number of invention disclosures to the university. Therefore, any apparent shift in the number of invention disclosures must be considered the joint effect of the policy change and the streamlining of the invention disclosure form. Apart from these changes, the management of invention disclosures was consistent from year to year. No other relevant changes were identified. For example, the amount of funds available for technology transfer at the University of Toronto remained relatively stable until after 2000. Since no other explanations for a change in the number of invention disclosures per year were discovered, any significant changes observed between 1991 and 2000 can be assumed to be a consequence of the policy change and the change to the invention disclosure forms.

The data analysis proceeded in two stages. In *Exploratory Data Analysis*, the data were visually inspected to investigate important properties of the data and to determine the subset of models most likely to model the time series adequately. Three types of plots were used to investigate the time series of University of Toronto invention disclosures: graphs of the raw and smoothed data against time, and box-and-whisker plots. In *Confirmatory Data Analysis*, tests were conducted to assess the fit of the models. The statistical analysis of the impact of an intervention upon a time series can be approached using regression methods, ARIMA (Auto-Regressive Integrated Moving-Average) methods, and non-parametric tests (Hipel & McLeod, 1994). ARIMA methods are often the first choice but the data set did not contain enough observations for the use of these methods. Non-parametric tests are less able to provide nuanced descriptive information and less sensitive than parametric (i.e. regression) methods and thus less likely to detect significant results. Therefore, the analysis was based on the application of regression methods. The results of these analyses are presented in Chapter 5.

3.4 Study 3

The study seeks to discover how university researchers' understand their technology transfer experiences, and to share this perspective in the researcher's own words as much as possible. This qualitative study should increase understanding of both the ways in which university intellectual property policies influence researcher's willingness to support technology transfer and the relative importance of these effects. Therefore, this study is expected to identify theories that can be used to explain aspects of the relationship between IP policies and technology transfer outcomes.

3.4.1 Methodology

The goal of a phenomenological study is to describe the meaning of a phenomenon as constructed by a small number of individuals who have experienced the same phenomenon (Creswell, 1998, p.122). This goal meshes well with the research question in this study: how do university researchers' understand their technology transfer experience? Therefore, the research approach will be grounded in a phenomenological tradition.

The research methodology closely follows the in-depth interviewing methods described by Seidman (1998). His approach is grounded in the phenomenological tradition and has been used to investigate how college educators understand their work experiences. Therefore, it appears appropriate for use in an examination of how university researchers understand technology transfer experiences, as an element of their work experience.

3.4.2 Participants

In designing qualitative studies, researchers must make decisions that affect the balance between the breadth and depth of a study. Since the purpose of this study was a deep investigation of researcher's understandings of technology transfer, the study was limited to a single university. The University of Waterloo was selected because of the university's intellectual property policy and the university's reputation for high levels of university-industry technology transfer. Unlike many other universities, Waterloo's IP policy confers complete ownership upon inventors within the faculty. This permits the broadest range of technology transfer experiences. Furthermore, Waterloo's intellectual property policy has often been linked to the relatively large number of spin-offs associated with this moderately-sized institution (Cross & Babensee, 1992, 1994). In order to explore this link, purposive sampling was employed in the selection of participants.

Purposive sampling is the norm in qualitative research, especially in phenomenological studies, in which the participants must have had the same experience (Seidman, 1998). By deliberately selecting participants with a certain set of experiences, the researcher engages in what Miles and Huberman refer to as criterion sampling (1994). In order to explore the link between the university IP and policy and spin-off formation, the participants were restricted to the cohort that introduced spin-off creation to the University of Waterloo and most of the participants were chosen for their involvement in spin-off activities. The cohort that introduced spin-offs to the University of Waterloo consists of senior and retired faculty members. When this thesis was written in 2006, the average age of the participants was 69 years, average number of years that the participants had been professors was 28, and the retired professors had between retired for eight years, on average. For comparison purposes, participants were also included who had engaged in licensing to established firms, or who had done significant development work through research contracts or industrial positions while on leave from their academic postings.

Potential participants were identified using news articles and contacts within the university community. An effort was made to identify and include unsuccessful technology transfer attempts for comparison purposes. These were more difficult to identify. As a result, most of the projects in which participants had been involved were successful in both in generating a return for the inventors and making the technology available to users and, thus, making the advantages of the innovation available to the public.

As a result of the gender imbalance among senior and retired professors, especially in the technical disciplines (Sussman & Yssaad, 2005), the participants within this study were all male. This was accepted because even if a female participant meeting the various criteria could have been identified, it would be exceedingly difficult to protect her identity.

One of the difficulties in investigating a topic that has become highly political is the possibility that the participants will be too involved in impression management to speak frankly. In order to avoid this possibility, the participants were assured that their anonymity would be preserved in the presentation of the research results. Several participants would not have participated without this assurance thus it proved to be an important aspect of the research design.

Seidman refuses to provide a guideline for the appropriate number of participants, stating instead that the researcher should seek a saturation of the information (1998). Creswell suggests that phenomenological studies are often quite small in size and that ten participants should often suffice (1998). Therefore, ten participants, who are senior and retired faculty from the University of Waterloo, and experienced in technology transfer, were interviewed in this study.

3.4.3 Data Collection

In accordance with Seidman's guidelines, the data collection consisted in taping and transcribing a series of three interviews with each participant (1998). The first interview provided general life history information, the second interview provided details of the participant’s experiences in technology transfer and the final interview offered the participant an opportunity to reflect on his experiences (Seidman, 1998). This structure provided the researcher with an opportunity to learn about how the participant makes sense of some of his experiences, in the context of both those experiences and his life history (Seidman, 1998). The successive interviews were usually spaced about a week apart.

Each interview began with an expanded prompt that reminded the participant of the structure of the interviews and the theme of the current interview. The interview themes and some sample prompts are listed in Table 6. The subsequent interview was then largely directed by the participant.

Occasionally follow-up questions would be posed to clarify descriptions that the participants had provided. For example, if the participant had commented that the university environment was supportive of technology transfer the follow-up questions may have included: ‘What aspects of the university environment were supportive?’ or ‘Were there any aspects of the university environment that weren’t supportive?’ Follow-up questions were used most frequently in the last interview of the series. In that interview, participants were occasionally asked about factors that other participants had identified, including intellectual property policies to allow the researcher to compare perspectives in the thematic analysis.

Table 6. Interview Themes and Typical Questions.

Theme	*Typical Prompts*
Life History, in particular, Career History	In this first of the three interviews, what I'd really like to do is find out about you: find out about your career history and find out about your life history. The goal of doing so is to give me the opportunity to ask more interesting questions in our next interview where we'll focus on your technology transfer experiences. Then in the final interview we'll focus on the things you have learned, what you would want to share, what you think other people should know. The objective of having an open ended interview is to allow you to discuss the things that you think are really important for me to know. The reason for the staged approach is to give me a better opportunity to do a good job of understanding what you have to say in later interviews and asking those good questions. On that note, I'd invite you to tell me about yourself and to start wherever you think would be appropriate.
Technology Transfer Experiences	When we met last time we talked about your career history. You provided me with an overview of your career. What I'd like to do today is to invite you to talk a little bit more about your experiences with the technology transfer projects you identified. What project would you like to discuss first? Why did you decide to become involved with that project?
Reflection on Experiences	In our past interviews, we talked about your overall career and focused on your technology transfer activities, especially Project X. In this final interview, what I'd really like to do is move on to find out what you're most proud of, what you'd like other people to know, and what you learned from your experiences. What stands out in your mind when you think about your technology transfer experiences? What would you want to tell a colleague who is considering taking on a technology transfer project to know? Given what you have said about your career and your technology transfer experiences, is there anything you wish had been different? Is there anything that surprised you?

The interviews lasted between 45 and 90 minutes each. As a result, each participant was interviewed for about 3 hours. The interviews were recorded using both a digital and an analog recorder. The best recording was provided to professional transcribers and a copy of the transcription was provided to the participants for their review. Altogether, the interviews took 24.5 hours and resulted in 431 pages of transcripts.

3.4.4 Data Analysis

3.4.4.1 Profiles and vignettes

The first step in the data analysis was the development of profiles for each of the participants because "crafting a profile or a vignette of a participant's experience is an effective way of sharing interview data and opening up one's interview material to analysis and interpretation" (Seidman, 1998). The profiles were created by repeatedly culling the most interesting excerpts from the transcripts for a series of interviews with a single participant. Content was most likely to be selected for inclusion in a profile if it was clear from the wording and tone that the participant felt strongly about the subject, or if the participant brought up the subject unprompted, or revisited the topic multiple times over the course of the interviews.

In the creation of the profiles, the transcripts were left in the participant's own words as much as possible while preserving the participant's dignity. Oral speech is often ungrammatical and can include many repeated words and filler works like ‘umm’ and ‘ahh’. The inclusion of these aspects of oral speech in written transcripts can make the participant appear inarticulate and thus appear disrespectful. Therefore, Seidman (1998) recommends editing the final set of excerpts in order to preserve the participant's dignity. Filler words and repeated words were omitted. Small grammatical changes were made; for example, verb tenses were corrected. Occasionally transitional text was included to replace filler words or to bridge between two excerpts from the transcripts.

The profiles also needed to be edited to protect the participant's anonymity. All person, place or organizational names, which could be used to identify the participant, were replaced. For example, proper names were often replaced with the individual's job title (“Kate Hoye” becomes “a Ph.D. student”); if the job titles had changed over time the most recent naming convention was used. Descriptive phrases that could be used to identify the technology transfer activity and hence the participant were replaced with more generic descriptions. For example, “the technology” or “the tools we developed” might be used in place of a description of reference to a spin-off's launch product. An effort was also made to edit out any unusual phrases that participants appeared to use regularly because these ‘catch-phrases’ might be identifying marks.

After the edits were completed, a review of the profiles identified as a concern that several profiles may allow readers familiar with the University of Waterloo community to identify the participants. Take for example a profile that contains three stories: one story that may identify the participant's faculty; another that may identify the type of technology transfer that the participant engaged in; and a third that discusses attributes of the market for the technology that was transferred. Separately none of the three stories could be used to discover the participant's identity but, together, the three stories may allow people familiar with the University of Waterloo to identify the participant. Therefore, it was decided that the profiles would not be displayed such that each profile is a continuous block in the usual manner (e.g. Seidman, 1985). Instead, after the thematic analysis, each profile would be divided thematically into vignettes and the vignettes would be displayed by theme with no information provided to link multiple vignettes to a single participant. These arrangements are expected to allow the presentation of a rich set of data while still preserving the anonymity of the participants.

3.4.4.2 Thematic data analysis

The second step in the analysis was thematic data analysis of the profiles. Unlike quantitative research, qualitative research is often inductive. In Seidman's thematic data analysis process, the data themselves suggest the constructs and the relationships between constructs (1998). This was done through immersion in the data in which the texts were read and coded with descriptive words and phrases (1998). Through the analysis process, these constructs appeared, merged, changed, and disappeared until it appeared that all of the relevant aspects of the data had been captured (1998). The emphasis in this analysis process was on identifying pervasive trends and reconciling them with contradictory or inconsistent passages (Seidman, 1998). The resulting themes are illustrated by the vignettes in Appendix F and discussed in Chapter 6.

3.4.4.3 In-depth interviewing, reliability and validity

Seidman has noted that the in-depth interviewing protocol is structured to produce reasonably reliable and valid results (1998). The structure of the interviews provides context for the participant's comments which the researcher can use to produce more reliable results (1998). The internal consistency of the results was a focus during the development of the profiles; topics were most likely to be included in the profiles if they were introduced in multiple sessions or if they espoused views that appeared consistent with the content of the other interviews. This approach is expected to reduce the possibility that a participant was intentionally or unintentionally misleading or that a profile is strongly affected by a participant's mood during a single interview. Therefore, this focus is expected to increase the reliability of the results. Validity was the focus during the thematic analysis. Valid constructs most likely to be identified when researchers looking for themes across participants (1998). In order to demonstrate the analytical rigor with which this analysis was conducted, the themes are illustrated with as many vignettes as possible so that interested parties can explore the relationship between the underlying data and the themes identified in the study.

3.5 Conclusions

This research is structured using a mixed method design. The purpose of this approach is to understand the research problem better by analyzing both quantitative and qualitative data. Three studies were used to accomplish this purpose. Study 1 is a quantitative study using a cross-sectional design to investigate the relationship between IP policies and the level of university technology transfer activity. Study 2 is a quantitative study using a longitudinal design to assess the impact of a change in the University of Toronto's IP policy upon researcher support for technology transfer at that university. Study 3 is a qualitative exploration of the perceptions of experienced academic entrepreneurs at the University of Waterloo. The benefit of the use of mixed methods design is that each study provides a different perspective on the research question and therefore the studies should provide a richer description of the phenomenon than would be available through only one method. All three studies seek to advance our understanding of the research question, namely: What relationship exists between university intellectual property policies and university-industry technology transfer? The results of the studies are presented in Chapter 4, Chapter 5, and Chapter 6, respectively.

Chapter 4
Study 1: Cross-Sectional Study of Canadian Universities

This chapter contains the results of a cross-sectional assessment of the relationship between university IP policies and aggregate university-industry technology transfer outcomes. The purpose of this study is to assess quantitatively whether or not university IP policies have a significant and substantial impact on university researcher support for technology transfer.

The chapter has three sections. The first section describes the IP policies held by the 37 Canadian universities in the sample population. The second section quantitatively analyzes the relationship between these policies and technology transfer outcomes. The third section presents a discussion of these results.

4.1 Description of the IP Policies held by Canadian Universities

The first step in this study was the collection of intellectual property policies held by the 37 degree-granting Canadian universities in the sample population. A complete listing of the universities and the descriptive variables for their IP policies is provided in Appendix A. This section describes four aspects of the policies that govern the incentives offered to university researchers who engage in technology transfer. The four aspects are: 1) whether or not the universities reserve the right of first offer on IP arising from university research, 2) the researcher's share of the revenues when the university commercializes the invention, 3) the researcher's share of the revenues when the researcher commercializes the invention, and 4) the threshold structures used by some universities to create different revenue sharing agreements for different amounts of revenue.

4.1.1 Right of First Offer

Right of first offer refers to the practice on the part of some universities of reserving the right to evaluate all university inventions that inventors are interested in having commercialized and to own and develop any inventions that the university deems commercializable. Since policies that do not reserve a right of first offer increase the researcher's control over the technology transfer activity, they are expected to act as an incentive and thus result in higher levels of technology transfer activity.

Right of first offer is only possible at the universities that have TTOs or some other capacity for reviewing applications and supporting patenting, licensing and spin-off activities. According to the available policies, seven of the 37 universities do not commercialize inventions and thus could not consider requiring a right of first offer.

Of the 30 universities that can support technology transfer, 13 reserve the right of first offer and thus are classified as "university-owner" universities and 17 universities do not reserve the right of first offer. It is important to note that "university-owner" universities allow the inventors to determine whether or not to pursue commercialization. However, inventors who are interested in commercializing their inventions in these institutions are required to give the university the opportunity to assess the invention and decide whether or not the university will commercialize the invention using its resources. The inventors can only commercialize the invention independently if the university decides it is not interested in commercializing the invention. Several universities still retain some control of inventions that are being commercialized independently. For example, at McGill University, faculty inventors need to obtain university approval to license inventions that they are commercializing without assistance from the university TTO (McGill University, 1985).

4.1.2 Researcher's Share of Revenues When the University Commercializes the Invention

University policies often define the share of the revenue that is provided to the inventors when the university commercializes an invention arising from university research. These clauses are only included at the 30 universities that have the capacity to support technology transfer. Of these 30 universities, 21 offer guidelines for the percentage of the net income that the institution will share with faculty inventors, including four that structure the revenue sharing using thresholds. The other 9 universities negotiate revenue sharing arrangements on a case-by-case basis. Of the 17 universities that offer guidelines but do not structure them using thresholds, twelve universities set the researchers' share at 50% of net income. Three universities in this group set the researchers' share at a lower level; the University of Toronto, the University of Alberta and Queen's University set the researchers' share at 25%, 33⅓ %, and 40%, respectively. Two universities set the researchers' share at above 50%; at McGill University and Simon Fraser University, researchers are entitled to 65% and 80%, respectively, of the net income derived from the commercialization of their inventions.

Of the five universities that diverge from the 50% revenue sharing norm, four are 'Medical-Doctoral' universities and all five are in the top 25 universities when ordered by research spending (RE$EARCH Infosource, 2005). This suggests that there is greater diversity in the policies held by the more research-intensive universities, perhaps because these institutions started developing intellectual property policies and technology transfer support systems before the norms emerged.

The universities that do not reserve the right of first offer have a wider range of revenue sharing arrangements than the universities that do reserve the right of first offer and they are more likely to hold policies that set the sharing lower than the norm value of 50%. Three of the ten "inventor-owner" universities provide the researcher with less than 50% and one "inventor-owner" university provides the researcher with more than 50%. One of the seven "university-owner" universities diverges from the norm value of 50% and it sets the researcher's share above 50%. This suggests that, in devising the policies, administrators in "inventor-owner" institutions may have chosen to take higher shares of financial returns in exchange for providing researchers with more autonomy in technology transfer activities.

4.1.3 Researcher's Share of Revenues When the Researcher Commercializes the Invention

Typically, university policies define the share of the revenue that is provided to the inventors when the inventor commercializes an invention arising from university research without the support of university technology transfer services. Independent commercialization by inventors can occur at university-owner institutions when the university has decided it is not interested in pursuing commercialization, and at inventor-owner institutions when the inventor decides not to involve the university in the commercialization.

Policies governing the inventor's share of the revenues, when the inventor commercializes an invention arising from university research, were identified in 36 of the 37 policies collected. Of the 36 universities with relevant policy statements, five universities negotiate revenue sharing on a case-by-case basis, and three universities stage the researcher's share using thresholds. Of the 28 universities that offer guidelines for the researcher's share but do not structure their guidelines using thresholds, 19 universities set the researchers' share at 100% of net income. In the remaining nine, four universities set the researcher's share at 50% of net income, three universities set the researcher's share at 75%, and the University of Alberta and St. Francis Xavier University set the researchers' share at 66.6% and 85 %, respectively.

Again, the universities that do not reserve the right of first offer have a wider range of revenue sharing arrangements than the universities that do reserve the right of first offer and they are more likely to hold policies that set the sharing lower than the norm value of 50%. Only one of the nine "university-owner" universities sets the researcher's share below 100%, whereas eight of the nineteen "inventor-owner" universities offer a smaller share of the revenue to the researcher. This is consistent with the earlier supposition that, in devising the policies, administrators may have chosen to take higher shares of financial returns in exchange for providing researchers with more autonomy in technology transfer activities and vice versa.

4.1.4 Thresholds for Revenue Sharing

Of the 37 universities, six institutions structure their guidelines for revenue sharing using thresholds based on the net income from the commercialization. The revenue sharing guidelines for these six universities are outlined in Table 7.

Table 7. Thresholds for Revenue Sharing

University	*Inventor's Share of Net Income when the University Commercializes the Invention*	*Inventor's Share of Net Income when the Inventor Commercializes the Invention*
McGill University	65% of any net income	80% of the first $100,000 65% of any further net income
Memorial University of Newfoundland	50% of the first $200,000 40% of the next $200,000 25% of any further net income	50% of the first $200,000 60% of the next $200,000 75% of any further net income
University of Acadia	Not applicable	100% of the first $20,000 75% of all net income
University of Guelph	75% of the first $100,000 25% of any further net income	100% of all income
University of Ottawa	80% of the first $100,000 50% of any further net income	100% of all income
University of Western Ontario	100% of the first $1,000 50% of the next $29,000 30% of any further net income	100 % of all income

Sources: (Acadia University, 2000; McGill University, 1985; Memorial University of Newfoundland, 1996; University of Guelph, 1991; University of Ottawa, 1997; University of Western Ontario, 1983).

For the cases in which the university commercializes an invention, all four of the universities that have tiered revenue sharing agreements offer an initial rate at or above the norm of 50%. As thresholds are reached, the researcher's share of the net income decreases. The final rate for the four universities ranges between 25% and 50%, which are the lowest rate and the norm for universities without tiered revenue sharing arrangements, respectively. In the many cases where the return from the commercialization is not substantial, these revenue sharing agreements provide a more significant financial reward to the researcher than is the norm, and they ensure that the university will benefit most in the rare cases where the return on the invention is worth millions of dollars.

Memorial University of Newfoundland has a tiered revenue sharing agreement for use in the cases where researchers commercialize their inventions independently. Since Memorial reserves the right of first offer, this tiered agreement will only apply when the university has determined that it is not interested in commercializing the invention. The inventor's highest percentage share in the tiered agreement (75%) is lower than the norm of among other universities (100%). However, faculty might see these incentives as equitable because the financial incentives offered by the Memorial policy to the commercializing entity are the same regardless of whether it is the inventor or the university that commercializes the invention.

McGill University also has a tiered revenue sharing agreement for use in the cases where researchers commercialize their inventions independently. McGill reserves the right of first offer; however, faculty members can request permission to commercialize their inventions independently. The policy at McGill appears to offer little financial incentive to commercialize independently of the university. In exchange for accepting the risk of commercialization, the inventors will receive at most $15,000 more than they would have if the university had developed the invention.

Acadia also has a tiered revenue sharing agreement for use in the cases where researchers commercialize their inventions independently. Acadia is one of the seven Primarily Undergraduate universities that had not developed technology transfer support services by 2000. Five of the Primarily Undergraduate universities claim up to 50% of the net income derived from these activities while providing no support for technology transfer activities. These IP policies seem to be designed to allow the university to benefit from whatever technology transfer activities might occur without the university's support; they are not primarily designed to encourage technology transfer.

4.1.5 Summary of IP Policies

Canadian universities currently hold a wide range of intellectual property policies, with most of the diversity derived from the way in which the policies are structured as opposed to the percentages of financial incentives offered by the policies. Many of IP policies studied preserve institutional flexibility by permitting the university to make arrangements on a case-by-case basis, and several more offered tiered financial incentives. These policies differ from those that specify a percentage share in terms of the structure of the policy. Among the universities that specify revenue sharing agreements without using thresholds, there is little diversity in the percentage shares provided to researchers by the policies that specify revenue sharing arrangements. The majority of the universities that specify the researcher's share of revenues assign the researcher half of the revenues after the repayment of IP development costs if the university develops the IP. An even larger majority assigns all of the revenues to the researcher if the researcher develops the IP independently.

4.2 Analysis

This section presents an analysis of the impact of the university IP policies on the amount of technology transfer activity. Counts of the U.S. patents held by each university are used as the measure of the amount of technology transfer activity at each institution because patenting relies less on the availability of resources external to the university than licensing revenues or counts of spin-offs. U.S. patents were chosen because the U.S. is the jurisdiction in which Canadian universities are most likely to patent inventions (Bordt & Read, 1999; Read, 2000, 2003, 2005). Three policy variables representing different incentives provided to researchers were investigated: 1) whether or not the universities reserve the right of first offer on IP arising from university research; 2) the researcher's share of the revenues when the university commercializes the invention; and 3) the researcher's share of the revenues when the researcher commercializes the invention.

The first part of this section presents an exploratory analysis of the respondent variable, U.S. patent counts. This analysis is followed by an investigation of the relationships between the respondent variable and the four explanatory variables: first the control variable, Maclean's institutional type, and then each of the three policy variables. In each case, the relationship is first explored using graphical methods and descriptive statistics to determine if statistical tests are likely to be productive. Where warranted, statistical tests are chosen based on the characteristics of the data.

4.2.1 U.S. Patent Counts

Exploratory data analysis of the response variable is an important precursor to tests of the relationship between explanatory variables and the response variable because it permits the identification of important qualities of the data (Hipel & McLeod, 1994). Descriptive statistics and a histogram were generated of the U.S. patent counts for the Canadian universities in the sample population to permit an investigation of the properties of the response variable (*M*=30.9, *SD*=52.9, *Mdn*=6. 0, *skewness*=2.67). As Figure 1 shows, the distribution of patent counts is substantially positively skewed; instead of having the symmetrical bell shape of the normal distribution, the bell is slanted so that the right tail extends much further from the center of the bell than the left. The Shapiro-Wilk test of normality confirms that the distribution is not normal (*SW*=.644,*p*<.001). This result means that nonparametric tests should be used whenever possible.

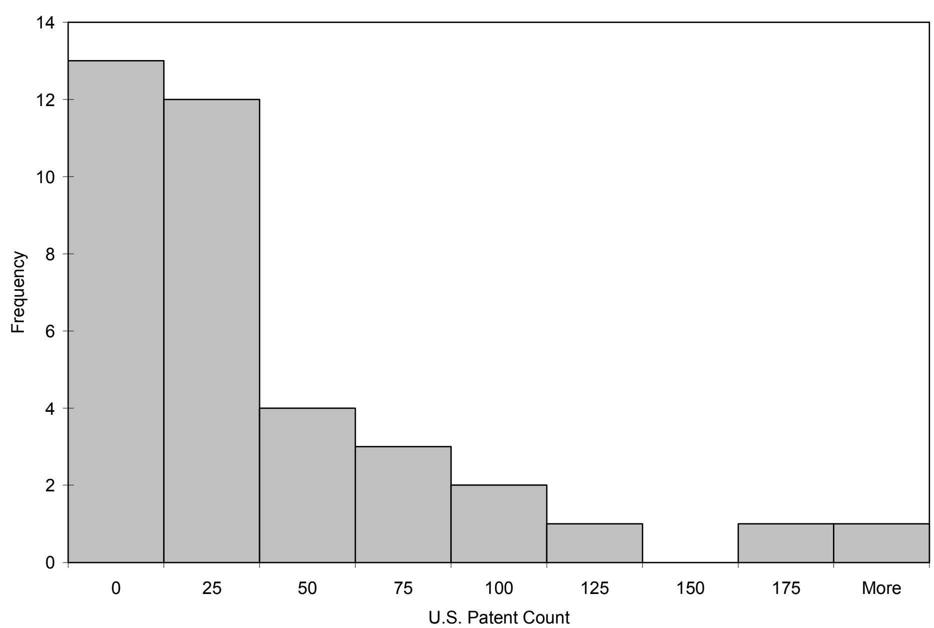


Figure 1. Histogram of U.S. Patents Held by Canadian Universities as of 1999.

4.2.2 University Research Intensity

University research intensity is expected to be an important determinant of the amount of technology transfer activity at a university because it will have a direct effect on the number of commercializable inventions arising from research at that university. A small university with few graduate level programs and little research funding is considerably less likely to have the opportunity to transfer technology than a larger university with many graduate level programs and a lot of research funding. As described in section 3.2.2.2, the Maclean's typology (Medical-Doctoral, Comprehensive, Primarily Undergraduate) was used to capture the research intensity of the various universities so that it can be employed as a control variable in studying the relationship between policy variables and technology transfer outcomes.

As the box plots in Figure 2 suggest, there is a sizeable difference between the numbers of patents held by universities in the three groups. The mean number of patents held by Medical-Doctoral, Comprehensive, and Primarily Undergraduate universities is 73.3, 19.6, and 0.3, respectively. The Kruskal-Wallis test, a non-parametric test of the difference of means of two or more populations, indicated that these differences are significant ($\chi 2$=28.2, p<.001). This result is strong evidence the U.S. patent counts capture important differences among the universities.

Also evident from the box plots in Figure 2, is the small number of patents held by Primarily Undergraduate universities. Only three of these universities held U.S. patents. The University of Prince Edward Island held two patents, and the University of Northern British Columbia and the University of Winnipeg each held one patent. These very small patent counts indicate that the group of Primarily Undergraduate universities was not engaged in technology transfer activities by 2000. Therefore, these universities will not be included in further investigations of the relationship between university IP policies and technology transfer outcomes.

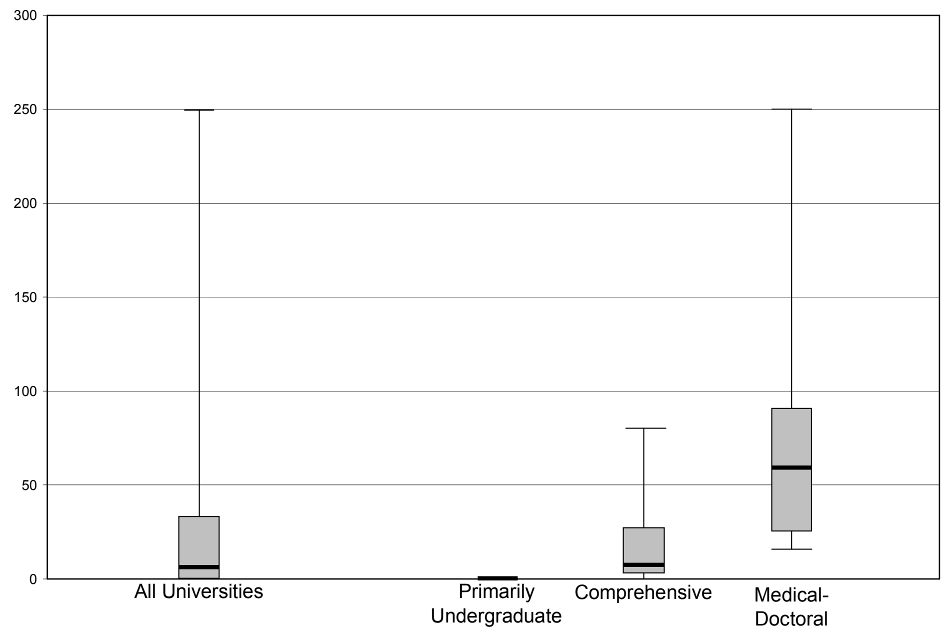


Figure 2. Box-and-whisker Plots of U.S. Patent Counts, Grouped by Maclean's Type.

4.2.3 Right of First Offer

Institutional right of first offer is only possible at the universities that have TTOs or some other capacity for reviewing applications and supporting patenting, licensing and spin-off activities. The sample contains 19 Comprehensive or Medical-Doctoral universities that have the capacity to commercialize inventions that arise from university research. These universities are the focus of this investigation.

Descriptive statistics were calculated for the patent counts held by two subgroups of this sample: universities that reserve a right of first offer and universities that do not reserve a right of first offer. As shown in Table 8, the universities that reserve the right of first offer hold, on average, almost exactly the same number of U.S. patents as the universities that do not reserve the right of first offer. However, the similarity of the means can not be directly interpreted because of the high variance. The high skewness and kurtosis of the distributions suggest that the distributions both contain influential outliers. This implies that both sets of universities have many universities that hold relatively few patents and a smaller number that hold many patents.

Table 8. U.S. Patents Held by Medical-Doctoral or Comprehensive Universities, Sorted by Right of First Offer.

Descriptive Statistic	*Universities That Reserve the Right of First Offer (n=9)*	*Universities That Do Not Reserve the Right of First Offer (n=10)*
Mean	62.8	56.4
Standard Deviation	77.0	48.5
Median	31.0	46.0
Skewness	2.2	1.4
Kurtosis	5.0	2.1

The Kruskal-Wallis test, a non-parametric test, was used to assess whether or not the means of the two subpopulations are significantly different. This non-parametric test was not significant (χ^2=0.060,p=.806). Therefore, there is no evidence that the two subpopulations are different.

In order to investigate further the apparent absence of evidence of a relationship between ‘right of first offer’ and the number of U.S. patents held by the various universities, this relationship was also explored using research intensity as a control variable. As shown in Figure 3, further splitting the universities into groups of Comprehensive and Medical-Doctoral universities, to account for the differences in research intensity, does not provide any evidence of differences between the universities that reserve the right of first offer and those who do not.

In summary, there is no evidence of a relationship between the right of first offer and the respondent variable, U.S. patent counts. If there is such a relationship, it could be obscured by the relationship between the inventor’s share of the revenue from university-commercialized inventions and right of first offer. Therefore, the relationship between right of first offer and U.S. patents counts is re-examined in conjunction with the researcher’s share of revenues from university-commercialized inventions in the next section.

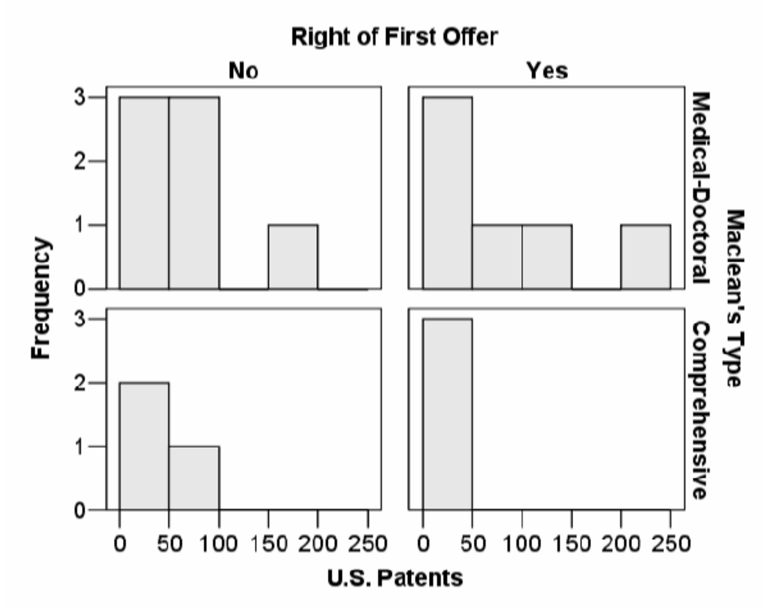


Figure 3. Histograms of U.S. Patent Counts, Sorted by Maclean's Type and into Universities That Do and That Don't Reserve Right of First Offer.

4.2.4 Researcher's Share of Revenues When the University Commercializes the Invention

The analysis of the relationship between the financial incentives and the U.S. patent counts at each institution is restricted to the universities that specified their revenue sharing agreements using flat rates, as opposed to revenue thresholds. In order to include in a direct comparison the universities that negotiate revenue sharing on a case-by-case basis or that use revenue thresholds to structure their revenue sharing agreements, assumptions would have to be made about how university researchers perceive these policies. Since there is no strong empirical or theoretical basis for these assumptions, the cross comparisons in this study focus on the eleven universities that specify their revenue sharing agreements using flat rates.

As demonstrated in Figure 4, there does not appear to be a relationship between the researcher's share of revenues from university-commercialized inventions and university counts of U.S. patents, even when research intensity is taken into account. There is no evidence of a relationship when the three Comprehensive universities are omitted, as shown in Figure 5.

This result suggests that there may not be a relationship between the two variables or that the relationship is masked by the effect of another variable. As noted earlier, the right of first offer appears to covary with the researcher's share of revenues; the institutions that offered less financial incentives than the norm are all universities that reserve the right of first offer. Therefore, the joint effects of these two variables are explored in the next section.

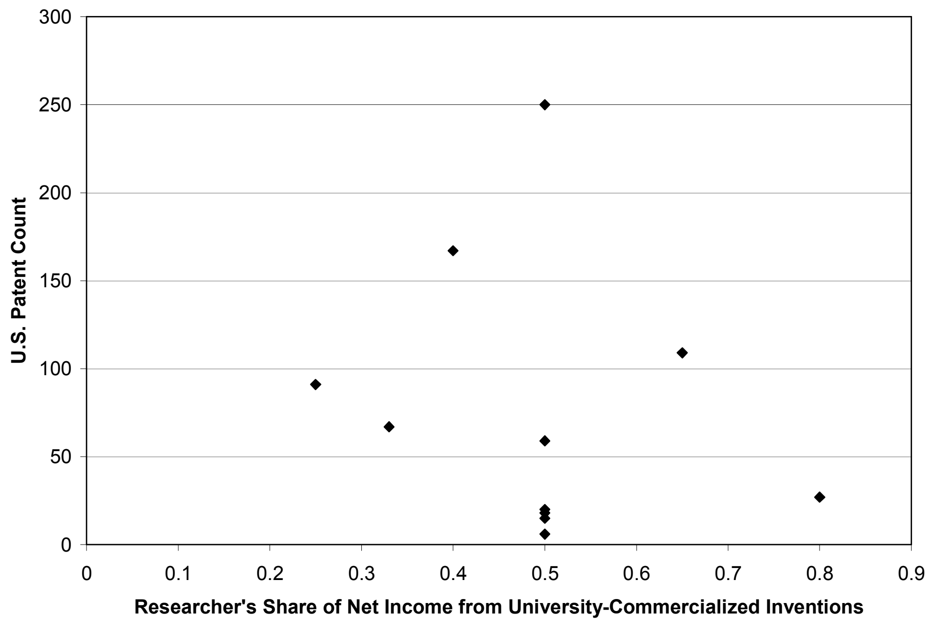


Figure 4. Scatter Plot of the Researcher's Share of Net Income from University-Commercialized Inventions versus U.S. Patent Counts for Medical-Doctoral and Comprehensive Universities.

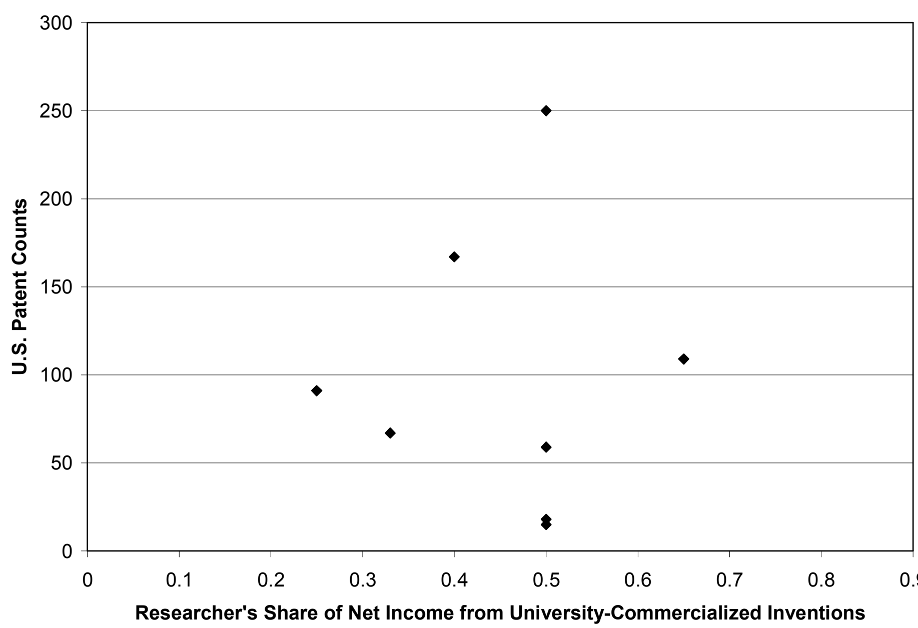


Figure 5. Scatter Plot of the Researcher's Share of Net Income from University-Commercialized Inventions versus U.S. Patent Counts for Medical-Doctoral Universities.

4.2.5 Researcher's Share of Revenues When the University Commercializes the Invention and Right of First Offer

Since only eleven universities specified the researcher's share of net income for university-commercialized-inventions, the relevant data were assembled in tabular form and visually inspected. The three Comprehensive universities, described by Table 9, are too small a set to demonstrate a relationship. Table 10 contains the information for the eight Medical-Doctoral universities. Among these universities, the two highest patent counts are held by a university that reserves the right to first refusal and an "inventor-owner" university, both of which offer their researchers a share of the research revenues that is close to the norm. From this inspection, it is clear that the data do not contain patterns of sufficient strength that statistically significant results are achievable. Therefore, no further analysis of these variables was conducted.

In summary, the data do not provide any evidence that the researcher's share of revenues from university-commercialized inventions or a university reserving the right of first offer have an effect on the amount of technology transfer at a given institution.

Table 9. Researcher's Share of Income from University-Commercialized Inventions and Number of U.S. Patent Held by Comprehensive Universities.

University Reserves Right of First Offer	*Researcher's Share of Net Income from University-Commercialized Inventions at Each University*	*Number of U.S. Patents Held by the University*
No	0.50	6
	0.80	27
Yes	0.55	20

Table 10. Researcher's Share of Income from University-Commercialized Inventions and Number of U.S. Patent Held by Medical-Doctoral Universities

University Reserves Right of First Offer	*Researcher's Share of Net Income from University-Commercialized Inventions*	*U.S. Patents Held by the University*
No	0.25	91
	0.33	67
	0.40	167
	0.50	15
	0.50	59
Yes	0.50	18
	0.50	250
	0.65	109

4.2.6 Researcher's Share of Revenues When the Inventor Commercializes the Invention and Right of First Offer

The researcher's share of revenues from inventor-commercialized inventions is expected to act as a greater incentive if the inventor has the option to proceed with independent commercialization compared to those institutions that reserve the right of first offer; if the university reserves a right of first offer, the inventor must expect that any valuable inventions will be claimed by the university. Therefore, the researcher's share of the revenues from inventor-commercialized inventions was only studied at universities that do not reserve a right of first offer.

At "inventor-owner" universities, incentives that encourage independent commercialization on the part of inventors were expected to decrease the number of patents held by the university because independently-commercialized inventions are less likely to include the institution as an assignee on the patent. However, the few universities that specify the inventor's share of inventor-commercialized inventions do not demonstrate the expected relationship. As shown in Figure 6, the two universities with policies that specify revenue sharing that is less than the norm hold an average number of patents relative to their peers. This finding does not suggest any relationship between the researcher's share of the income derived from inventor-commercialized inventions and the level of technology transfer activity at a given university.

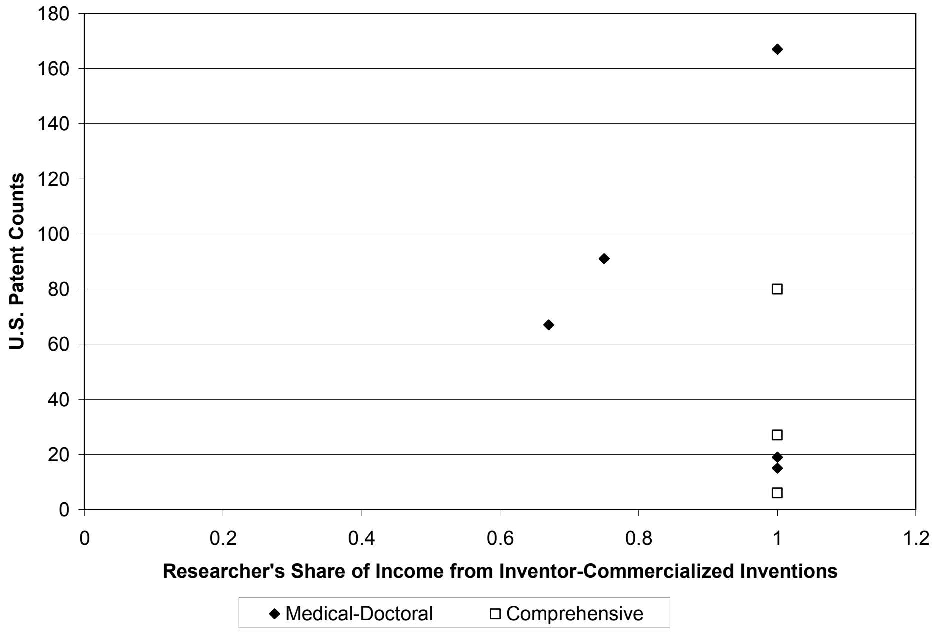


Figure 6. Scatter Plot of the Researcher's Share of Net Income from Inventor-Commercialized Inventions versus U.S. Patent Counts for "Inventor-Owner" Medical-Doctoral and Comprehensive Universities.

4.3 Discussion

This study did not discover any evidence that there are relationships between the financial incentives or the amount of autonomy provided to researchers by university IP policies and university-industry technology transfer outcomes. This section will explore the following three possible causes of this failure to demonstrate a relationship.

Possibility 1. University IP policies have no significant effect upon technology transfer activity at a university.

Possibility 2. University IP policies have significant effects upon technology transfer activity at a university but the effects are obscured by the inadequacies of the data used in this study.

Possibility 3. University IP policies have significant effects upon technology transfer activity at a university but the effects are obscured by the effects of other variables that also vary across the set of institutions.

4.3.1 Possibility 1.

It is possible that the incentives offered to faculty inventors by university IP policies have no significant effect on technology transfer outcomes. There is some evidence that this may be the case at least with respect to right to first offer. Clayman investigated the AUTM data for two groups of 16 research-intensive, Canadian universities, one with eight "inventor-owner" universities and another with eight "university-owner" universities (2004). He expressed each outcome as a ratio relative to millions of dollars of research expenditures, to account for differences in research intensity across universities, and calculated averages for each group (2004). The data, summarized in Table 11, do not demonstrate any relationships. Unfortunately, Clayman's work also suffers from the same problem as the study described in this chapter; the AUTM data used in the research do not include technology transfer activities undertaken by inventors without the support of the TTO. Therefore, Clayman's work is also subject to same limitations discussed in the next section and neither of these studies are strong enough, either theoretically or in terms of the data used in the assessment, to rule out the possibility that these incentives do have an impact. The only conclusion that can be made is that there is no evidence that allowing inventors to commercialize their inventions results in a decrease in the amount of technology transfer achieved by the TTO at the university.

Table 11. Technology Transfer Outcomes Per Cdn$1M of Research Expenditures, Grouped by Right of First Offer (Adapted from Clayman, 2004).

University Reserves Right of First Offer	*Invention Disclosures Received*	*Licences & Options Executed*	*Licence Income Received*	*U.S. Patents Issued*	*Spin-off Companies Formed*
Yes	0.701	0.148	12,101	0.090	0.020
No	0.493	0.138	12,327	0.090	0.023

4.3.2 Possibility 2.

If there is a significant relationship between the incentives provided by university IP policies and the amount of technology transfer at a given university, it could have been obscured by problems with the data used in assessing the relationship.

The most significant problem with the data used in the study is that the measure of the technology transfer outcomes is likely to be biased towards "university-owner" universities and that this bias could have obscured relationships of interest. The counts of the U.S. patents held by the universities do not include any patents developed by university faculty members independently of the university. Since there are likely to be more commercialization activities undertaken independently of the university at "inventor-owner" universities, the use of this measure may obscure the relationship between the amount of autonomy offered to researchers by the university IP policy and patenting activities at universities. The only conclusion that can be drawn from this is that, even excluding all independently developed patents, there is no evidence that universities that allow their researcher's control of technology transfer produce fewer patents. This suggests that either there is either no difference between institutions that reserve right of first offer and those that do not, or that the institutions that do not reserve right of first offer have more technology transfer activity than those that do not.

The bias in the technology transfer outcome measure is also important when interpreting the lack of evidence of a relationship between the financial incentives offered by the university IP policies and the number of patents held by the universities. As discussed in section 4.1.2, universities that do not reserve the right of first offer have a wider range of revenue sharing arrangements than the universities that do reserve the right of first offer and they are more likely to hold policies that set the sharing lower than the norm value of 50%. Therefore, the revenue sharing agreements are correlated with whether or not the university reserves a right of first offer. This means that the bias towards "university-owner" universities may also obscure relationships between the revenue sharing arrangements and technology transfer outcomes.

The only remedy for these problems would be the use of a measure that accounts for all technology transfer activity at both "university-owner" and "inventor-owner" universities, regardless of whether the active party is the university or the inventor. No such measure has been identified among the measures tracked by the universities or collected in the AUTM or Statistics Canada annual surveys. Designers of further cross-sectional studies would be advised to investigate the feasibility of surveying university researchers to obtain a less biased measure.

While the bias in the technology transfer outcome variable is the most significant limitation related to the choice of data, other aspects of the data also pose challenges. The data set was small from a statistical perspective because of the small number of universities in Canada and because policies could not be located for every university. It is possible that a relationship could be discovered if it was possible to obtain policies and data for every university. Another problem with the data is that, as with most technology transfer outcome variables, the distribution of the number of U.S. patents held by Canadian universities is quite positively skewed. This requires either that the data are transformed using a log transformation, for example, or that non-parametric tests are used instead of parametric tests. Both of these approaches reduce the likelihood that a relationship will be identified. In the assessment of the importance of financial incentives, this problem is compounded by the very small number of institutions that are comparable because they specify their revenue sharing using a flat rate and by the lack of diversity in the rates specified by these institutions. Together, these characteristics of the data could obscure any relationships between policy variables and technology transfer variables even if an unbiased technology transfer outcome variable could be collected. To address these concerns, future studies need to use an unbiased measure of technology transfer activity, and to increase the sample size, perhaps by moving to another unit of analysis. Future studies may also benefit from an assessment of the changing importance of individual patents. As TTOs acquire more resources they may begin to practice more aggressive patenting strategies, including protecting a single technology with a cluster of patents, which would skew analyses towards highly patentable technologies despite the fact that less patentable technologies can also have social and economic value.

4.3.3 Possibility 3.

If there is a significant relationship between the incentives provided by university IP policies and the amount of technology transfer at a given university, it could have been obscured by the effects of other variables that also vary across the set of institutions. These other variables could obscure the true relationships between the IP policies and technology transfer outcomes in one of two ways: 1) by having a direct impact on the amount of technology transfer at that institution; or 2) by having an impact on the relationships themselves. For example, the amount of money available to do patenting and licensing at a given university could have an effect on the number of patents that are based on research at that university. This would be an example of a direct effect on the outcome variable. If the amount of money available for patenting and licensing is a function of the revenue sharing agreement between the university and its faculty inventors, then this variable could also have an impact on the relationship between university IP policies and technology transfer outcomes.

It is important that these other factors are identified and their effects are determined. This will permit a better assessment of the impact of policy variables. Even more importantly, the role of these other variables will determine whether or not there is an optimal policy for all Canadian universities. If institutional variables like research intensity or culture are found to influence the relationship between university IP policies and technology transfer, the policy that best supports technology transfer at one institution may be sub-optimal and potentially destructive at another. Therefore, it is imperative that university IP policies are studied in a broader context.

4.4 Conclusions

In spite of the many reasons why university intellectual property policies can be presumed to have an impact upon university-industry technology transfer, comparisons across institutions have not demonstrated any relationships. It is possible that the true effects of IP policies are obscured by the effects of other variables that also vary across the set of institutions or by differences in ways in which technology transfer measures are gathered and reported. However, this study has demonstrated that further cross-sectional studies are unlikely to produce significant results without access to a significantly broader and more reliable data set. Further investigation of these possibilities is expected to have important implications for policy. Therefore, two additional studies have been conducted that are longitudinal and qualitative in nature.

Chapter 5

Study 2: Quantitative Analysis of Impact of an IP Policy Change

This chapter contains the results of the quantitative analysis of the impact of the University of Toronto IP policy change on annual counts of invention disclosures. The primary purpose of this study was to assess whether or not the University of Toronto IP policy change had a statistically significant effect on annual invention disclosures, a measure of researcher support of university-industry technology transfer.

This chapter is organized into four sections. The first section provides a brief description of the University of Toronto in order to familiarize the reader with the organizational context of the study. The second section describes the exploratory data analysis, in which plots of the data were visually inspected to identify properties of the data that are of interest and suggest variables for inclusion in the models. The third section presents the results of the confirmatory data analysis in which the impact of the policy intervention was assessed by comparing models of the impact, principally using regression analysis. The second and third sections are further supported by Appendix C, in which the statistical tests are discussed in more detail. The final section in the chapter includes a discussion of the limitations of the study and the implications of the results.

5.1 Background on the University of Toronto

The University of Toronto is one of Canada's largest and most research-intensive universities. It offers a wide range of degree programs from the undergraduate through to the graduate level, including 75 doctoral programs (University of Toronto, 2005). Professional degrees are offered through the university's 14 professional faculties (University of Toronto, 2005). In 2005, student enrollment was approximately 70,000, of which approximately 60,000 were full-time students (University of Toronto, 2005). It is affiliated with a number of hospital research institutes in the Toronto region; faculty members are often cross-appointed and the university and research institutes conduct joint research projects (University of Toronto, 2000). According to the AUCC database of the data created for the 2003 Maclean's survey, the University of Toronto had about 560 faculty members who were eligible for research funding from the Natural Sciences and Engineering Research Council (NSERC), and about 630 faculty who were eligible for research funding from the Canadian Institutes for Health Research (CIHR). In the past five years, the University of Toronto has consistently reported receiving the most research money per faculty member of any Canadian university (RE$EARCH Infosource, 2001, 2002, 2003, 2004, 2005). Since the University of Toronto has a large and active faculty cohort in technological areas, the university is expected to conduct a great deal of research that could potentially generate commercializable technologies. Therefore, it is reasonable to assume that the university is capable of supporting a relatively high level of technology transfer activity.

5.1.1 Intellectual Property Policies at the University of Toronto

On January 1st of 1990, a new hybrid IP policy came into effect at the University of Toronto (1990). Prior to this date, no significant changes had been made to the incentives provided to researchers since at least 1977.

Prior to the policy change, the University of Toronto had held a policy wherein the university owned the IP created in the course of university research. Invention disclosures were made to an Inventions Committee at the university. If the Inventions Committee determined that the invention had some value, the committee would direct the inventors to assign the invention to the university and the university would assign the invention to the University of Toronto Innovations Foundation, an organization founded to commercialize technologies developed at the University of Toronto. A technology manager who worked at the University of Toronto during this period reported that, in practice, all invention disclosures were accepted by the committee and hence assigned to the Innovations Foundation. There was an increasing number of invention disclosures per year over the early 1980s and this increasing workload was not matched by an increase in resources at the Innovations Foundation. By the late 1980s, faculty members were complaining that the Innovations Foundation was ineffective and unresponsive and invention disclosures were in decline. An investigation by technology managers revealed that faculty wanted to have ownership of their inventions. This may have been, in part, because they did not trust the Innovations Foundation with the commercialization of their inventions.

A new policy was devised that allowed researchers to develop their inventions independently of the university. If the inventors choose to ask for assistance, the Innovations Foundation will assess the invention and decide whether or not to commit internal resources to the development of the invention. If the Innovations Foundation chooses to develop the invention, it will pay for the acquisition of the appropriate legal protections, the marketing of the technology, and the legal costs of creating and maintaining licences with receptor firms. In these cases, the university researcher will receive 25% of the net revenue. If the Innovations Foundation chooses not to develop the technology, the ownership of the technology rests with the inventor, who can then seek other avenues for commercialization. If the university researcher chooses to develop the invention independently, the researcher is responsible for protecting and commercializing the innovation and providing 25% of the net revenue from these commercialization activities to the university.

This policy shift significantly reorganized the rights and responsibilities of faculty inventors and the university and it is likely that the most significant change is the difference in the amount of autonomy provided to the researchers. The new policy provided university researchers with greater autonomy; they could choose to approach the university or they could choose to develop their inventions as they saw fit without the intervention of the university TTO or the Innovations Foundation. This change did have some effect on the financial incentives offered to researchers. If they developed their technologies independently they could retain a higher share of the net income than if they allowed the university to develop the technology. However, relative to other Canadian universities, the researcher's share of the financial returns remained below the norm in both the case where the university develops the technology and the case where the inventor develops the technology. Therefore it is likely that the most significant aspect of the policy change was the change in the amount of autonomy provided to researchers.

The time series of annual counts of invention disclosures provided by the University of Toronto TTO and used to assess the impact of the policy shift is especially interesting for two reasons. Firstly, the University of Toronto is the only institution that has been identified that permits inventors to commercialize technologies independently of the university and that collects reasonably reliable institution-wide data that include the activities pursued independently. Often institutions fail to track activities pursued independently of the university's TTO and this bias in the data can corrupt comparisons of universities with different policy structures by systematically underestimating the level of activity within "inventor-owner" universities (Hoye & Roe, 2003). Furthermore, the University of Toronto started tracking technology transfer measures well before the policy shift. This makes it possible to compare the institution's activities prior to the shift to those after the shift.

In order to assess the impact, if any, that this policy shift had on the university's technology transfer activities, a time series of the changing counts of invention disclosures was investigated. Under both the old and new policies, faculty members are required to submit an invention disclosure to the university at the start of the commercialization process. Unlike patents, licences, and spin-offs, invention disclosures are created shortly after the faculty members decide to commercialize a technology and do not rely heavily on the availability of commercialization resources, such as investment capital, funds for prototype development and intellectual property protection, and business expertise. As a result, the number of invention disclosures reported at a university is more closely linked to researcher support for technology transfer than the other outcome variables that are currently tracked, such as licence revenue and returns from the realization of spin-off equity. Therefore, the assessment of the effects of this policy shift has been based on an investigation of the trends in the numbers of invention disclosures submitted in the thirty-year period centered on the policy change.

5.2 Exploratory Data Analysis

Visual inspection of a time series, as introduced by Tukey (1970), is an effective way to pursue the "numerical detective work required to explore important properties of the data" and to determine the subset of models most likely to model the time series adequately (Hipel & McLeod, 1994, p.177). Three types of plots were used to investigate the time series of University of Toronto invention disclosures: graphs of the raw and smoothed data against time, and box-and-whisker plots.

The raw time series, shown in Figure 7, was inspected for evidence that the policy change of 1990/1991 affected the number of invention disclosures. This plot shows a significant increase in the number of invention disclosures reported annually between fiscal years 1991/1992 and 1992/1993. Furthermore, annual counts of invention disclosures appear to be relatively constant from year to year prior to that point, and steeply increasing from year to year after that point. These findings suggest that there is a break point between fiscal years 1991/1992 and 1992/1993.

Smoothing functions make underlying trends in the data more apparent (Hipel & McLeod, 1994). Therefore, in order to investigate the possibility of a breakpoint in 1992 further, the data were split into two time series, one before and one after the breakpoint, and smoothed using two different functions. The results of smoothing with a three-year centered moving average are shown in Figure 8. The results of smoothing with the 4253H function are shown in Figure 9. This latter function involves calculating running medians of 4, then 2, then 5, then 3, then applying a Hanning smooth in which a running weighted average is calculated using weights (¼, ½, ¼), and it is a standard smooth in the assessment of time series (Hipel & McLeod, 1994). These plots were also inspected for evidence that the policy change of 1990/1991 affected the number of invention disclosures. The smoothed plots confirmed the findings of the scatter plot of the raw data, in that both smoothed series demonstrated an abrupt increase in 1992 and a higher rate of increase from year to year after 1992.

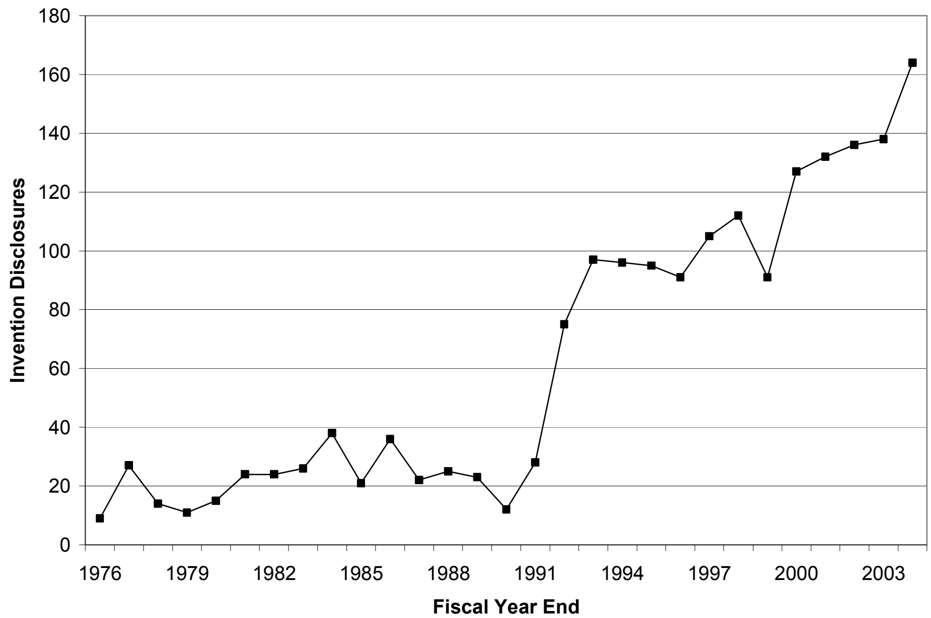


Figure 7: University of Toronto Invention Disclosures for Fiscal Years 1975/1976 to 2003/2004

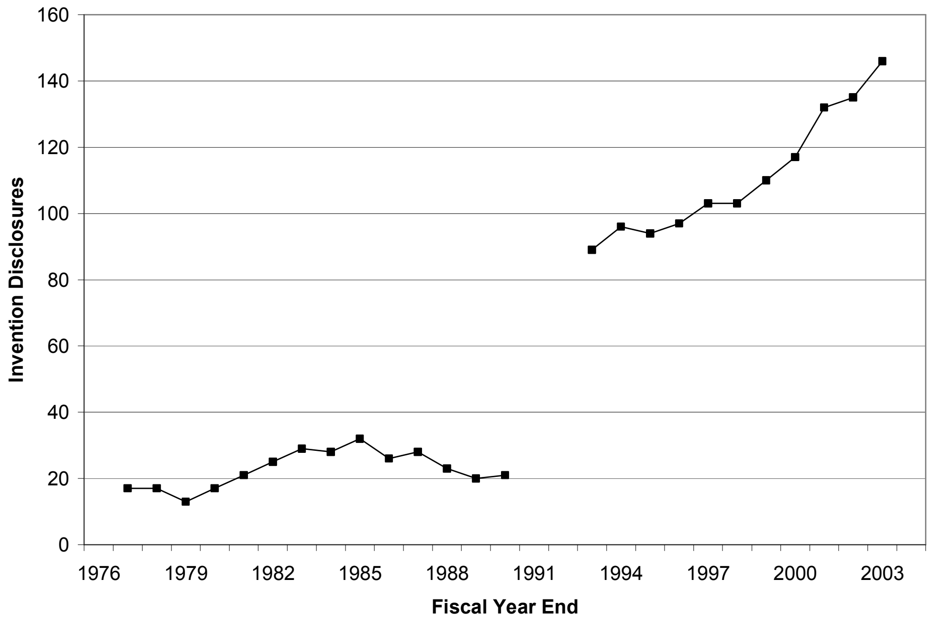


Figure 8: Centered Three-Year Moving Average of University of Toronto Invention Disclosures for Fiscal Years 1975/1976 to 2003/2004

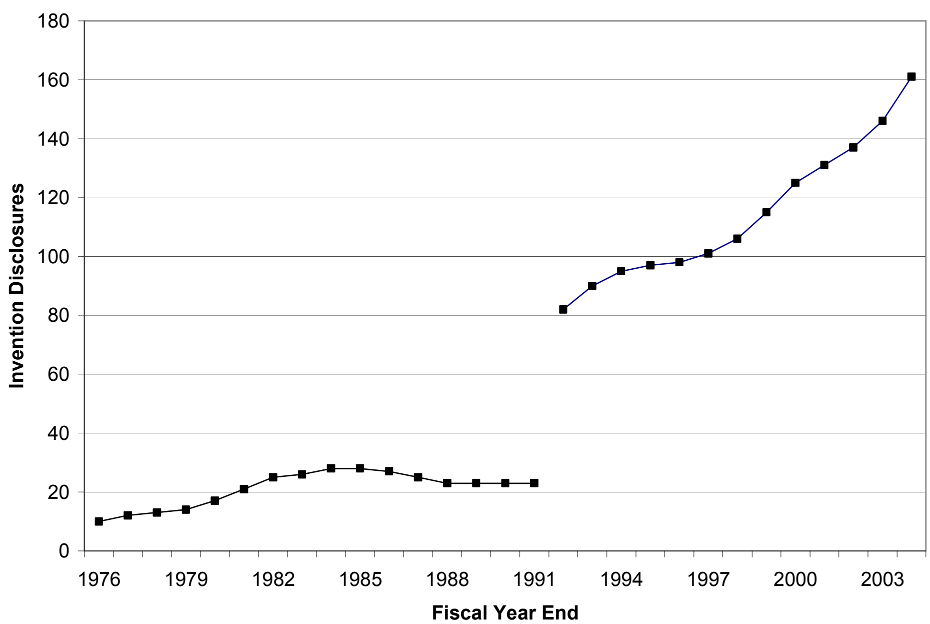


Figure 9: 4253H Smooth of the University of Toronto Invention Disclosures for Fiscal Years 1975/1976 to 2003/2004

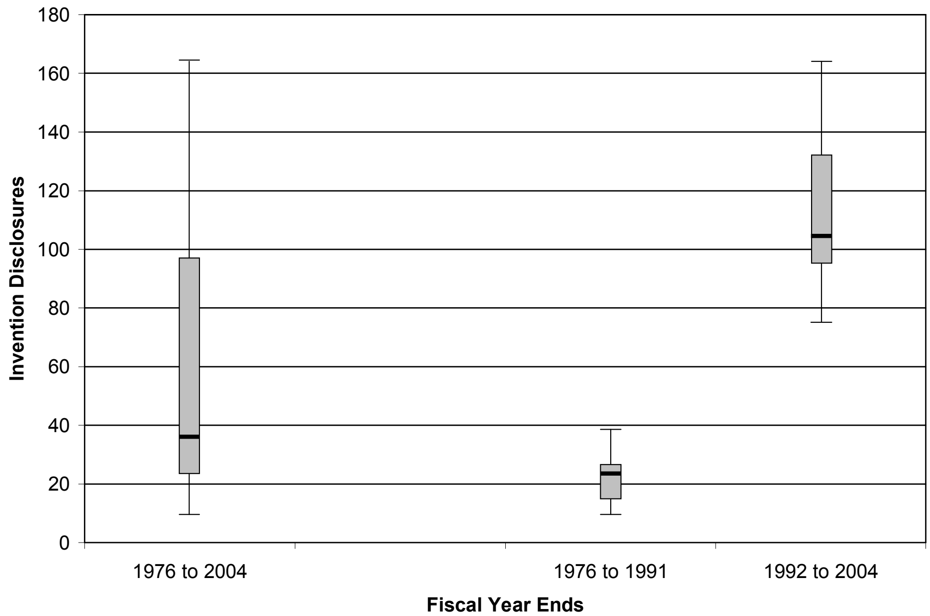


Figure 10: Box-and-whisker Plots of Invention Disclosures

Box-and-whisker plots are also helpful in identifying structural changes to distributions caused by an intervention because box-and-whisker diagrams summarize five values describing population distributions. A box-and-whisker plot was created in order to compare the time series to two of its subsets: one including only fiscal years up to and including 1990/1991; and the other including only fiscal years after 1990/1991. In this box-and-whisker plot, the top and bottom of the rectangle correspond to the 0.75 and 0.25 quartiles respectively, the dark band across the rectangle identifies the median, and the lines attached to the rectangle stretch to touch to the maximum and minimum values. The substantial difference in the medians, 0.25 quartiles, and 0.75 quartiles for the two subpopulations, shown by Figure 10, reaffirm the existence of a breakpoint in 1992.

Visual inspection can also be used to assess data for violations of the assumptions of the analytical method (Hipel & McLeod, 1994). In this case, the box-and-whisker plot was used to assess whether or not the time series of invention disclosures violated the assumptions underlying regression methods by demonstrating heteroscedascity or non-normality.

Residuals are said to be heteroscedasctic or to demonstrate heteroscedascity when the variance of the residuals is a function of one of the independent variables (Keith, 2006). When heteroscedascity exists, tests of significance are no longer valid because the standard errors tend to be understated, which can give a spurious impression of accuracy (Chatterjee et al., 2000). Box-and-whisker plots, in which the data are grouped by the different levels of the independent variables, are an effective strategy for identifying heteroscedascity. In this case, the most helpful grouping is that shown in Figure 10. The large difference between the heights of the two box-and-whisker plots of the subpopulations demonstrate that the two groups have different variances and suggests that heteroscedascity might be a problem. To investigate further, the variances of the two subpopulations were calculated. The earlier data set was found to have a variance of 70.1 and the later data set was found to have a variance 637.5. Therefore, the ratio of variance between the high and low variance sets is less than 10:1. Under these circumstances heteroscedascity is not a concern; transformations of the data are not required and the regression modeling can proceed (Keith, 2006).

Regression analysis also requires that the data have a normal distribution. Box-and-whisker plots are helpful for diagnosing non-normal distributions because normal populations map to symmetrical box-and-whisker plots. All three of the box-and-whisker plots in Figure 10 are sufficiently asymmetrical to warrant further exploration. The Shapiro-Wilk test was used to assess the normality of the three populations because it is more sensitive than the more common Kolmogorov-Smirnov with Lillefors correction and the population size is very small. The overall time series was found to have a non-normal distribution (W=0.85, p=.001). There was no evidence that the data series representing the years prior to the policy intervention and after the policy intervention had non-normal distributions (W=0.95, p=.477; W=.94, p=.430 respectively). This suggests that the non-normality of the overall population is a consequence of the underlying trends in the data rather than a non-normal noise component. Therefore, regression analysis can proceed without a transformation of the data but the residuals generated by fitting the model need to be assessed for normality. Violations of this assumption will indicate that the model fit is inadequate.

In summary, the exploratory data analysis suggested that regression analysis is feasible and that the models should include effects on both the average number of annual disclosures and on the increase in these disclosures from year to year.

5.3 Confirmatory Data Analysis

The statistical analysis of the impact of an intervention upon a time series can be approached using regression methods, ARIMA methods, and non-parametric tests (Hipel & McLeod, 1994). ARIMA methods are often the first choice when modeling time series data because they provide a mechanism for mitigating the impact of autocorrelation. Autocorrelation exists when the differences between the modeled values and the actual values associated with successive observations are correlated; it can cause the standard errors to be understated and thus undermine tests of significance (Chatterjee et al., 2000). However, use of an ARIMA model typically requires at least 50 observations and the time series of interest contains only 29 observations (Montgomery & Johnson, 1976). The feasibility of ARIMA methods was tested using SPSS DecisionTime, which indicated that it was not possible to create a significant intervention models using ARIMA methods of analysis. Non-parametric tests are less able to provide nuanced descriptive information and less sensitive than parametric (i.e. regression) methods and thus less likely to detect significant results. Therefore, the analysis was based on the application of regression methods and steps were taken to ensure that the results were not corrupted by the presence of autocorrelation.

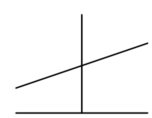
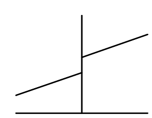
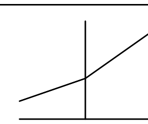
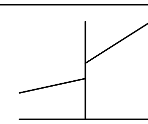
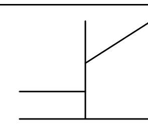
5.3.1 Modeling the Impact of the Policy Intervention

Visual inspection suggested that the policy intervention resulted in an abrupt increase in both the annual count of invention disclosures and the year-to-year increase in the number of invention disclosures after the intervention. To test the statistical significance of these patterns in the data, four different models of the impact were generated using forced-entry regression and compared to a baseline model that did not allow for any changes over the predicted breakpoint. The five models are summarized in Table 12.

Each of the five models was fitted to the data, then regression diagnostics were performed. The regression residuals were inspected to ensure that they conformed to the following three assumptions:

1. The residuals should have a normal distribution. Often a non-normal distribution is a consequence of other violations.
2. The residuals should be homeoscedastic, which means that they display equal variance across the different levels of the explanatory variables. When this condition is not met the residuals are said to be heteroscedastic and the significance of the model and parameters can be spuriously inflated.
3. The residuals should be independent of one another. When residuals display trends or relationships between one residual and the next, the data are said to display autocorrelation. This type of violation also results in spurious inflation of the tests of significance.

Table 12: Models of the Impact of the Policy Intervention

Model	Model Specification	Diagram
1	• Slope and intercept held constant	
2	• Slope held constant • Intercept allowed to change at breakpoint	
3	• Slope allowed to change at breakpoint • Intercept held constant	
4	• Slope and intercept allowed to change at breakpoint	
5	• Slope and intercept allowed to change at breakpoint • Slope before breakpoint is held at zero	

Violations of these three assumptions, especially the third assumption, are important for two reasons. First, these violations suggest that the model does not fit the data adequately. Therefore, the decreasing number of violations displayed by the successive models in Table 13 indicate that the model that assumed that the policy intervention had some effect on the invention disclosure counts fit the data better than the baseline model, which assumed that the policy intervention had no effect. This is evidence that the policy intervention had an effect on the invention disclosures. Second, when the assumptions are not met, the tests of significance are not directly interpretable. Therefore, only Models 4 and 5 can be directly assessed for fit using the tests of significance.

Table 13: Summary of Regression Diagnostics for Models 1 through 5

Model	*Residuals are Normal*	*Residuals are Homeoscedastic*	*Residuals are Mutually Independent*
Model 1	No	No	No
Model 2	Yes	No	No
Model 3	Yes	Yes	No
Model 4	Yes	Yes	Yes
Model 5	Yes	Yes	Yes

In order to assess all four of the models of the impact of the policy intervention (Models 2-5), each one was compared to Model 1, which assumed the policy intervention had no impact, using an *F*-test (for details please see Appendix D in the Model 2 section). This test was appropriate in this context for three reasons. First, the test results will not be corrupted by the violations noted in Table 13. While the *F*-test is based on the sum of the squared errors (SSE) of the models, the violations are most extreme in the case of the baseline model and thus it will have the most spuriously understated errors. This will result in a more conservative test than a situation in which none of the models demonstrate violations like autoregression. Second, the *F*-test takes into account the number of parameters in each model when assessing the relative goodness of fit. This means that Models 2 through 5 can be compared against the less complex Model 1. Third, if a model that allows for the policy intervention to have an impact is shown to fit the data significantly better than Model 1, it will be statistical evidence that the policy intervention had an impact. As the test results summarized in Table 14 show, Models 2, 3, 4, and 5 were all found to provide a significantly better fit at the .05 level than Model 1. Therefore, there is evidence that the policy intervention had an impact.

Table 14: *F*-tests Comparing the Models of the Invention Disclosure Time Series

Model 1 Compared v.s.	*F*	F_{crit}
Model 2	25.6	$F(1,27,.05) = 4.21$
Model 3	24.2	$F(1,27,.05) = 4.21$
Model 4	47.4	$F(3,25,.05) = 2.99$
Model 5	91.8	$F(2,26,.05) = 3.37$

A closer comparison of the models allows a more nuanced description of the impact of the policy intervention. As discussed earlier, only Models 4 and 5 were free of violations of the assumptions underlying regression analysis, and thus have directly interpretable tests of significance. The tests of significance, summarized in Table 15, show that all the parameters of Model 5 were significant at the .05 level and that one of Model 4's parameters was not. Therefore, the tests of significance indicate that Model 5 fits the data best. This indicates that prior to the policy change there was no significant change in the number of invention disclosures from year to year but that there was a significant change from year to year after the policy intervention. Furthermore, the intervention caused an immediate increase in the number of invention disclosures.

In summary, the interrupted time series analysis of the University of Toronto invention disclosures provides strong evidence that the policy intervention had significant and substantial effects on the annual counts of invention disclosures.

Table 15: Parameter Estimates for Models 1 through 5

Model	*Level at Policy Intervention*		*Rate of Change from Year to Year*	
	Just Before 1991	*Just After 1991*	*Before 1991*	*After 1991*
1	67.8		5.2	
2	40.6	95.0	2.5	
3	44.5		2.3	7.8
4	26.9*	71.2*	0.6	6.5*
5	22.2*	71.0*	0†	5.9*

* Significant at the .05 level

† Fixed at zero by the model

5.3.2 Assessing the Practical Significance of the Policy Intervention

The changes in slope and level are both significant but need to be evaluated to determine whether they are of practical significance. The Model 5 parameter estimates indicate that prior to the policy intervention there were 22.2 ± 4.7 inventions disclosed per year. Immediately after the intervention, the number of disclosures increased by 49.0 ± 12.2. There is no question that this immediate increase is substantial when compared to the pre-intervention disclosure rates. Furthermore, the number of invention disclosures continued increasing from year to year by 5.9 ± 1.4 disclosures per year. In the thirteen documented years since the policy intervention this increase from year to year has accounted for an increase of approximately another 77 invention disclosures per year. In summary, the best-fitting model has been shown to be the one in which both the slope and the level changed at the break point, and the magnitudes of these changes were of practical significance. This is strong evidence that the policy intervention had a significant and substantial impact on the annual counts of invention disclosures.

To investigate the practical significance of the effects of the policy intervention further, the University of Toronto's invention disclosures were compared to those of other comparable universities. All of the available AUTM Surveys were collected, resulting in a dataset spanning fiscal years 1992 to 2003. Of the G10, a group of research intensive Canadian institutions, only the University of Alberta, the University of British Columbia, McMaster University, Queen's University, the Université de Montreal, and the University of Western Ontario submitted their invention disclosure counts for five or more of the eleven years that the survey has been collected. These six universities were used to establish a frame of reference for the invention disclosures reported by the University of Toronto. As shown in Table 16, the mean number of invention disclosures per institution ranges between 20 and 108 disclosures a year. This is strong evidence that the abrupt increase of 29 disclosures that the University of Toronto experienced over the break point is quite substantial. The data also show that, between 1992 and 2003, the University of Toronto is among the top three universities in the group of reporting institutions in terms of having the highest sustained levels of invention disclosures. This continues to be true even when the different sizes of the institutions are taken into account by calculating the ratio of the mean number of annual invention disclosures to 2003 estimations of the number of researchers eligible for research grants in the natural sciences and engineering (NSERC) and medicine and health (CIHR). These comparisons to other members of the G10 suggest that the University of Toronto has one of the best records in Canada in terms of having inventions disclosed to the university.

Table 16. Comparing University of Toronto Invention Disclosures to other Research-Intensive, Canadian Universities. Based on AUTM data for Fiscal Years 1992 to 2003.

University	*Annual Invention Disclosures*			*Mean Annual Number of Invention Disclosures Per 100 NSERC and CIHR Eligible Researchers**
	Mean	*Median*	*Standard Deviation*	
Alberta	58	60	19.97	7
British Columbia	108	108	19.88	12
McMaster Univ.	32	34	10.77	6
Montréal	44	37	32.82	5
Queen's Univ.	33	33	5.37	9
Western Ontario	20	12	16.08	4
Toronto	105	97	18.58	9

* Source: Maclean's Magazine data for 2003.

It is also possible to compare the trend over time for this group of comparable universities to the trend over time for the University of Toronto. Between 1992 and 2003, the mean number of invention disclosures for the group rose by 2.20 disclosures a year. Over the same time period, the invention disclosures counts for the University of Toronto rose by 4.72 disclosures a year. This result is strong evidence that the increase in invention disclosures per year associated with the policy intervention is a substantial gain. It also confirms that post-intervention, the University of Toronto is quite competitive with other research-intensive Canadian universities in terms of both level and increase in the number of invention disclosures from year to year.

5.3.3 A Review of Other Outcomes

The chief drawback to the use of invention disclosures as an outcome variable is the absence of a strong link between this early stage activity and the desired outcomes of university-industry technology transfer activities. Policies that change the number of invention disclosures may also have an impact on the quality of the disclosures. An increase in the number of non-viable inventions disclosed is not a boon to the university, the regional or the national economy; it creates the risk that scarce resources will be spent on either non-viable innovations or on screening the technologies and thus detract from the possibility of successful transfer of the viable technologies. If that were the case at the University of Toronto, we would expect to see its productivity figures, over time, significantly lagging that of other research-intensive universities in Canada.

There is no evidence that the increase in the number of invention disclosures was associated with a decline in the quality of the disclosures. As shown in Table 6, the University of Toronto's technology transfer outcomes per U.S.$1M of research expenditures, are reasonably consistent with the averages for Canadian universities, especially considering that the University of Toronto's measures do not include the outcomes generated by its research hospital affiliates, unlike most other research-intensive universities in Canada. The University of Toronto exceeds the average number of spin-off companies per U.S.$1M in the top ten most research-intensive universities and colleges in both Canada and the United States. The only measure in which it appears to lag the two groups of research intensive institutions substantially is 'Licence Income Received'. This measure consistently displays the most variability because it is highly negatively skewed by the inclusion of 'big winners' (Clayman, 2004). For example, the Canadian university that receives the most licence income, about $10M per annum, receives ten times that of the second most 'productive' university, and the vast majority of its licence revenue is derived from a single technology that is widely licensed (Clayman, 2004). Similarly, the U.S. means for this measure are skewed by the inclusion of technologies earning between $30M and $70M per annum (Clayman, 2004). The resulting skewness of the data makes it impossible to interpret even large differences in average licensing revenues. The available data provide no evidence that the gains in the number of invention disclosures at the University of Toronto are associated with a drop in quality of the research disclosures; it can not be ascertained whether the lower Licence Income Received from the University of Toronto's invention disclosures resulted from lower quality inventions or whether the licensing revenues simply reflect the element of chance involved in the distribution of these 'big winners'. The productivity measures for the University of Toronto are consistent with the measures for the ten most research-intensive Canadian universities for all but the most variable of the cumulative performance measures for Canadian universities. Like other research-intensive Canadian institutions, the University of Toronto receives less licence income per dollar of research expenditure than the U.S. top twenty universities but has more spin-offs than the U.S. top twenty universities.

Table 17. University of Toronto versus Means of Canadian & American Top 10's Cumulative Outcomes for Fiscal Year 2002. All figures U.S.$ and per $1M Research Revenues (Adapted from Clayman, 2004).

Institution(s)	*Invention Disclosures Received*	*Licences & Options Executed*	*Licence Income Received*	*U.S. Patents Issued*	*Spin-off Companies Formed*
University of Toronto	0.793	0.171	$7,343	0.067	0.049
Cdn Top 10	0.601	0.169	$17,141	0.088	0.025
U.S. Top 20*	0.582	0.173	$56,973	0.153	0.017

* Adjusted to account for the inclusion of indirect costs of research in research expenditures.

5.4 Conclusions

5.4.1 Limitations of the Study

The main limitation of this study is that it is based on only one policy shift at one university. It is possible that the observed relationship may be spurious. Ideally, different policy shifts at different universities would have been studied to strengthen the generalizability of the results but no data were available. The study of multiple institutions would have provided the opportunity to investigate the role that institutional or environmental variables play in determining the impact of a policy intervention.

The study of other institutions would also have permitted the isolation of the effects of the changes to the invention disclosure form at the University of Toronto. It is possible that the streamlining of the form that reduced it from about eight pages to two pages, shortly after the policy change, increased the number of invention disclosures. However, the interest that faculty members expressed in owning their inventions is inconsistent with the changes to form having a substantial, long-term impact; it is difficult to imagine an inventor who is seriously interested in independently commercializing a technology and who would be derailed by an eight page form.

Another limitation pertains to the AUTM data used in the broader assessment of the University of Toronto's technology transfer outcomes. This data set is widely used because it is one of the few instruments that reports institution-specific data. However, the AUTM members do not always track and report data using the same definitions for 'invention disclosures', 'spin-offs', and so on. Therefore, researchers should be cautioned that cross-institution comparisons require careful scrutiny.

5.4.2 Implications

This study provides the first empirical evidence that a change from "university-owns" to "inventor-owns" intellectual property policies can have a significant and substantial impact on university researcher's willingness to engage in technology transfer. The findings of this study suggest that the policy intervention at the University of Toronto had a significant and desirable impact on the level of technology transfer activity at that institution.

The immediacy of the observed effect has implications for the type of relationship between the policy change and the outcomes of interest. The paper by Siegel, Waldman, Atwater and Link (2004) that was discussed in section 2.2.3.2.2, included a quote that suggested IP policies may have an effect on hiring and retention of faculty who support technology transfer and that this effect may account for inter-institutional differences in technology transfer activities. In other words, some policies are more attractive to faculty that are involved in technology transfer and this influences their decisions to remain with a given university and to which universities they will consider moving. The immediacy of the effect observed in this chapter, suggests that this relationship did not account for the effect. This suggests that a significant proportion of the effect was a result of an increased propensity of faculty members already present in the university to participate in technology transfer activities.

On first inspection the findings of this study appear to contradict Study 1, the study that was discussed in Chapter 4. That cross-sectional study failed to find any relationship between the incentives offered by university policies and technology transfer outcomes reported by universities. However, these studies are consistent if other institutional differences influence the relationship between IP policies and university-industry technology transfer. This would mean that the individual character of each institution best fits a different policy and that achieving this fit can create important benefits. If this is the case, it is possible that the University of Toronto can realize benefits from a change to a policy, without requiring that that policy also be highly effective at other institutions. In other words, the optimal policy may depend on local or institutional variables.

The time series analysis can not predict which local or institutional factors had a role in the success of the University of Toronto policy change. However, the description of the policy change by a technology manager who worked at the University of Toronto during the time of the policy change, suggests three intertwined factors. Firstly, the technology manager reported that faculty members saw ownership of the IP as a desirable incentive, which suggests that the university culture was relatively supportive of technology transfer activities. Secondly, many faculty members complained that the University of Toronto Innovations Foundation was ineffective and uncommunicative, which suggests that by the time of the policy shift there was widespread distrust of the competence of the organization designated to commercialize their inventions. This last aspect of the situations appears to have been a consequence of the third factor, a persistent gap between the workload of the Innovations Foundation and its resources. Considered together these factors suggest that the ideal IP policy for a university needs to be designed in response to the institution's resources, culture, and the perceptions of key actors, including faculty members, and that these perceptions may be influenced by the university's history in terms of technology transfer activities.

If this is the case, national convergence to a single policy is likely to damage researcher support for technology transfer at some universities. This suggests that widespread policy changes should only be adopted in the face of a persuasive, empirical evidence of other benefits from such a move. In the absence of strong, empirical evidence of other benefits, individual universities should be encouraged to entertain policy innovations that best fit their strengths and needs.

More research is necessary to determine which factors are most likely to influence the relationship between university IP policies and university-industry technology transfer. Since individual perceptions appear to matter and there is not yet a strong theoretical base describing the relevant dimensions, the most effective research strategy will be qualitative, interview-based research because this kind of inductive research is capable of providing theoretical direction in emerging research areas. Therefore, an in-depth interview study of faculty members, who have been involved in technology transfer activities, was conducted at the University of Waterloo, and is described in Chapter 6.

5.4.3 Summary

This study provides statistical evidence that university IP policies can be a significant factor in determining the effectiveness of institutions by influencing university researcher's willingness to participate in technology transfer activities. Increasing researcher control of technology transfer by switching from a ‘university-owns’ to a ‘inventor-owns’ system appears to have stimulated higher levels of invention disclosures. More research is needed to determine the generalizability of this conclusion and to isolate any other factors that determine the impact of a policy change.

Chapter 6
Study 3: Qualitative Investigation of Faculty Inventors' Experiences

This chapter presents the results of the qualitative investigation into faculty inventor's experiences with technology transfer. This study seeks to discover how university researchers' understand their technology transfer experiences, and to share this perspective in the researcher's own words as much as possible. The thematic analysis of the open-ended interviews is expected to provide insight into the individuals and the environment that first supported technology transfer activities at the University of Waterloo, where the activities include the creation of some of the university's high-profile spin-off companies. The goal of this study is the identification of theories that can be used to explain aspects of the relationship between IP policies and technology transfer outcomes.

The chapter is organized into four sections. The first and second sections provide context for the study. The first section provides a brief description of the University of Waterloo in order to familiarize the reader with the organizational context of the study. The second section briefly describes the technology transfer, research and teaching activities of the participants. The third section provides the results of the analysis conducted according to the methodology described in 3.4. The final section in the chapter includes a discussion of the limitations of the study and the implications of the results.

6.1 Background on the University of Waterloo

This brief description of the university is provided so that scholars unfamiliar with the university will have a context for the study. The University of Waterloo dates its history from the first classes held within the institution, in July of 1957 (Redmond, 2006). As a result, some of the senior and retired faculty and staff remember the founding of the university and the early period in which the university expanded very quickly. The University of Waterloo is now classified by the Maclean's magazine as a 'Comprehensive' university. The primary differences between Comprehensive universities and the larger 'Medical-Doctoral' universities, like the University of Toronto, are that Comprehensive universities offer fewer doctoral programs and do not have medical programs. Thus, they do not have and are not closely affiliated with hospital research centers. Like many 'Comprehensive' universities, UW is medium-sized in the context of Canadian institutions. In 2004, student enrollment was 23,000, of which 2,500 were part-time students. According to the AUCC database of the data created for the 2003 Maclean's survey, the University of Waterloo had about 480 faculty members who were eligible for research funding from the Natural Sciences and Engineering Research Council (NSERC), and about 40 faculty who were eligible for research funding from the Canadian Institutes for Health Research (CIHR). In other words, UW has almost any many faculty members who are eligible for NSERC grants as the much larger University of Toronto. Therefore, it is reasonable to assume that the university is capable of supporting a moderately high level of technology transfer activity, which makes it a viable site in which to study technology transfer. However, the distribution of technologies and receptor industries is expected to differ from 'Medical-Doctoral' institutions,

6.1.1 Intellectual Property Policy and Technology Transfer Information

University of Waterloo technology transfer measures were explored with the goal of quantitatively describing technology transfer activities at the University of Waterloo over the years in order to provide a context for the qualitative analysis. This exploration led to the conclusion that IP policies are a factor in the information flows associated with technology transfer. As described in earlier sections, the University of Waterloo IP policy allows ownership to vest with the inventors; inventors have no need to interact with the university Technology Transfer and Licensing Office (TTLO), with one exception. The university requires that faculty inventors disclose their inventions to the TTLO. This exception has little practical impact because, the University of Waterloo like many other institutions, has not enforced the requirement and, as a result, it is has not been observed (Siegel, Waldman et al., 2003). As a result, it is quite likely that the records maintained by the TTLO have underreported technology transfer activity in the past. For example, a University of Waterloo technology manager explained that he sometimes found out about University of Waterloo spin-off companies by reading the local newspaper. He indicated that he did the best he could to provide valid statistics to organizations like AUTM but that he wasn't confident in the completeness or the consistency from year to year of the data. This finding suggests that IP policies are a factor in the information flows in a university concerned with technology transfer activities. This suggests that the 'inventor-owner' configuration may make it more difficult for the university to design and provide appropriate supports for technology transfer activities.

This information gap also has a research implication. The data provided by the University of Waterloo to organizations like AUTM is likely to be biased, in that it does not include activities undertaken by the inventors without TTLO assistance, and unreliable, in that it may have been collected and reported inconsistently from year to year. The following discussion of technology transfer measures is limited to spin-off formation because it wasn't possible to confirm the validity and reliability of the measures related to licensing activities.

6.1.1.1 Spin-off Formation at the University of Waterloo

The University of Waterloo is well-known in Canada for having a relatively large number of spin-offs. This interest in university spin-offs prompted several reports (Cross & Babensee, 1992, 1994; Pricewaterhouse Cooper, 2001). As a result, it is possible to verify the AUTM spin-off creation counts from the 1980-1995 time period. Table 18 displays the University of Waterloo data from that period as well as the data for the other Canadian universities which participated in the AUTM surveys. Within this set of moderately to highly research-intensive universities, the University of Waterloo reported the third largest number of spin-offs between 1980 and 1995, and had the third highest ratio between the number of spin-offs and the number of full-time faculty members eligible for research funding in medicine or the natural and applied sciences. The University of Waterloo spin-offs are credited with a significant role in the development of a cluster of approximately 450 firms in the Kitchener-Waterloo-Cambridge-Guelph region, worth approximately six billion dollars a year (Xu, 2003). Xu reports that the firms are export-oriented, with 95% of their sales to leading technology markets including California and Japan, implying that they are internationally competitive (2003). The spin-off activity is also likely to spur further academic involvement in technology transfer at the University of Waterloo. Bercovitz and Feldman (2004) report that professors who observe either peers or academic leaders engaged in technology transfer are much more likely to engage in technology transfer themselves. Most of the participants in this study started participating in technology transfer activities before the University of Waterloo had developed a reputation for spinning-off companies. The interviews with the participants provide access to the environment that produced the high-profile spin-offs and contributed to both the local high-technology cluster and a continued entrepreneurial culture at the University of Waterloo.

Table 18. Spin-off Companies Associated with Canadian Universities, 1980 to 1995.

University	*Spin-offs launched between 1980 & 1995*[4]	*Full-Time Faculty Eligible for Research Funding*[5]		*Spin-offs per 100 Full-Time Faculty Members (NSERC & MRC)*
		NSERC	*MRC*	
University of British Columbia	57	547	465	5.63
Simon Fraser University	31	212	4	14.35
University of Waterloo[6]	**20**	**464**	**29**	**4.06**
University of Calgary	14	294	273	2.47
Queen's University	13	270	103	3.49
University of Alberta	10	451	436	1.13
University of Victoria	5	185	10	2.56
Carleton University	4	218	9	1.76
University of Manitoba	2	324	337	0.30
University of Western Ontario	0	279	305	0.00

[4] Source: (Association of University Technology Managers, 1996).
[5] Source: Association of Universities and Colleges of Canada (AUCC) database of data generated by participants in the 2003 Maclean's Magazine survey.
[6] The report of 20 spin-offs is credible because it is supported by the detailed listing of 20 spin-offs involving technology transfer from the universities in Cross and Babensee's "Spin-off Company Profiles" (1994).

6.2 Background on the Participants and their Activities

The participants are senior or retired faculty members from the pure and applied science and mathematics departments at the university. Each participant had experience with technology transfer activities or had conducted contract work and extensive research in industry. Most of the participants had been involved with spin-off firms. Many of the participants had been involved in multiple technology transfers. Half of the participants who had licensed technologies or had been involved in the formation of spin-off companies had been involved with the commercialization of multiple technologies. As a result, the group of ten participants was responsible for the transfer from university to receptor organizations of twelve distinct sets of technologies. This evidence of the existence of a class of serial commercializers is not unique to this study. Pries found that many of the participants in his survey of faculty members involved in technology transfer at four universities in South-Western Ontario had been involved with multiple transfers (Pries, 2006). Shane and Khurana (2003) found that, for faculty members at M.I.T., each patent already commercialized by a spin-off increased the probability that they would have another technology commercialized by a spin-off, to a statistically significant extent.

The participants' involvement in university-industry interactions were characterized by a wide range of activities usually beginning many years before formal attempts to transfer technology through licences or spin-off. These university-industry interactions included: 1) offering seminars, courses and workshops to industry at both on-campus and at firm sites; 2) conducting contract research for industry; 3) consulting with industry; 4) participating in trade conferences and expos attended by industry and/or the users of the technology; 5) doing sabbaticals in industry; 6) leaving the university to work in industry for a time; 7) participating in committees and professional groups that also include industry; 8) maintaining informal communications with contacts developed through these means; and, 9) maintaining contacts with students and colleagues who have moved into industry. Rahm (1994) has described researchers exhibiting these behaviour patterns as 'boundary-spanning' researchers. She has demonstrated that 'boundary-spanning' researchers differ from 'university-bound' researchers in a number of ways; for example, they are more likely to engage in a wide range of interactions with industry (1994). Therefore, Rahm's findings will be used to analyze the results of the thematic analysis.

The outcomes associated with the set of technology transfers are substantial. The transfers succeeded in making available to the market ten of the technologies and therefore succeeded in improving the quality of life by making improved products and services available to individuals in Canada and abroad. With the formation of new ventures, jobs have been created in the Waterloo region, which is evidence that the transfers have contributed to regional economic development. Several of the spin-offs are international leaders in their fields and hence competitive in international markets. This suggests that these firms are contributing to Canada's international competitiveness and, hence, to the health of the national economy.

Many of the spin-off companies were formed using the private capital of the faculty members and staff members who had been involved in developing the technology. Only a few technologies were developed with the assistance of the University of Waterloo Technology Transfer and Licensing Office or a similar support organization. As a result, the university was not granted royalties or equity shares in every case. However, the university derived other benefits from the technology transfers studied through these interviews, including sponsoring of research on campus, donations, and the increased number of local high-technology companies who act as employers for graduates and co-operative education students. Media coverage of the success of the high-profile spin-offs also appears to have contributed to the university's reputation (e.g. Keenan et al., 2006).

An effort was made to include transfers that differed in the extent to which they were successful. As a consequence, the financial results for the set of transfers vary. So far, three transfers have generated no returns, four transfers have resulted in returns comparable to less risky investments (i.e. investments in the stock or bond markets), four transfers have resulted in substantially bigger returns, and the last transfer is still in a developmental phase.

Apart from their involvement in technology transfer activities, contract work and research in industry, there is evidence that the participants were highly productive in both the research and teaching domains. The ten participants had generated approximately 5 peer-reviewed publications per year, on average, over their careers to date. As a group they had generated a total of 34 books and 93 patents. Many of the participants had received prestigious research awards, some had been granted teaching awards, and two talked of receiving consistently high teaching evaluations and commendations from their students.

6.3 Results of the Thematic Data Analysis

This section reviews the steps involved in the thematic data analysis, briefly describes the codes that were developed to capture important aspects of the data, and then elaborates on the results by providing a description of the data associated with each code.

6.3.1 The Thematic Data Analysis Process

The analysis of the interview data proceeded in two steps. First, profiles were developed for each of the participants by repeatedly culling excerpts from the transcripts for a series of interviews with a single participant. Content was most likely to be selected for inclusion in a profile if it was clear from the wording and tone that the participant felt strongly about the subject, or if the participant brought up the subject unprompted, or revisited the topic multiple times over the course of the interviews. These profiles were broken up in vignettes, one to three paragraph excerpts. Second, through an iterative thematic analysis process the vignettes were coded with descriptive labels suggested by the data.

The coding was conducted using a software package developed to assist with this type of qualitative research, QSR's nVivo, version 6.0. By the end of the first few iterations, twenty codes had emerged. Once all of the vignettes were associated with at least one of the codes, the codes and relationships between the coded data were reviewed. Some of the original codes, like 'University-Industry interactions' were associated with many excerpts that the resulting set of excerpts was unwieldy. Other codes, including 'Effects of co-op,' were associated with only one or two excerpts. A new hierarchical set of codes was created, in which all of the individual codes were organized according to five over-arching themes: university-industry activities; 2) university environment; 3) rewards and reward systems; 4) attitudes; and, 5) career decisions. Each of these top-level themes contains between two and six themes; there are 17 sub-themes, altogether. This hierarchical structure facilitated the development of a more intelligible structure by permitting the subdivision of unwieldly datasets using sub-themes, and the consolidation of less substantial sets of excerpts. During this process, three of the codes associated with the smallest sets of themes were merged with other themes. For example, the vignette associated with the 'Effects of co-op' was included with 'Success factors' under 'University-industry activities.' The purpose of the coding was to reduce and organize the large amount of data produced by the study; the constructs were created to communicate the results and should not be used as a theoretical framework without further development using the broader technology transfer literature. The coded vignettes are presented in Appendix F, with each excerpt presented under the code to which it contributes the most. The following subsections describe each of the themes, using the interview data in conjunction with information about the technology transfers, in order to convey a rich depiction of the participants' behaviours, environments, attitudes, and experiences.

6.3.2 University-Industry Activities

This over-arching theme explores attributes of the technology transfer activities and other university-industry interactions in which the participants were involved. It is further divided into six sub-themes: 1) opportunity recognition & catalysts for technology transfer; 2) participants' roles in technology transfer activities & relationships with spin-off firms; 3) time demands; 4) learning and identification of mistakes; 5) success factors; and, 6) outcomes.

6.3.2.1 Opportunity recognition & catalysts for technology transfer

In their narrative descriptions of their technology transfer activities, some of the participants provided insight into the ways that they identified research projects of interest or the ways that they identified opportunities for technology transfer. The participants' involvement in university-industry interactions appeared to be an important factor in the recognition of research and technology transfer opportunities. In other cases, opportunities to transfer technology were influenced by the availability of resources for commercialization, especially human capital, or the difficulty in identifying established firms that were interested in commercializing the technology.

An important factor in the recognition of research opportunities was the participants' exposure to industry. As mentioned in section 0, many of the participants engaged in a wide range of university-industry interactions and these interactions often started well before any formal transfers. Many participants identified these interactions as an important source of interesting problems.[7] The most extreme case of industry involvement in problem selection was the use by one participant of informal and formal groups, which included industry contacts, with whom he would discuss and prioritize research problems. Not all research projects were selected based on the participants' familiarity with the industry. Other factors that led researchers to select research projects included the social value of the research project, the extent to which it offered a possibility to increase the university's reputation,

[7] Some of the excerpts that demonstrate this phenomenon are included under the 'Outcomes' theme.

and the opportunity for student learning, in that it was an appropriate topic for a graduate thesis. In some cases, applied research projects themselves appeared to increase participants' awareness of the market; "during the project, we were also exposed, through conferences and visitors, to people who wanted to use the technology."

The participants' exposure to industry also appeared to be an important factor in the recognition of opportunities for technology transfer. In the most direct case, a business person familiar with the industry approached the research group and suggested that they form a venture. In many of the other cases, university researchers appear to have decided that technologies presented opportunities and appeared confident in their abilities to assess market forces. For example, one participant observed, "We knew, having looked at the market, that there was a need." Another commented, "The tools that we had developed seemed like the basis of a company or a business plan." A third participant made an explicit link between his interactions with industry and his ability to recognize opportunities:

> [I knew there was a market for the technology because] being a technical person, I go to conferences, I go to trade shows. I can see which way the market is going … it would be important to this industry because then they can have a faster manufacturing line. That doesn't take an Einstein to figure out."

Another important aspect of opportunity recognition was the availability of resources for commercialization. Several ventures were created because individuals involved in the research group were leaving the university, either as recent graduates of research degrees or as staff or faculty members from the research group who desired a career change. A participant noted:

> Some people in the research group decided that they had enough of working within the university. They wanted to go out and try new things; they were all going to go out and get big jobs. We recognized that these people were very bright and they had a bit of an entrepreneurial bent to them, so we suggested we would finance a company, set them up in business.

Many technology transfers occurred through spin-offs rather than through licences. In many of these cases, the faculty inventors unsuccessfully sought to license their technologies to established businesses before deciding to start new ventures, or pursued spin-off formation because they thought that the invention wasn't sufficiently appropriable to be licensed.[8] This finding suggests that modeling technology transfers as a free choice between licensing and forming spin-offs is invalidated in many cases by the lack of receptor capacity. DiGregorio (2003) had suggested that faculty inventors may choose to form spin-offs rather than engage in licensing if the returns from spin-off activity are expected to be greater. This reasoning was not provided by any of participants interviewed in this study.

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[8] Some of the comments to this effect are provided under the theme 'Experiences with Technology Transfer Support Organizations.'

In summary, it appears that faculty inventors' participation in a broad range of university-industry interactions allows them to identify research projects with industry significance and recognize technology transfer opportunities. Another factor that was mentioned in multiple cases, was the availability of resources for commercialization, especially human capital. Counter to DiGregorio's theory, the likelihood of achieving a higher payoff through spin-off formation versus licensing, did not appear to be a factor. Instead, many of the participants explored licensing first and turned to spin-off formation when a receptor organization for the technology could not be identified.

6.3.2.2 Participants' roles in technology transfer activities & relationships with spin-off firms

The participants' roles in technology transfer activities varied substantially across the different types of transfers and, among the spin-offs, across the different relationships between the participant and the firm. In many cases, the participants were key actors in the technology transfers. They were lead people in arranging patenting and licensing or they took on leadership roles within the management structure and technical staff of the spin-offs. In other cases, the participants took on a supporting role, providing technical support and doing "missionary work," which typically consisted of doing presentations, teaching courses or leading workshops to develop interest in the spin-off's products or services. This role suggests that even the inventors who remained within the university had substantial contact with industry and thus the opportunity to develop business knowledge.

Several of the professors who were involved with spin-offs chose to remain within the university. In many of these cases, other individuals who left the university to work in the spin-off took on leadership roles. There was no obvious relationship between the extent to which a faculty member was central to the technology transfer and the success of that transfer in making the technology available to users, in job creation, or in producing a substantial return for investors.

The participants' roles evolved over time. A couple of individuals reported that the people who left the university to join the spin-off firms found their roles evolving away from research towards management. For example, participants reported that:

> My board of directors advised me that I had to let go the research; had to let somebody else run the research of the company and I did.

> We were very fortunate in that the people who left the university and who were really operationally running the business, were able to go through those various levels … In the early days, the managers were in on every aspect of the product, then they'd say, 'Here's the general scope, here's what we want' … the managers were able to keep going to different levels of the organization, realizing that they could not micromanage stuff.

The individuals who remained with the university reported that their relationships with the spin-offs grew less close over time, observing that, "it didn't need its close ties with the university anymore," and, "any organization, once it's set up, takes on a life of its own … they diverged because they had to." In the interviews, the tone of these remarks suggested that faculty inventors were comfortable with this evolution. Another participant expressed this comfort explicitly:

> I view the company's growth a lot like raising a child: starting very small and nurturing it, playing an advisory role with it as it gets a little older, being cut off completely for a couple of years because the company thinks it can do a lot better without you, and then slowly recognizing where you can contribute and you come back in to play and the relationship gets re-established on good terms. And that's sort of very much the way that my work with the company has worked. And it's been fine with me.

The individual role of a faculty member appears to hinge on the extent to which they were interested in taking part in business activities, as opposed to their attitudes to technology transfer in general. A participant who elected to leave the university to work full-time in his spin-off noted, "I felt that, if I could use [my invention] and develop real products and have some effect on science by developing those things, it would be great fun to do," whereas, a participant who remained within the university said:

> I'm not quite entrepreneurial in the same sense that some other people are because I don't have the business interests in working with the company and getting it going. I thought it was a good thing. I was definitely interested in seeing it happen but I was not the one to figure out how to make a company work and I was not about to give up my job here in order to get into the company, either.

In summary, the participants' roles evolved across time, and varied across different technology transfer activities and, for those engaged with spin-off companies, the different relationships they had with the spin-off firm. However, there was no clear relationship between the role of the faculty inventor(s) and outcomes of the transfer.

6.3.2.3 Time demands

The different roles held by the participants had a substantial impact on the time demands created by their decisions to engage in technology transfer. A number of individuals reported that the time associated with the technology transfer simply displaced their other consulting activities and thus did substantially influence the distribution or size of their workload. A participant described his technology transfer activities as taking place, "once a week for a couple of hours. It was like consulting." Other individuals reported doing up to the equivalent of a second full-time job.

> I worked forty hours a week at the university; I had a huge number of graduate students. I worked for the company probably twenty to thirty, sometimes forty extra hours a week. So it was a fairly tiring time. It was hard physically, it was hard mentally.

This was most often the case with individuals who had high levels of involvement with a spin-off, while maintaining much of their regular professorial workload within the university.

The faculty inventors acknowledged that time management was a significant concern. Almost all of the faculty inventors who maintained their university roles while taking on significant involvement with technology transfers acknowledged, explicitly and without prompting, the importance of ensuring that their teaching, research and service at the university did not suffer from their other activities. This commitment to a 'boundary-spanning' role was facilitated by the ability to take leaves of absence or sabbaticals to work on the spin-off, or to arrange to have reduced teaching and service loads by having the spin-off reimburse the university for some or all of their salary.

In conclusion, the participants' comments regarding the time demands associated with involvement in technology transfer activities suggested that the time demands varied depending on the faculty inventor's role but that, for some faculty inventors, the time demands were substantial. This strongly suggests that policies and programs that allow the faculty inventor to reduce their university load for a period will be effective tools in encouraging faculty members to engage in technology transfer.

6.3.2.4 Learning and identification of mistakes

Many participants identified things that they had learned during their technology transfer activities or mistakes that they had made. The majority of the learnings demonstrated a focus on non-technical issues. For example:

> It is a difficult market … very niche, very narrow and established.

> I was looking down on understanding the law. Later on, when I was hit hard, then I said, 'Oh! You have to understand the laws.

> One of the things I would certainly consider, is moving the company into the U.S. in a much earlier stage so that it would have access to the grants that are available in the United States for company development. There's nothing in Canada that matches.

> It's important to choose your partners carefully.

> There seem to be two kinds of businesses in the technology world. In one kind of business is you've got a good idea and now you have to figure out who would ever want to buy it and why. So you have to create a market place. That's hard. The other idea is they absolutely need this product because if they don't have it, their business will be destroyed.

> If you're going to commercialize something, patents are pretty important things.

These comments suggest that, through their experiences, the participants constructed and refined their understanding of non-technical as well as the technical issues related to industry.

6.3.2.5 Success factors

When attributing their success in applied research projects and technology transfer activities to various factors, the participants tended to discuss non-technical success factors. These included:

> [Publications have helped me develop contacts] hundreds of times … It leads to agencies wanting you to look at some research problems.

> I try to keep aware of what's going on in the financial world and other things like that and I think that's helped me in trying to understand the impacts and the relevance of a large amount of things that I do in research…

> There's an old saying, "The devil is in the details." Of course it is in the details but you have to hire people that you can trust to look after the details.

> The two reasons for success: one is we pay attention to detail and the other is we stay on the problem long enough to solve it… We stay on the problem once we identify that this is really what we want to do.

Like the learnings and mistakes identified by the participants, the success factors demonstrate that the participants are attuned to a wide range of business issues beyond technological factors.

6.3.2.6 Outcomes

In telling the stories of their experiences with technology transfer, participants often described various outcomes resulting from their activities, in which they feel pride or satisfaction in having achieved or frustration at not having achieved. These outcomes provide insight into the participant's goals for technology transfer and their definitions for success. In review, the outcomes cited were found to be quite diverse. Participants were most likely to describe the impact of their university-industry activities upon their students, in terms of the virtues of the technology, in terms of the broader impact on the university and the economy, and in terms of the extent to which the activities themselves were enjoyable.

The advantages that participants felt that they were able to offer their students included access to more interesting problems to solve in graduate work, better opportunities to conduct research by using an international network of researchers and industry contacts, contact with potential employers through applied research projects, and access to teaching that balances theory and applications. For example, one participant observed:

> A student that I met with at a conference last week, he is an executive with a big technology company. If I didn't interact with industry, I wouldn't have given him a good project, good leadership and good advice so that he could achieve what he achieved with his Ph.D. thesis. I think, overall, that my students, my Ph.D. students, also benefited from my activities.

With respect to the value provided by their technology, several participants focused on the usefulness of their technologies, often expressed as positive feedback from users. Examples include:

> …one of our test users was so in love with the invention that he didn't want to give it up. We took this as the supreme compliment.

> I've had very beautifully inscribed letters from users, thanking me and that sort of thing. I've been on the local news, [laughs] and so on. And that, in a way, is rewarding.

> [The benefits of university-industry technology transfer are] two things: interesting problems and how to modify what we were doing so it would be more useful. Don't we all want to feel that we are being useful?

The goal of bringing technology into use was also indicated by a participant who was frustrated by the lack of success with respect to a technology transfer attempt:

> The dissatisfaction here is that this a design that people could be using. I'm not worried about the money involved; I'm not even thinking about that. I'm just thinking here is a design that people could be benefiting from but it's not out there now because of the myopic view of industry. I'm bordering on anger…

An alternate perspective on the way the participants' value of their technology was provided the statement, "I'm also really proud of our technology; our technology is leading edge."

Several participants took pride in the impact of their technology transfer activities on the university community and the broader economy:

> I always felt that one of the most satisfying things was the number of people working at the company. These are Canadians who have good jobs, they're taking home money, they're paying taxes. It's good for the Canadian economy, it's good for everybody.

> I feel that I contributed quite a lot to the university but at the same time I feel the university contributed to me. It's mutual good feeling.

> The research project that led to the spin-off is the activity that I'm most proud to have been involved in. The spin-off activity is probably lower because I value the research and teaching aspects of what I do higher than the commercialization. On the other hand, I recognize the importance of the commercial activity, in contributing to the community, having it pay back the university in many ways through hiring of people from here and through direct funding back into the university, through research contracts and through donations. Those things are very, very important contributions.

A number of participants described the technology transfer activities as intrinsically rewarding, noting that the activities were fun, interesting, challenging, and that, "It's been an interesting life; the years have gone by extremely fast." These comments suggest that the participants derive value from the experiences themselves, as opposed to their outcomes.

Other outcomes cited included the development of a network of contacts beyond academe, increased stature in the research community as result of making research more accessible, better publications resulting from the broader awareness of issues developed by doing work with industry.

Overall, three aspects of the outcomes cited by participants are especially noteworthy. Firstly, none of the participants cited their personal financial gains as a source of pride even though several transfers demonstrated significant returns on investments. This finding doesn't appear consistent with the expectation that financial rewards for technology transfer activities are a significant driver of behaviour. Secondly, the set of rewards are quite diverse and include effects on students, colleagues, the university and the wider community. If the anticipation of these benefits are significant drivers of involvement in technology transfer, models of faculty inventors motivations will have to be significantly more complex than they have been to date. Finally, the existence of this broad set of emotionally-significant outcomes and the presence of intrinsic motivators suggests that faculty inventors may be emotionally invested in their activities. Modeling the faculty inventor as a rational economic actor, who is primarily influenced by cost-benefit analyses, will not account for these effects.

6.3.3 University Environment

This theme explores several aspects of the university environment that appear to influence technology transfer activities. This top-level theme is further divided into four themes: 1) peers and group norms; 2) academic leadership; 3) university culture; and, 4) experiences with Technology Transfer Support Organizations (TTSOs).

6.3.3.1 Peers and group norms

Interactions with peers and the research group or departmental norms that are upheld by these interactions are expected to encourage or inhibit technology transfer. Some participants described their colleagues to be unsupportive of their technology transfer activities. Those who found their colleagues unsupportive of their activities described the colleagues' objections as stemming from: 1) envy; 2) the attitude that applied work isn't intellectually challenging; 3) the idea that having connections with industry mean that you can't be a real scientist; or, 4) the belief that the faculty inventor is "getting rich at the expense of the university." This last participant also observed, "It was not a good situation for me." When prompted, other participants either described their colleagues as having attitudes ranging from very unsupportive to very supportive, or hadn't experienced any difficulties at all. These participants attributed the supportive attitudes of their peers to a broad acceptance of spin-off activity at the University of Waterloo, deriving in part from experiences of some of the benefits including access to contract research funding provided to the university by successful spin-offs.

Overall, there was no clear relationship between group norms as expressed by colleagues' comments and the participants' behaviour. However, at least one participant found his colleagues' disapproval to be troubling. This suggests that group norms may be a factor in some situations even if it wasn't generally the case at the University of Waterloo.

6.3.3.2 Academic leadership

The extent to which university administrators, including department chairs, deans, vice-presidents and presidents support technology transfer activities can also be expected to encourage or inhibit technology transfer on campus. Most participants described the university's administrators as very supportive of technology transfer activities. Since the participants experience with technology transfer span many years, many different administrators were identified by name as supportive of technology transfer. Some participants reported that they felt encouraged to engage in technology transfer because they saw the administration as supportive of independent action. One participant described this as a trust relationship:

> I think there was a lot of trust too in those days. The trust was primarily internal, like from the dean to the chair of the department, the administrators trusted you to go out and do something useful and they gave you literally free rein to do it.

Another participant observed, "you never felt that you were being held back. That you shouldn't go out and do things" and that, "one of the vice-presidents of research, even to this day, whenever I see him he asks about the company." In yet another case, a faculty inventor who offered to develop the technology within the university was directly urged to commercialize it through an independent spin-off:

> We really tried to set an organization up within the university and so we had meetings with university administrators. I remember one day the Vice President of Research said, "Why don't you just set this thing up outside the university?" I said, "Well, there certainly would be less red tape and that seemed to be a good idea." … That was a very significant moment because it was almost a sigh of relief. I didn't want to rip the university off. I

> wanted the university to have every opportunity to participate if they wanted to but it became obvious that there were so many problems that it would have been better for us to do it ourselves. All of us in the start-up breathed a sigh of relief, when they said, "Why don't you take it outside?" That was a famous moment.

More than one participant had had experiences with an administrator whom they found to be unsupportive of their involvement in technology transfer. The behaviours that communicated this lack of support, included failing to honour deals with faculty inventors who wanted to have their spin-off cover some or all of their salaries so that they could carry reduced loads in order to spend time with a new venture. The administrator is alleged to have penalized them for the reduced loads when they wished to retire, in violation of the agreements. These behaviours were attributed to the administrator's lack of support for technology transfer because they appeared to target those professors with substantial involvement in contract research and technology transfer selectively.

Overall, the general consensus was that many individuals in the university's administration had been very supportive over many years. The message received by most of the participants was that they were empowered to engage in technology transfer. However, it was also clear that, for a few participants, a single administrator had done a lot to sour their experiences. Therefore, academic leadership was an important factor in determining faculty member's behaviours and experiences.

6.3.3.3 University culture

Many participants described the university and its culture when reviewing their careers and describing their technology transfer experiences and most of their descriptions of the university culture depicted it as changing significantly. In the early days of the university, the university is described as an exciting, entrepreneurial place, full of innovative and eclectic people and opportunities for individuals to push themselves and to contribute to building something. One participant mentioned that taking a job at the university was taking a gamble because it was such a new institution. In describing that time, another participant noted that the university was growing during a "revolution of young people," which was "an era that was very amenable or conducive to doing what you want…it was a different era than today." As these descriptions approached present day, many participants talked about increasing bureaucratization, "like a creeping fungus" and a loss of entrepreneurial spirit, although a couple of participants also voiced their opinions that the environment attracted people with energy and enthusiasm or a an interest in technology transfer.

These descriptions of early experiences within the university suggest that the university may have been more likely than other universities to hire faculty members who were relatively high risk-takers because the faculty hired by the university had to be willing to work in an institution that was not yet established. The experience of building new programs in a time when the university had few rules and procedures may have been a formative experience for new faculty members. It also may have led to the retention of staff members and graduate students that otherwise would have left the university environment. Thus the university's culture over time could have changed as its reputation increased and it became a more desirable environment for more conservative individuals. Certainly the university has had to introduce more policies and regulations relative to the early days in which, "everyone, including the graduate students, could go to a party at one house." In conclusion, the university's early culture appears to have been conducive to technology transfer by attracting risk takers and by empowering individuals to contribute to the university in their own way.

6.3.3.4 Experiences with Technology Transfer Support Organizations (TTSOs).

Many participants discussed the university's Technology Transfer and Licensing Office (TTLO). However, some participants discussed other organizations external to the university that filled much the same function; these organizations are henceforth referred to as External Technology Transfer Supports Organizations (ETTSOs). These types of technology transfer support organizations are widely expected to act as brokers between faculty inventors and companies that wish to contract or license research and to support the formation of university spin-off firms by mediating between academic and corporate culture. In a recent Canadian study, less than half of the faculty members interviewed acknowledged this role; university administrators were much more likely to do so (Fisher & Atkinson-Grosjean, 2002). In this study, about half of the participants in this study acknowledged the role that the TTLO or an ETTSO had had in at least one of their technology transfer activities.

A genuinely surprising finding from this study is the extent to which the participants' comments were negative. The TTLO and the ETTSOs were valued for their provision of resources in the form of money for patenting, or contacts. None of the comments acknowledged a brokerage role beyond infrequent mentions of resources provided by the support organizations. Furthermore, several of the participants shared stories that alledged that TTLO or ETTSO staff members had behaved unethically by seeking to profit personally from their activities in a manner inconsistent with their positions or had engaged in other questionable practices. Other stories conveyed frustration with their experiences with the organizations. For example, one participant felt unsupported while he struggled with the patent office's response to his patent application. Another participant recounted asking the TTLO not to license his invention to a certain company because he knew them to act dishonestly only to have them grant that company an exclusive licence. Yet another decided to reject the TTLO's offer to help with subsequent patents after the office decided not to assist him with the first patent. Finally, a participant was quite angry when the equity that he provided was transferred to a TTSO and thus didn't provide any value to the university as a whole.

When asked why they had not chosen to approach the TTLO for assistance, several other participants indicated that the TTLO couldn't help them because the TTLO's only strength was in licensing and their product was unsuitable for licensing or that the TTLO's systems were so bureaucratic that involvement with the office would be more constraining than it would be beneficial. The participants seemed to be skeptical of the extent to which the TTLO could help them although a few of them mitigated these comments by observing that they had had little interaction with the TTLO. One participant also added that it appeared that the office was staffed by good people who tried hard but that the office was understaffed and demoralized by their struggle to live up to faculty inventor's expectations.

At this juncture, it is important to observe that this study is not an attempt to present a historical or investigative account in which the facts have been verified with multiple types of sources. Instead, the purpose of this account is to present the faculty inventors' perspectives and it is only based on their accounts. This subsection is important from this perspective, and only from this perspective, because it makes it clear that the TTLO and ETTSOs have failed to make a positive impression on this cohort of faculty inventors. This lack of trust in the competence of the TTSOs has almost certainly increased faculty inventors' propensities to commercialize inventions independently of the TTSOs.

6.3.3.5 Summary of the university environment

This set of four sub-themes has addressed four aspects of the university environment that were identified through the interview process. Some participants found most of their colleagues to be supportive of their technology transfer activities; others were accused of prostituting science and the university. The university's administration was widely cited as an instigator of technology transfer activities. In particular, participants appeared to be empowered to act independently because of an implicit understanding that it was acceptable, even desirable. The university's culture was most often described as having been very empowering because, during the years in which new programs were introduced and the university expanded very quickly, there was a sense of tremendous excitement and involvement and because there were few rules and procedures to constrain the faculty inventor. However, the problems with alleged unethical behaviour on the part of an employee in the university TTLO were probably consequences of this unregulated environment. What is clear from faculty inventors' accounts is that the TTLO has not established a good reputation with the cohort of interviewees.

6.3.4 Rewards and Reward Systems

This theme contains vignettes related to rewards and rewards systems related to technology transfer activities. These rewards systems are elements of the university environment; they were captured in this top-level theme because of their importance with respect to this thesis. This top-level theme is further divided into three themes: 1) Intellectual Property (IP) policies; 2) financial rewards; and, 3) other reward systems.

6.3.4.1 Intellectual Property (IP) policies

In discussions of IP policies, most participants were adamant that the University of Waterloo IP policy was a contributing factor to high levels of technology transfer, and especially spin-off company formation at the university. The reasons offered for this were manifold but tended not to be directly linked to experiences that the participants had had. Instead, the descriptions tended to describe the advantages of the University of Waterloo policy over other universities, with which the participants had had no experience, or relative to hypothetical situations. The interpretation of these comments is somewhat more complex.

The following excerpt provides insight into the participant's understanding of the important factors by presenting the course of events that he imagines would occur if the University of Waterloo adopted a university-ownership position:

> In most cases, would it make a huge difference in how things actually end up? Like who makes how much money from what? How much does the university gain? How much does the individual gain on the projects that get commercialized? Probably not because there's already a sharing between individuals and the university in various ways. A reasonable university would probably still try to encourage the individuals by actually paying them fairly richly for doing the commercialization and allow the same kind of activity to go on. So, in the instances where commercial activity takes place, my guess is it would be structured very similarly to the way they are now. I don't think as many would take place. Certainly, not in the short run at Waterloo. I think that there'd be a big drop. What's worse is that, in the long run, the potential would go down because we would hire fewer entrepreneurial-type people. I'm absolutely convinced of that. It would be a very bad move for Waterloo.

This comment acknowledges that it would be possible for the university to share financial rewards and allow "the same kind of activity to go on" but predicts that there would be a big drop in activity. If individuals are rewarded richly for involvement in activities that are "structured very similarly to the way they are now," nothing has changed except the ownership of the IP. A review of the other excerpts suggests two possible reasons why faculty inventors may attribute so much importance to the ownership of the IP. The first possible explanation is that the ownership of the IP has been imbued with emotional and cultural significance. The second possible explanation pertains to the perceived limitations of the university Technology Transfer and Licensing Office.

The following excerpt is evidence that IP may have been imbued with emotional and cultural significance:

> One of the things that Waterloo has done, that I think is a catalyst for what's happened to Waterloo in terms of turning out new companies, is that Waterloo has encouraged people to put the results of their work into practice. And they've done that by allowing the people who do the research to own the results of the research. … I think the feeling is that it's part of what the university wants us to do. And you then go the extra step and see it applied.

> If you're going to do a lot of extra work, if you're going to do the eighty hours a week to get something going and the university owns ninety percent of it, whatever you produce, then you will lose incentive to do it. And it's not only the money, it's control. You know that you worked your buns off and in the end it doesn't matter because if the university owns the technology and they decide that you're not going to use it in that way and then everything you worked for could be destroyed in a moment. I mean, if you do it, if you own it, then you're responsible for it for

> better of for worse. If you make a mistake, then you suffer. If you do well, then you see things grow. You don't have that other ownership body out there who really controls what you're doing and has the ultimate say in what you're doing. It's also pride, I think, and you do something because you want to see it flourish.

> The most important [way to foster academic entrepreneurship], is the one I mentioned. That the intellectual property rights reside with the researcher. The sense of ownership… it's more, "Is this a part of you?" You're reputation is on the line. It's your idea that's on the line. So it's more a sense of ownership, I think, than pride.

This participant explicitly identifies the feeling of ownership as opposed to the contractual definition of ownership. This perspective strongly suggests that legal ownership of the IP also has emotional and cultural significance. The emotional significance appears to derive from identifying closely with the technology and the technology transfer. The cultural significance is the empowering message that the university recognizes this identification on the part of the inventors and entrusts the further development to them.

This quote also suggests that ownership may have a broader significance:

> I think we've been so successful because I think one of our key features here is the intellectual property policy, which basically says, "You create it, you own it." Other institutions have much more complicated policies. There's an attempt to require that the university should share in the ownership. When that happens, the first thing that happens is you get into discussions as to who owns what. You know, if I have an idea in this office and then I rent a garage down the street and do all my work in the garage down the street, does the university have a share? I don't have any idea how you decide that. So, you don't want to even go there. I mean, can you imagine if I have an idea and then I go and try and sell it, and get into an adversarial situation where the university is challenging my right to have ownership of this idea? Because they paid me to have the idea didn't they? I mean, paid my salary. Did I have the idea in the shower? Did I have it in this office? I have no idea. This really complicates situations very easily. If the university just says, "You own them," it is has eliminated a lot of the complication. First of all, the IP policy's simple. It's a very good thing because frankly it avoids a whole lot of wasted energy on trying to figure out what make sense.

In this excerpt the participant is imagining his response to a university that claims some ownership of his IP. His hypothetical response involves developing the technology in a garage down the street and, possibly, having an adversarial experience with the university over his right to own and, presumably, sell his idea independently of the institution. This excerpt suggests that this participant identifies strongly with his IP.

The second possible explanation is grounded in the statements by many of the participants that their technology transfer activities would not be possible if the university owned the IP. In a number of cases, these statements appear to be related to the lack of trust in the competence of the TTLO, identified in section 6.3.3.4. Consider the following quotes:

> I think that if the university-owner model were applied right across the board to every bit of IP developed or every product or research product or service, it would work fine for some. Others, like our type of thing, it just doesn't work. It wouldn't be practical. I'm not sure how other university-owner institutions operate but, I think there has to be some flexibility in that.

> …universities then often set up corporations to exploit this IP. They hire people, some of these people are very competent, but, 1) they probably don't understand what it is they're selling in many cases and, 2) they don't have any passion about it. They're just selling something. You don't have the originator behind the idea, the person who said, "I think this is just terrific. I've just got to go out and make this happen." I think there's a real problem there. I think if you look at some of these corporations that have been set up to exploit university IP, they're not very successful. I could be wrong but that's my sense.

> I have personal opinions about how well the TTO works but I don't want to comment because I've never used them. We've always gone our own way. We have enough collective understanding let's say.

> The university policy of inventor-ownership is supportive of this spin-off formation. It means that the individuals have the option to put more effort into something with the potential payoff to themselves, as opposed to the university dictating that whatever the individuals do, the university has the right to decide how things happen with it and therefore you're always subject to the university's whims: whether or not something can be commercialized in the way that you think it should be or could be. My guess is that the company wouldn't have started if the intellectual property was university-owned. Who within the university would have said, 'Let's do it?' And how would the university have convinced us, the people who actually did it, that we should do it on their behalf?

In several of these cases, participants argue that the Technology Transfer Offices are not capable of managing technologies that are not highly appropriable or not able to support spin-off formation. However, it seems highly likely that these views are shaped by the participants' experiences lack of confidence in the Technology Transfer and Licensing Office. Note, for example, that university ownership would subject faculty inventors to the "whims" of the institution. This proposed relationship is consistent with the qualitative study that determined that, "faculty decisions to disclose are shaped by their perceptions of the benefits of patent protection. These incentives to disclose are magnified or minimized by the perceived costs of interacting with TTOs and licensing professionals" (Owen-Smith & Powell, 2001). In both cases, perceptions of the TTOs interact with the power of incentives to influence faculty inventor behaviour.

In conclusion, the participants' discussion of the university IP policies suggests that the ownership aspect of the University of Waterloo policy is highly attractive to faculty inventors. It also appears that this attractiveness may be explained by some combination of two factors: 1) an emotional and cultural significance to the ownership of IP that promotes identification with the technology and the technology transfers and empowers inventors to engage in transfers independently of the university; and, 2) a lack of confidence in the competence of the university's Technology Transfer and Licensing Office.

6.3.4.2 Financial rewards

The financial rewards governed by university IP policies have been a focus of most of the quantitative work relating IP policies and technology transfer outcomes. In this thematic analysis, financial rewards are discussed separately from IP policies because they were linked in so few of the participants' statements. Instead, financial rewards were justified by a description of the participants' investments of time and money, seemingly in a cautious or defensive tone, or participants provided evidence that financial rewards were not prime motivators. Several statements also discussed the participant's lack of desire to accrue and/or flaunt personal wealth and the inadvisability of this approach in the context of academe.

The following quotes, expressed by individuals who received impressive returns on their investments in technology transfers, are examples where the participant appears to be justifying their personal gain:

> Everybody who worked on the research project that was the basis for the spin-off was given an opportunity to invest. I had reasonable access to money, so I was able to invest without risk. In other words, if the money disappeared, it disappeared. I wasn't going to cry. Well, I'd cry but not very much. So we were all in this together. We continued to do our research but we invested in a little company that was just starting up. We were always very careful to make sure that we always did our job at the university and we followed the policies and rules at the university very carefully. It wasn't the case that it was all very well orchestrated because you can not ever create the perception that working at the university is a way to get rich because it isn't. There's nothing wrong with making investments. We all do that. It's called the stock market, bond market or whatever. If we can work together so that we both win, that's a good thing to do, which is what happened. So, I want to be very careful how one says that because

> it can be very easily misinterpreted.
>
> You have to have some motivation for the people doing it. I don't think the commercialization always happened as much without that incentive. People will just pursue their research. Why do people, who are just doing pure research, who aren't doing commercialization, why do they publish in journals? There are three reasons. First, they want to let their colleagues know what they're doing, and they want to be able to read what their colleagues are doing. The second thing is it's publish or perish, right? And the third is you don't get research money unless you publish. These things would happen but not to the extent that they happen without the monetary incentives. Also, we did a lot of research as part of our jobs but we also spent a lot of time that wasn't the university time pursuing these things.

Other participants talked about how financial goals were secondary goals in the technology transfer process:

> I'm more interested in having satisfied users, just to talk to them and say, 'How are you finding it?' and have their eyes light up and them say, "It's the greatest thing since sliced bread." If, afterwards, I made a little money that would be a benefit but that wasn't a certainty at that stage of the game. In fact, if it was money that I was interested in I might have taken a different route. I would have short-circuited some of the things to get to the answer quicker.

The third set of quotes discussed the acquisition of personal wealth and conspicuous consumption. Two participants were quite clear that they were not interested in engaging in conspicuous consumption:

> When I say I am not interested in money, all it means is that I'm not interested in accumulating personal monetary worth … Now the company has to be profitable. If the company is not profitable it will not create more technology. I'm interested in technology. If you look at the core values of this company you'll find that our aim is to create better and better technology but to do that you need money, therefore you have to be profitable. And I know how to look after a company to make sure that it is profitable. But I'm not personally interested in a lot of money. There is a limit on how much I can eat, there is a limit how much I can wear, there is a limit on how much I can travel. Those needs could be satisfied, not with millions, but maybe with thousands ... I could afford to have a house which is 200,000 square feet with swimming pools and extravaganza and all that. I'm not interested. I'm interested in comfortable clothes. For example, the shirt I'm wearing probably cost $30 or $40. If I was interested in money, I would get a shirt

> which cost $400 or $500. I got a present, an Armani shirt which cost $400. But I really don't need a $400 shirt. You see the difference?
>
> When entrepreneurs outside of academia, make it big, they expose it. Like an entrepreneur friend of mine and his Ferrari. In that culture that's one of the marks of success. Counting wealth in an academic institution is, in my opinion, not smart. You don't see me driving up here in a Rolls Royce. I own a modest car, I mean it's a nice car, but it's a modest car. I don't own a Ferrari, I'm not interested in one and all that stuff.

Like the second of the two prior quotes, a third quote on the topic of conspicuous consumption suggests that it may be counter to norms for acceptable behaviour within the university:

> I think in academia, you can create real serious problems for yourself if you talk about making money through technology transfer. Academia does not celebrate wealth. That's crass, that's commercial. They celebrate other things, they celebrate publications, they celebrate good teaching, they celebrate honours: The Order of Canada, Fellow of the Society of Canada, and that kind of stuff. There is a different set of criteria by which they measure success. You can be poor as a church mouse but, by God, you've got three hundred publications. Now, is that good or bad? I'm not going to comment. It's all where you stand.

Overall, the excerpts related to financial rewards suggest that this type of success is not widely accepted, much less celebrated within the University of Waterloo. In other words, the desirability of this outcome may be attenuated by group norms through interactions with peers. As a result, financial incentives may have less power to motivate behaviour. Alternatively, the participants may have been conditioned to devalue the significance of financial rewards in shaping their own behaviour. Therefore, it isn't clear from these self-reports to what extent these rewards motivate engagement in technology transfer relative to other possible outcomes or to what extent the negative social dynamics surrounding financial rewards decreases their appeal.

The other implication of this finding is a practical issue. The lack of acceptance means that a focus on financial performance may be quite divisive within the university and increase the likelihood that those faculty members engaged in technology transfer experience conflicts with their colleagues. The outcomes that appear to be more acceptable are identified in the 'Outcomes' section and include positive impacts on scholarship, mentoring of graduate students, teaching performance, the university and the regional or national economy.

6.3.4.3 Other reward systems

Four vignettes identified factors within the university, pertaining to the tenure and promotion system, that didn't support applied research or technology transfer effectively. The first vignette notes that tenure and promotion committees do not recognize industry outreach activities, like offering workshops and courses, as significant activities even though they transfer knowledge to industry much more effectively than publications in at least some fields. The second vignette was offered by a participant who had excelled in all areas of his university career, including teaching. He feels strongly that universities should allow its faculty members to specialize in pure research, applied research, or teaching, provided that they maintain high standards of quality. The rationale provided is that the faculty members and the university would benefit from allowing individuals to specialize rather than pursue excellence across a range of activities. The third vignette suggests that bottom-up approaches to university-industry interactions are far more effective than large top-down developments, and that a problem with the university environment is the extent to which the promotion system discourages risk-taking. The fourth vignette notes that the promotion and tenure system doesn't promote interactions with industry because it is incapable of recognizing design work. This fourth vignette further suggests that this gap is problematic in the applied disciplines because application is part of the motivation for the work; it is the stage that provides satisfaction to the applied scientist:

> Applied math and science students are rewarded by the phenomenon, 'Look, Ma, what I built!' Whereas pure math and science students very often are rewarded by the Eureka phenomenon, 'Now I understand!' Well, for a lot of applied students, understanding something isn't the end of it. How do you apply it? To what? Build what? That's why many of those students, once they graduate, get somewhat alienated from the university. The university's rewards system isn't involved in this sort of, 'Look, Ma, what I built!' sort of thing. It's, 'Look, Ma, what I now understand.'

These diverse views on university reward systems reflect the evolving concerns of academics as the "second revolution" increases university-industry interactions and the universities experience increasing pressure to demonstrate their social value and relevance. These suggestions and others like them are of interest because they may represent opportunities for university administrators to introduce supports for high quality applied research and technology transfer activities.

6.3.5 Attitudes

This theme captures information regarding the participants' attitudes towards research directions and the role of the professor and/or the university in society and some descriptions of those aspects of being a professor that they do or don't enjoy. Therefore, this top-level theme is further divided into two themes: 1) attitudes; and, 2) job elements and job satisfaction.

6.3.5.1 Attitudes

The researchers made a number of statements that revealed some of their attitudes towards appropriate research directions. These attitudes included the beliefs that: 1) basic (or pure) and applied research co-evolve; 2) that universities researchers should do long-term research not short-term research; 3) that research directions need to be flexible enough to pursue significant work rather than clinging tightly to a mission; and, 4) that research in the applied disciplines should balance between doing research in order to produce new knowledge with no concern for practical application and producing practical solutions with no concern for generating new knowledge. Short excerpts demonstrating these attitudes include:

> Applications feed the theory and theory feeds the applications. It seems to me there's got to be that interaction.

> …it's not the short-term goal that you should be pursuing it. It's the long term goal. It's to light the path so that you or other people then can do the applications in the future.

> There's too much focused research, mission-oriented research. If you make it too narrow I think it's going to choke off things … if you have the flexibility to go in the direction and the inclination to apply what you're doing then I think having a greater flexibility has a much greater social value in the long run.

> If you get to be at a point where you're just a minion of the industry then what will happen is you will gradually be shifted from fundamental research to being a product designer because product design is the thing that industry wants. … The researcher wants to generate new information that people can use. A lot of universities couldn't even care whether it's useful. ... They're the two ends of the spectrum. … our faculty's role is to act as an interlocutor between those two things.

When describing the faculty member's role in relationships with industry, a participant suggested that he acted as a 'dictionary' or 'lexicon' for industry and another described his role as that of an 'interlocutor.' All of these words imply that the faculty members are envisioning themselves in a boundary-spanning role, making academia accessible to industry and vice versa. One participant claimed that all academic work should be made available for application to other problems. Another participant suggested that researchers that meet their obligations with respect to teaching, research, and service should be free to engage in any extra-curricular activities, especially if they provide social benefits. These elements all suggest that the boundary-spanning researchers in the participant group hold attitudes that are quite positive towards technology transfer. This result coincides with Renault's finding that researchers who engage in technology transfer are more likely to hold non-traditional views of academe, in which university-industry involvement is seen as a positive activity in at least some contexts (Renault, 2006).

6.3.5.2 Job elements and job satisfaction

Another way to gain insight into individuals' relationships with their jobs is to ask them to identify the aspects of their work that they find rewarding. In the third interviews, many of the participants were asked to identify those aspects of being a professor that they found to be most enjoyable, especially if they had chosen to remain in the university rather than join a spin-off company.

Two participants identified the autonomy that they experience as the best part of the position:

> I think it is being my own boss…

> [The best part about being a professor is that] I get to do what the hell I like. I enjoyed the acting part of teaching and I enjoyed having all these bright people around to sort of discuss and argue with and being able to maintain that. But just freedom is the thing. You can't price that.

Several other participants discussed their engagement in research and problem-solving, in a manner that suggested that these activities were intrinsically rewarding:

> I let [my hands-on involvement in research] go but I didn't give up trying to stay with the technology: going to conferences, understanding it, I'm just not doing hands on research. Sometimes I miss it, so whenever I have to give a talk about technologies, I sit down and I research. I enjoyed it very much, you know.

> [The best part of my research day is] trying to come up with ideas that make sense.

> I think it is a beautiful subject. There's a certain beauty to the logic. But it's very hard to explain to people who don't know the field.

> I like working on projects with colleagues. … I think the attraction in working with colleagues is that quite often you're plowing new ground, in the sense that you're solving new problems. As applied scientists that's what we like doing, you know.

Other aspects of their roles as professors that the participants found satisfying were interactions with students and colleagues. One participant elaborated on his satisfaction with his position by adding that he didn't enjoy dealing with the details of research accounts and so on:

> I don't like the bureaucracy that goes along with some of the research contracts and projects. … Particularly, now that our university's become more bureaucratic over time… I probably spend much more time than I want to on dealing with the financial services people and so on, keeping track of accounts and stuff like that. Doing all the paperwork that goes along with research contracts. That's the drudgery of it.

6.3.6 Career Decisions

This theme includes excerpts related to two aspects of career management: 1) work/personal life balance; and, 2) mid-career change.

6.3.6.1 Work/personal life balance

In cases where the participant experienced high time demands because of their involvement in technology transfer, they were asked about the impact of these activities on their personal life. These participants credited their families, and especially their spouses, as having been very supportive. In most of these cases, the participants had wives who did not work outside the home and who "kept the operation at home going" while the participants spent long hours at the university and in technology transfer activities. A number of participants appeared to see the question as relevant to understanding their experiences. For example, one prefaced his remark with, "That's a good question." Another expanded on his experiences by observing that he had a friend, whose spouse had not been supportive of his technology transfer activities, and that the time demands, "tore the marriage apart."

This is of interest in a research context because it suggests that this first cohort of 'academic entrepreneurs' were only able to pursue the technology transfer activities that they pursued because their spouses were able to support them, in many cases, by taking on most of the responsibilities in the home. The number of professors who currently experience this type of support of their professional activities has declined probably as a result of changing social norms and the entry of many women into the work force. For example, a recent quality of life survey at M.I.T. found that, among tenured faculty, 65% of women and 29% of men are in dual-career families (Massachusetts Institute of Technology, 2002). This reinforces the observation, first made under the 'Time Demands' theme, that university policies that govern a professor's ability to take leaves of absence or sabbaticals, or to carry reduced teaching and administrative loads are likely to be very important in encouraging technology transfer.

6.3.6.2 Mid-career change

Some participants made it clear that their decision to move into a spin-off company was triggered by a desire for a mid-career change. This desire was fuelled by a mixture of factors, including a fear that personal research productivity was in decline, boredom with the university position after having held it for many years, a desire to see research results put into use, and a desire to build a company, "where you can see the results."

The university pension system was identified as an obstacle to these mid-career changes, in that the penalties for early retirement were viewed as prohibitive. As a result, at least one spin-off company had a more gradual growth pattern until the Special Early Retirement Program was offered in 1996 as a cost saving measure by the university. Obstacles to these mid-career shifts are undesirable, not just because they may inhibit spin-off formation, but because they result in individuals who no longer want to work within the university environment remaining because they feel trapped.

In conclusion, flexible pension policies may encourage venture formation by releasing senior professors who have accumulated commercializable technologies and know-how from the university's "golden handcuffs."

6.3.7 Summary

The previous subsections have presented the themes derived from interviews with participants who have had experience with technology transfer. Overall, these themes demonstrate that, even a small number of serial entrepreneurs display a wide range of interests, concerns, and motivations in the context of technology transfer. The next section discusses these findings and presents several ways in which the findings can be linked to models of motivation.

6.4 Discussion

This discussion further synthesizes the thematic data by focusing on, firstly, the participants as 'boundary-spanning' professors and, secondly, their motivations.

6.4.1 Boundary-Spanning Professors and Business Knowledge

Most of the participants can be described as 'boundary-spanning' professors because they have displayed a wide range of interactions with industry over a long period of time. This 'boundary-spanning' behaviour pattern is of interest because it provides faculty members with access to business knowledge through university-industry interaction and business knowledge is likely to be critical success factor, especially in the creation of university spin-offs. Section 2.2.2.2, in the literature review, introduced the concern that faculty inventors are not likely to be able to transfer technology to industry because their lack of business knowledge would prevent them from being able to make critical decisions effectively, including, for example, the selection of an appropriate target market. These predictions appear to be implicitly based on the understanding that the faculty members have little exposure to the business world. This concern would suggest that the more central a faculty inventor is to the technology transfer activities, the less likely the transfer is to succeed. No such pattern was observed and the boundary-spanning researchers appeared to have a great deal of access to business knowledge through their interactions with industry.

In four of the 'University-Industry Interaction' sub-themes, participants demonstrated access to and acquisition of business knowledge. The activities described in the 'Roles' indicated that most of the participants, even among those who remained in the university, had significant exposure to business knowledge through involvement in "missionary work." These efforts to build market interest in a product or service, included providing workshops, seminars and courses, writing proposals, and giving presentations to prospective clients. The excerpts associated with the 'Opportunity recognition' sub-theme, suggest that many participants were able to identify opportunities for licensing or venture creation using their own understanding of the market. This suggests that, even before they were involved in technology transfer activities like licensing and spin-off formation, these participants had developed substantial business knowledge. The large number of business issues, raised in the excerpts associated with the 'Learnings and identification of mistakes' and 'Success factors' sub-themes, suggest that participants continued to develop and refine their business knowledge through their technology transfer experiences. Overall, most of the 'boundary-spanning' participants appeared to exhibit a 'learning by doing' approach, where the process began with involvement in a diverse set of university-industry activities well before initiating licensing or spin-off formation. Under these conditions, it is unsurprising that several of the technology transfers were catalyzed by the availability of resources for commercialization; the awareness of the market preceded the decision to engage in technology transfer.

Given these dynamics, it is quite likely that most serial commercializers are boundary-spanning professors. This finding would be significant because boundary-spanning professors are known to differ significantly from their peers in identifiable ways; by definition, they exhibit a characteristic behaviour pattern. This suggests that this subgroup of the university population could be deliberately targeted in the design of technology transfer support programs. In designing supports valued by this small percentage of the university community, one would be likely to address much of the commercialization activity within the community. Furthermore, one would be targeting the population that is most likely to have the kind of knowledge of the industry that could contribute to the success of any transfers.

6.4.2 Motivations for Engaging in Technology Transfer

This study also provides significant insights into the participants' motivation for engaging in technology transfer as well as the research that led to the technology transfer opportunities. This section will demonstrate that it is possible to begin to make connections between established theory in the entrepreneurship literature and the rich description provided by this theoretical study. The analysis will focus on the reasons why it may be helpful to model faculty inventor's motivations using need theories of motivation.

All of the 'needs' theories of motivation model behaviour as a response to unsatisfied needs. Modern need theories account for differences in the patterns of behaviour exhibited by different individuals by positing that different individuals experience different needs to different extents. Therefore, need theories may be able to address some of the differences between faculty members who engage in technology transfer and those who do not. Various aspects of the participants' behaviour and self-descriptions suggest that they may be motivated by a need for achievement.

6.4.2.1 Need for achievement

Section 0 presented evidence that the participants in this study are highly productive researchers and capable teachers. Together with their involvement in technology transfer, these successes suggest that this set of individuals strives for excellence across different contexts. In the 'Outcomes' and 'Job Elements and Job Satisfaction' sub-themes, participants described business challenges they experienced and the solving of problems as fun activities. The participants who identified the need for a career change were clearly driven by the need to engage in new challenges. Together these aspects of the participants' behaviours and self-descriptions suggest that these academic entrepreneurs may share a 'need for achievement' with other entrepreneurs. Need for achievement is defined as "behaviour towards competition with a standard of excellence" by McClelland, the theory's originator

(McClelland et al., 1953; as cited in Steers & Porter, 1987, p. 60). Motivation by this need leads individuals to pursue activities that are challenging, that require individual effort and skill, that involve personal responsibility for outcomes and that result in feedback (Shane, 2003).

It has been robustly empirically demonstrated that this motivation leads to a higher probability that an individual will choose to exploit an entrepreneurial opportunity and to a higher probability that their new venture will be successful, in the case of technical as well as non-technical ventures (Shane, 2003). An exploration of this characteristic in the context of academic entrepreneurship could have important theoretical and policy implications. Exploring a theoretical concept in a new context permits researchers to identify any aspects of the concept that are context dependent and thus can help them to refine the theory. This theoretical development could also have policy implications. If academic entrepreneurs share important characteristics with non-academic entrepreneurs, it may be possible to support both groups with the same governmental programs and thus to offer effective programming at a lower cost. If academic entrepreneurs do not share defining characteristics with entrepreneurs, they will need to be supported in different ways and the theoretical advances may permit some understanding of the ways in which the programs will need to differ.

6.5 Conclusions

The participants' behaviours identified them as 'boundary-spanning' researchers. Their statements in interviews were consistent with this assessment, in that they disclosed that the participants' attitudes towards university-industry interaction were quite positive. Further analysis of the participants statements suggested that these boundary-spanning behaviours provided the participants with access to business knowledge that allowed them to 'learn by doing,' even before their first experiences with licensing or venture creation. This helps to explain how the participants could achieve commercial success, in contradiction with the position that faculty inventors lack the business knowledge required to successfully transfer technologies.

The study also determined that faculty inventors' motivations are significantly more complex than their depictions in the literature to date. The participants expressed interest in achieving a wide range of outcomes, including benefits realized by the participant's students, colleagues, and the country's economy. Their involvement in technology transfer was also tied to intrinsic rewards; spin-off creation was fun. None of these elements have been captured by previous studies.

The complexity of these motivations suggests that it may be appropriate to introduce models of motivation from more established fields, like entrepreneurship and industrial-organizational psychology. The discussion of the need for achievement demonstrated that the qualitative results can be used as a bridge between the literatures. This type of work is expected to generate testable hypotheses (e.g. academic entrepreneurs have higher levels of need for achievement than non-entrepreneurial colleagues) that are important in the substantive domain, which in this case would be technology transfer research.

The analysis of the incentives offered by IP policies generated theories that were no less complex. The primary incentive, among those granted by the university's IP policy, was ownership of the IP. The participants' comments suggested two possible explanations for the value placed on this ownership. The first explanation is that this ownership is imbued with an emotional and cultural significance that encourages faculty inventors to identify with their technologies and empowers them to pursue technology transfer. The interpretation of the IP policy as an empowering message from the university administration appears to be consistent with participant's perception of the university administration and the university culture, in general. The second explanation is that this cohort of faculty inventors has little confidence in the competence of the TTSOs and therefore prizes the freedom to work independently. This explanation hinges on the negative experiences of interactions with the TTSOs by members of the cohort. It is possible that both explanations for the high desirability of IP ownership are in effect at once. Contrary to the findings of quantitative work conducted in the U.S., it wasn't clear that financial incentives were a key determinant of technology transfer behaviour. The extent to which financial incentives influenced participant's decisions was quite ambiguous, perhaps as a result of group norms that do not celebrate and can be hostile to success in this domain.

In summary, the analysis suggested that the motivating power of the incentives offered by IP policies is dependent on their interpretation by members of the university. These interpretations appear to be shaped by institutional variables including organizational history, group norms, leadership, and culture. This finding means that it isn't possible to interpret the incentives offered by a university's IP policy without investigating the perceptions of those policies, which significantly undermines the value in further cross-comparisons between universities on the basis of policy statements.

6.5.1 Implications

The main finding of this study is that the motivating power of the incentives governed by IP appears to be sensitive to organizational characteristics, including group norms, academic leadership and university culture. This suggests that institutions are most likely to effectively support technology transfer when their IP policy fits their organizational context. For example, at the University of Waterloo, a shift to a university-ownership policy is likely undermine a culture that prizes autonomy and places emotional significance on ownership. However, it may be possible to mitigate or remove this effect by increasing faculty confidence in the competence of the TTLO.

Another important finding was associated with the observation that technology transfer activities could impose high time demands. Many of the faculty members who were involved with spin-offs and remained in the university reported that they were able to do so because they had a spouse who, "kept the operation at home going." This is not true for many younger professionals, which suggests that programs and policies that allow people to temporarily reduce their university load or take leaves of absence so that they can engage in technology transfer activities will grow in importance as a way to sustain technology transfer activities. Universities can also consider making their boundaries more porous to mid-career scientists, who wish to embark on a new career, by ensuring that the pension systems do not prohibitively penalize early retirements.

6.5.2 Limitations and Future Research

This study has three main limitations. Firstly, it included a small number of participants at a single institution, which strongly limits the generalizability of the results. Secondly, it relies on retrospective self-reports, which can be contaminated by ex-post-facto rationalizations and can be limited by the extent to which the participants can clearly remember events that have taken place in the past. Thirdly, the participants belonged to a single cohort. As a result, their experiences are likely to be significantly different from other members of the University of Waterloo. An attempt was made to identify all possible cohort effects, including the decline in the number of faculty members with a spouse in the home, and the cultural and structural changes at the University of Waterloo over the years, but it is possible that cohort effects were not identified or not fully explored.

Future research could address these limitations by conducting cross-comparisons between institutions, in the style of study 1, using surveys of faculty interpretations rather than policy statements as an independent variable in order to access faculty members' perceptions. Given the relationships observed between social and cultural variables and interpretations of the IP policies, there may also be value in investigating the interactions between psycho-social organizational variables, like the management styles at TTOs, and interpretations of university policies.

Chapter 7
Conclusions

This chapter is structured as follows. The first section summarizes the results of the three studies undertaken in this research. The second section responds to the research question in light of the results of the three studies, considered together. The next section of the chapter discusses the theoretical and policy implications of these results. The last section reviews the limitations of the research and makes suggestions for future research directions.

7.1 Summary of Results

This research investigates the relationship between those incentives for faculty support of university-industry technology transfer that are governed by university intellectual property policies and technology transfer outcomes at Canadian universities. It extends the literature on this relationship by exploring it in a new context. The context for the studies is Canada, where some universities retain control over the development and other universities let the ownership and control vest with the inventors.

The first study seeks to explain cross-institutional patterns in the numbers of patents held by Canadian universities using variables that represent the financial incentives and control offered to faculty inventors by the universities' policies. Unlike studies conducted in the U.S., the comparisons across institutions do not demonstrate any relationships. This may be a consequence of a difference between the U.S. and Canada in the importance of the financial incentives for faculty support of technology transfer as governed by IP policies. However, it is also possible that the true effects of the IP policies are masked by the effects of other variables or by bias in the data, which failed to capture technologies developed by university faculty members without the participation of their university.

The second study investigates the impact of a policy change at the University of Toronto, using interrupted time series analysis techniques. This study provides the first statistical evidence that university IP policies can be a significant factor in determining the effectiveness of institutions by influencing university researcher's willingness to participate in technology transfer activities. At the University of Toronto, increasing researcher control of technology transfer by switching from a 'university-owns' to an 'inventor-owns' system appears to have stimulated higher levels of invention disclosures. The principal limitation with this type of longitudinal model is that it is impossible to isolate any other factors that may have determined the effect of the policy change.

The third study investigates the experiences of faculty inventors at the University of Waterloo through in-depth interviews and thematic analysis of the resulting qualitative data. The first key finding is that the faculty members who were involved in technology transfer engaged in 'boundary-spanning' activities, often starting well before their involvement in technology transfer activities. These boundary-spanning activities provide a mechanism by which the participants can acquire business knowledge. Therefore, the faculty inventors' involvement in boundary-spanning activities leads to a tentative explanation for the faculty inventors' ability to manage many of the technology transfers successfully. The analysis also provides insight into the relationship between university IP policies and faculty inventor behaviour. The comments by the participants suggest that the motivating power of the incentives offered by IP policies is dependent on their interpretation by members of the university. These interpretations appear to be shaped by institutional variables including organizational history, group norms, leadership, and culture. For example, the desirability of ownership of IP may derive in part from a lack of confidence in the competence of the university's Technology Transfer and Licensing Office. This finding means that it isn't possible to interpret the incentives offered by a university's IP policy without investigating faculty members' perceptions of those policies. Therefore, the cross-comparison of institutions in the first study may be flawed by a reliance on the IP policies themselves rather than faculty members' perceptions and interpretations of those policies.

Together the three studies suggest that university intellectual property policies are effective levers with which to stimulate university-industry technology transfer but that the policy must fit with the organizational context in order to be productive.

7.2 Key Findings

This research is designed to address the question: What, if any, relationship exists between university IP policies and university-industry technology transfer? The research demonstrates a relationship between the IP polices and technology transfer outcomes and suggests that the relationship may be multi-faceted. Prior literature has assumed that IP policies influence faculty inventor support for technology transfer which affects technology transfer outcomes. The findings of Studies 2 and 3 are consistent with this type of relationship. The research also suggests that there may be other types of relationships between the IP policies and technology transfer outcomes. University IP policies appear to influence the TTO's access to information. In Study 3, a technology manager observed that his TTO did not have any reliable channels for gathering information about inventor-commercialized university inventions. It is plausible that having limited access to information about technology transfer activities at a university, a situation which is only expected to occur at 'inventor-owner' universities, probably limits the effectiveness of university support for technology transfer at that institution. Since the effectiveness of the TTO and other university support systems is expected to have an effect on technology transfer outcomes, this relationship deserves further research. The research also suggests that university IP policies may influence hiring and retention. In Study 3, an expert academic entrepreneur suggested that the University of Waterloo's 'inventor-owner' policy attracts faculty members who are especially supportive of technology transfer. This effect could help some institutions create strongly supportive environments for technology transfer which should lead to high levels of technology transfer activity. A relationship between IP policies and university hiring and retention could also contribute to the development of a country's stock of highly-qualified personnel. Since many faculty inventors are known to be highly productive researchers, holding desirable IP policies may also help universities attract and retain 'star' scientists. For both of these reasons, the hypothesis that IP policies influence a university's ability to hire and retain highly productive researchers deserves to be a focus of further research.

7.3 Implications

7.3.1 Theoretical Implications

As the literature review indicated, prior work has posited that IP policies influence researcher support for technology transfer and thus affect technology transfer outcomes. Therefore, the development of a stronger understanding of this relationship is the focus of theory development in this research.

The quantitative literature to date has tended to adopt an ‘economic agent’ model of faculty member behaviour. Although such models can address many types of factors, the model employed in the studies only considers financial factors. According to this interpretation of the model, the university researcher is directly influenced by the costs and benefits of multiple courses of action. This research contributes to a broadening of that conception. Study 2 demonstrates the significance of research autonomy in the technology transfer process, a non-financial incentive. Study 3 explores the motivations of faculty inventors and identifies a complex set of desires and goals that include both extrinsic and intrinsic rewards. These findings establish the need to explore more sophisticated models.

The subsequent analysis briefly demonstrates that it is possible to use the qualitative data to access the more sophisticated theoretical models that have been developed in other fields. Qualitative research can provide insight into why phenomena occur. These insights can be used to identify theories outside of the substantive area of research that are expected to be meaningful in the context of the substantive area. For example, this research suggests that serial commercializers exhibit higher need for achievement than their colleagues. In other words, need for achievement, a concept from organizational behaviour theories of motivation, is expected to be a useful way to understand faculty inventors’ motivations in the context of future technology transfer research. This is an example of the way in which building bridges between a substantive area of research and areas of research with richer and more established theories makes it possible to generate testable hypotheses that are expected to be significant in the substantive area. From this perspective, Study 3 provides a rich entry point for the introduction of theory to technology transfer research. The third study also contributes to theory development by identifying several factors that may determine the extent which faculty inventors can effectively transfer their technologies. For example, it identifies the role that ‘boundary-spanning’ behaviours have with respect to the acquisition of business knowledge.

Overall, the three studies significantly broaden our understanding of the relationship between university IP policies and university-industry technology transfer and suggest many future directions for further theory development. It is hoped that the rich entry point for theory development, which Study 3 presents, will yield even stronger results through future work.

7.3.2 Policy Implications

The international policy landscape currently favours the use of federal policies and legislation that cause university IP policies to converge to a national standard. In many cases, the standard policy is one of “university-ownership.” For example, the Canadian Expert Panel on the Commercialization of University Research’s report called for all Canadian universities to adopt a “university-ownership” policy, citing the boom in activity in the United States after the introduction of the Bayh-Dole Act (1999). This research suggests that this policy approach will not be productive for three reasons. Firstly, there is no empirical evidence that a "university-owns" model is more effective or efficient than the "researcher-owns" model. Study 2 is the only quantitative study that could be located that demonstrates any significant difference between the two models and the "inventor-owner" model appears to have better stimulated technology transfer at the University of Toronto. Therefore, there is no empirical argument for convergence to "university-ownership". Secondly, the importance of the institutional variables identified in Study 3 suggests that policy makers must use a great deal of caution when importing 'best practices' from other institutions and countries. The effectiveness of the policies and incentives appears to be heavily dependent on achieving a fit with organizational factors. Thirdly, convergence to any single policy would almost certainly make it more difficult for a university to adopt a different policy in the future. University administrators would no longer be able to introduce new policies at their institutions in order to address challenges within the system or changes in the university environment. In effect, the university would abandon that which appears to be a powerful lever for promoting support for technology transfer and thus reduce its ability to innovate and respond to challenges. In Canada and in other countries, policy makers are cautioned that any attempt to optimize at a national level is premature. As the literature indicates, the "second revolution" and our understanding of its ramifications are still too embryonic to seek to optimize at the expense of our flexibility to learn and adapt.

Instead of standardizing IP policies, policy makers and university administrators should consider: 1) strengthening the university TTOs; and, 2) developing university programs and policies that are designed to meet technology transfer objectives by capitalizing on institutional strengths.

1) Studies 2 and 3 made it clear that some faculty inventors at both the University of Toronto and the University of Waterloo viewed the technology transfer support as inadequate. Individuals at both universities suggested that the offices were under-funded and under-staffed. At the University of Toronto, negative perceptions of the Innovations Foundation appeared to discourage the disclosure of inventions in the years prior to the policy change. At the University of Waterloo, negative perceptions of the technology transfer office discouraged faculty inventors from seeking support. This implies that universities and governments can improve technology transfer outcomes by providing more resources to technology transfer offices. Since faculty inventor behaviours hinged on confidence in the competence of the offices, these behaviour patterns may be slow to change. Therefore, investments in TTO staffing and provision of funding for core functions, like patent protection, should be, at a minimum, multi-year commitments. With respect to the delivery of core services, only long-term funding can be expected to enable the TTOs to develop stronger relationships within the university and the community.

2) Policy makers can also work towards both technology transfer objectives and the development of appropriate support programs and polices by structuring additional support for technology transfer in the form of funding competitions. Technology transfer is associated with a variety of objectives. The development of specific funding streams would allow policy-makers to target high priorities within these objectives (e.g. the creation of new economy jobs). These competitions would provide funds for the development and support of

> programs and policies that address a given objective and still create the flexibility necessary for innovation by allowing the universities to meet the objective in different ways. University programs should be selected based on the feasibility of the program design and the extent to which they capitalize on the university's strengths and opportunities. For example, a research-intensive university with strengths in less appropriable technologies could focus on spin-off creation, a research-intensive university with strengths in highly-appropriable technologies could focus on licensing to small- and medium-sized enterprises, and a less research-intensive university could develop programs in support of student entrepreneurship.

In summary, the current trend towards standardization of IP policies is not expected to yield optimal results. Instead, policy makers and university administrators are advised to focus on strengthening TTOs and programs and policies that both address technology transfer objectives and fit the universities' strengths and opportunities.

7.4 Limitations and Future Research Directions

The principal limitation of the research is the lack of generalizability. The research design assumes that the cross-sectional study will be able to provide generalizable results and that the longitudinal and qualitative studies will refine the understanding achieved through that cross-sectional study. Since Study 1 does not identify any statistically significant results, the assertion that IP polices appear to be important in the context of university-industry technology transfer rests entirely on findings at two research-intensive universities. Therefore, the focus of future research will be on broadening this investigation, which can be achieved in a number of ways.

One approach to broadening the quantitative work presented in this dissertation would be revisiting the cross-sectional design. Future studies could take into account the interaction between faculty inventors' interpretations of the incentives determined by IP policies and other institutional variables, including the management style of the technology transfer office. The chief concern with respect to this work would be finding technology transfer outcomes that are not biased towards 'university-ownership'. This measure is sufficiently important to conducting quality work in technology transfer that the development of a 'spin-off' and 'licensing' database would be a worth-while investment.

The qualitative work presented in this thesis can also be extended. One promising avenue for this future work would be to conduct interview studies on research motivation at a wider range of universities, including universities that currently have 'university-owner' policies. This qualitative work is expected to yield many insights into the research question, especially the ways in which faculty inventors' perceptions of incentives are influenced by their universities' IP policies, and technology transfer in general.

Last but not least, this research can be extended by continuing to explore technology transfer in Canada and a variety of other national systems of innovation. This research provided novel insights into technology transfer by extending the research from the United States to Canada. Further work in outside the U.S. is expected to identify those theories that are most robust and the factors that determine whether or not policies and programs that appear effective in one context will be productive in another context. This work is imperative for interpreting academic results such that they can support effective policy making. The need for this type of future research implies a final policy direction: The need for governments to support research into technology transfer at universities and in institutions other than high-profile U.S. universities, and, more broadly, management of technology research in a variety of economies. The importance of institutional factors in this research is an example of the need for local solutions to policy questions, and the need for local solutions will be best met by the development of local research capacity.

Appendix A
Canadian University Intellectual Property Policies as of 1999

The following measures were used to represent each policy:

Right of First Offer: This measure was used to evaluate the control that the policies provide to researchers. When the policies were evaluated, a '1' was recorded if the university reserves the right of first offer and a '0' was recorded if the university does not reserve the right of first offer.

Share of Revenues When University Commercializes Invention: The percentage of net income provided to the researcher, when the university commercializes the innovation, was recorded.

Share of Revenues When Inventor Commercializes Invention: The percentage of net income retained by the researcher, when the researcher commercializes the innovation, was recorded.

There were three circumstances where it is not possible to record a single percentage for the researchers' share of revenues. If the percentage provided to the researcher is not specified in advance but negotiated on a case-by-base basis, the word 'Negotiated' is recorded. If the university does not support technology transfer activities by developing IP, 'Not Applicable' is recorded. If the revenue sharing agreement is structured using thresholds, above which the researcher's share of the revenue changes, 'Threshold' was recorded.

The data for all of the policies included in the study are presented in the following table.

University Name	*University has Right of First Offer*	*Inventor ownership if the University develops the IP*	*Inventor ownership if the Inventor develops the IP*
Acadia	0	Not Applicable	Threshold
Alberta	0	0.333	0.666
Brandon	1	0.5	Not Applicable
British Columbia	1	0.5	Negotiated
Brock	0	0.5	1
Calgary	0	0.5	Negotiated (0.75 to 0.9)
Cape Breton (UCCB)	0	Negotiated	1
Carleton	0	0.5	1
Concordia	0	Not Applicable	0.5
Dalhousie	0	0.5	1

University Name	*University has Right of First Offer*	*Inventor ownership if the University develops the IP*	*Inventor ownership if the Inventor develops the IP*
Guelph	1	Threshold	1
Lakehead	0	0.5	0.75
Laurentian	0	Negotiated	1
Laval	1	Negotiated	1
Manitoba	0	Negotiated	Negotiated
McGill	1	0.65	Threshold
McMaster	1	0.5	0.75
Memorial	1	Threshold	Threshold
Montréal	1	Negotiated	1
Mount Allison	0	Not Applicable	1
Mount Saint Vincent	0	Not Applicable	Negotiated
New Brunswick	0	Not Applicable	0.5
Nipissing	1	0.5	1
Northern British Columbia	1	Negotiated	1
Ottawa	1	Threshold	1
Prince Edward Island	1	0.5	1
Queen's	0	0.4	1
Regina	0	Not Applicable	1
Simon Fraser	0	0.8	1
St. Francis Xavier	0	Not Applicable	0.85
Toronto	0	0.25	0.75
Trent	0	0.5	0.5
Victoria	1	0.5	1
Waterloo	0	Negotiated	1
Western Ontario	0	Threshold	1
Wilfrid Laurier	0	Negotiated	Negotiated

University Name	*University has Right of First Offer*	*Inventor ownership if the University develops the IP*	*Inventor ownership if the Inventor develops the IP*
Winnipeg	0	Negotiated	0.5

The following 11 universities were investigated but policies were not available.

Had no policy by January, 2000:

- Saint Mary's University
- St. Thomas University
- University of Windsor

Policy could not be found (nonrespondent):

- Bishop's University
- Ryerson University
- Université de Moncton
- Université de Québec à Montréal (UQAM)
- University of Lethbridge
- University of Saskatchewan
- University of Sherbrooke
- York University

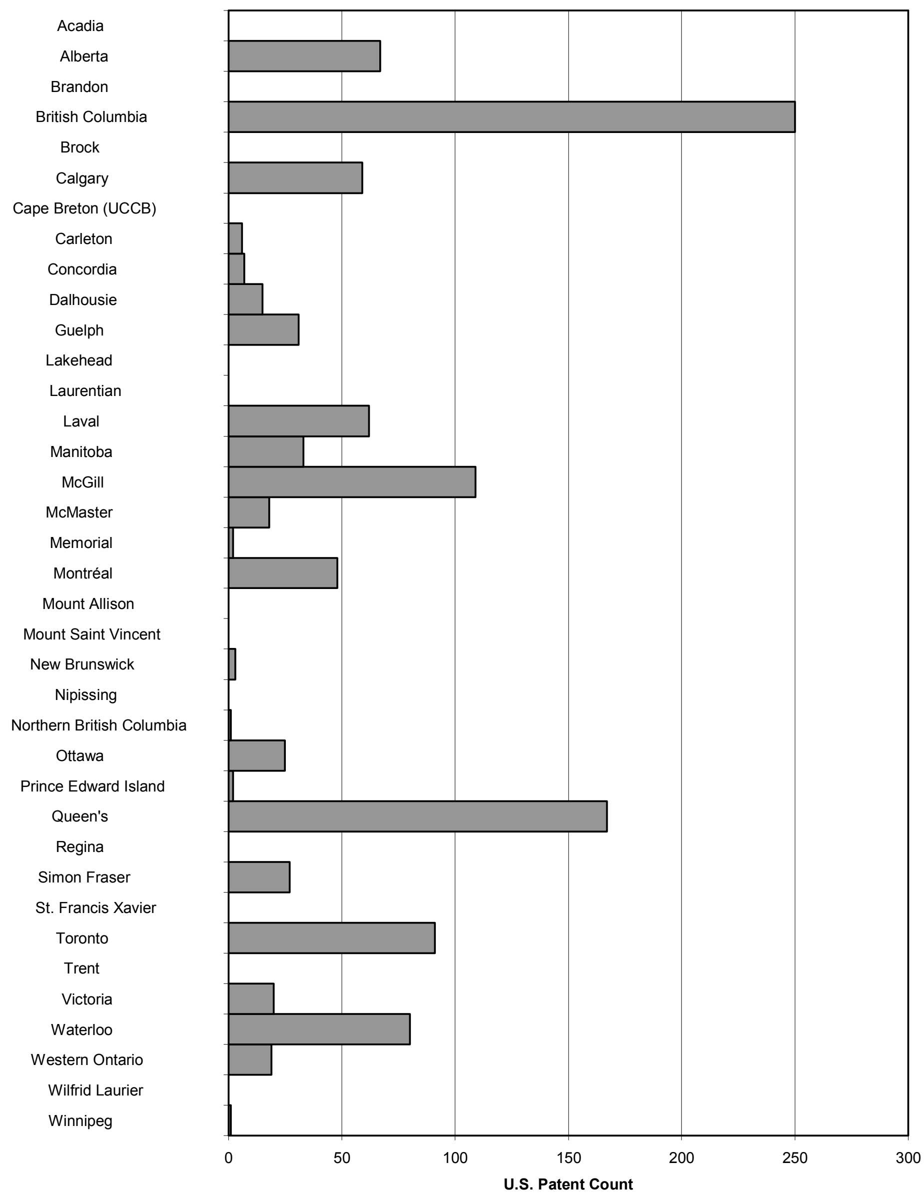
The following eleven universities are not included in the study but are included among "Canada's Top 50 Research Universities," a listing of the 50 Canadian universities that have the highest research expenditures (RE$EARCH Infosource, 2005):

- Nova Scotia Agricultural College
- Royal Military College
- University of Northern British Columbia
- University of Saskatchewan
- 7 members of the Université de Québec:
    - Institute national de la recherché scientifique
    - École de technologie supérieure
    - Université de Québec à Trois-Rivières
    - Université de Québec à Chicoutimi
    - Université de Québec à Rimouski
    - Université de Québec en Abitibi-Témiscamingue
    - Université de Québec en Outaouais

Appendix B

U.S. Patents Held by Canadian Universities as of 1999

The following U.S. patent counts were obtained through university-specific searches of the Delphion Intellectual Property Network online searchable patent database in October and November of 2000. Therefore the patent counts should include at least all of the active patents held by each university by 1999. For each university a search was conducted for all U.S. patents with the university name listed as the assignee.



Appendix C
Detailed Results of Statistical Analyses for Study 2

This appendix contains the details of the statistical analyses of the impact of the policy intervention on the University of Toronto invention disclosure time series. Unless stated otherwise, all of the analysis was conducted using SPSS, version 13.0. The first section describes the regression diagnostics applied to each of the five regression models of the policy intervention. The next five sections describe the five models. The last two sections discuss ARIMA modeling of the intervention and non-parametric tests of the intervention respectively.

Regression Diagnostics

The regression analysis of the five models of the policy intervention includes diagnostic checking of the assumptions underlying regression analysis. After each regression model is used to estimate model parameters, the model must be subject to diagnostic checking, which ensures that the errors, or the differences between the values predicted by the model and the actual values, do not violate any of these assumptions. The key assumptions and methods used in diagnostic checking of these assumptions are outlined in Table 19.

Table 19: Regression Diagnostics

Characteristics Expected of the Residuals	*Diagnostic Checks*
Normal distribution	• Shapiro-Wilk test of normality
Constant variance	• Comparisons of the variance of the residuals before and after the break point
Independence of each other	• Durbin-Watson test for autocorrelation • Visual inspection of scatter plots of the standardized residuals versus the independent variables

Model 1

This model, specified in Equation 1, assumes that the policy intervention had no impact on the number of invention disclosures made per fiscal year.

Estimation of the model parameters yields three important tables of data that summarize the model: Table 20: Coefficients of Determination for Model 1, Table 21: Sum of Squared Errors for Model 1, and Table 22: Parameter Estimates for Model 1.

Equation 1: Regression Equation for Model 1

$Y^{ID}_i = \beta_0 + \beta_1 X^{FY}_i + \varepsilon_i$,

where Y^{ID}_i	=	the number of invention disclosures in Fiscal Year i
β_0	=	an estimate for the number of invention disclosures to expect at the break point of the series (1990/1991)
β_1	=	an estimate for the increase in invention disclosures from one fiscal year to the next
X^{FY}_i	=	the difference between Fiscal Year (FY) i and Fiscal Year 1990/1991 (ex. $X^{FY}_{1985/1986}$= -5)
ε_i	=	residual for fiscal year i

Table 20: Coefficients of Determination for Model 1

R^2	*Adjusted R^2*
0.835	0.829

Table 21: Sum of Squared Errors for Model 1

	Sum of Squares	*df*	*Mean Square*	*F*	*p*
Regression	55831	1	55831	136.8	<.001
Residual	11021	27	4.8		
Total	66853	28			

Table 22: Parameter Estimates for Model 1

Parameter	*Estimate*	*Standard Error*	*t*	*p*
β_0	67.8	3.8	17.9	<.001
β_1	5.2	0.4	11.7	<.001

The coefficient of determination indicates that the model accounts for 83.5% of the variance in the number of invention disclosures reported annually and the adjusted coefficient of determination indicates that the model's fit is still good when the degrees of freedom are taken into consideration. The *F*-test of the model was significant at the 0.01 level which also suggests that the fit of the model is very good indeed. However, the model fit can not be properly interpreted until the diagnostic checking is complete. The regression diagnostics for Model 1 are summarized in Table 23.

Table 23: Regression Diagnostics for Model 1

Characteristics Expected of the Residuals	*Diagnostic Checks*	*Violation*
Normal distribution	• Shapiro-Wilk test of normality indicates that there is strong evidence that the errors are not normal, W=0.91, p=0.017	Yes
Constant variance	• Variance of the residuals before and after the breakpoint (544.1 and 121.2 respectively) differed by less than a factor of 10, therefore heteroscedascity is not a concern (Chatterjee et al., 2000)	No
Independence of each other	• Durbin-Watson test for autocorrelation of the residuals indicated that first-order autocorrelation is present: d=0.581<d_L(2,29,.05)=1.34 (Chatterjee et al., 2000) • The presence of autocorrelation suggests that the relationship between time and the annual counts of invention disclosures is not adequately captured by the model • The scatter plot of standardized residuals versus fiscal year end, in Figure 11, shows a pattern in the residuals across the fiscal years prior to the IP intervention • This pattern suggests that the violations probably stem from having the model fit the first half of the data series less well than the latter half	Yes

Model 1 violates two of the three assumptions. This is unsurprising given that the premise of the analysis is that this baseline model will not fit the data as well as a model that considers the impact of the policy intervention. Typically the main concern when regression models exhibit autocorrelation is the effect on the tests of the significance of the fit of the model and of the significance of the parameters. Autocorrelation tends to result in underestimates of the errors and thus spuriously inflates the tests of significance. Since the model in question is the baseline, against which the models of the policy intervention will be compared, any spurious inflation of the measures of the model's fit will result in a more conservative test of the impact of the policy intervention provided that the other models do not exhibit more violations or more extreme violations of the key assumptions. Therefore, the baseline model will be used as a point of comparison of the fit of each model of the impact of the policy intervention and the extent to which these models do or do not violate the assumptions underlying regression analysis.

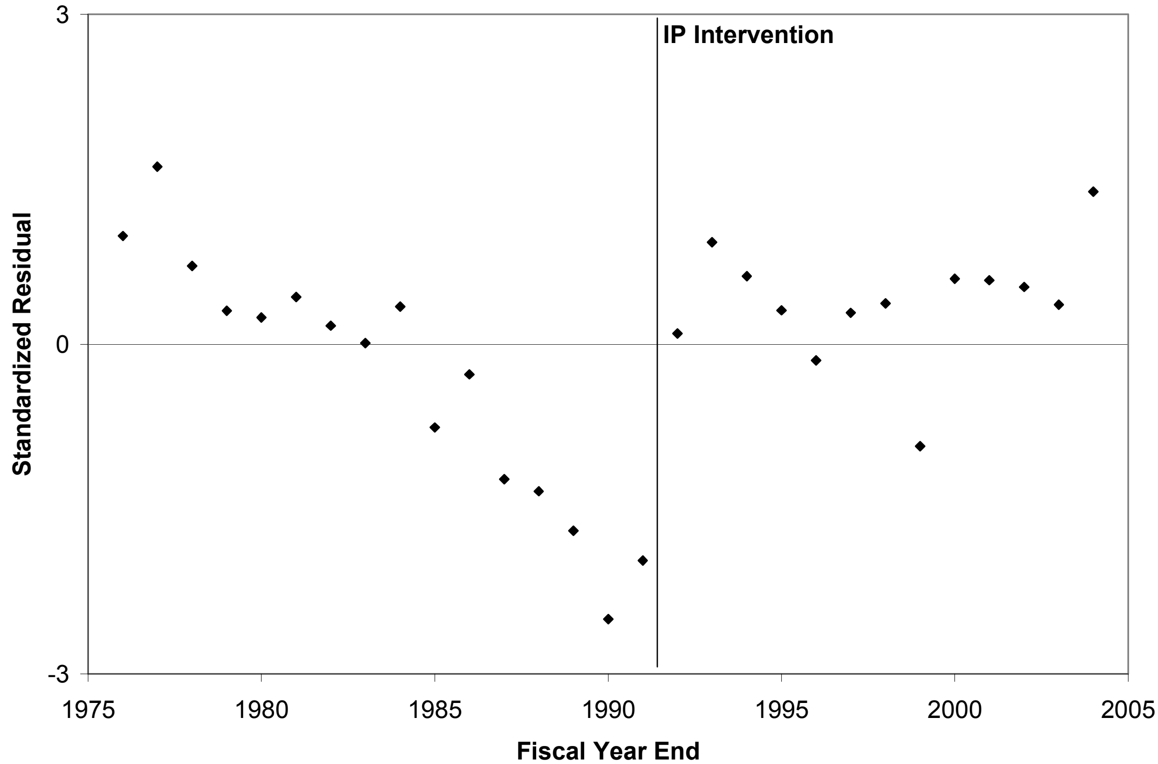


Figure 11: Scatter Plot of Standardized Residuals for Model 1 versus Fiscal Year End

Model 2

This model, specified in Equation 2, assumes that the policy intervention had an immediate impact on the number of invention disclosures made per fiscal year but it did not affect the rate at which the number of invention disclosures changed from year to year. Estimation of the model parameters yields three important tables of data that summarize the model: Table 24: Coefficients of Determination for Model 2, Table 25: Sum of Squared Errors for Model 2, and Table 26: Parameter Estimates for Model 2.

Equation 2: Regression Equation for Model 2

$Y^{ID}_i = \beta_0 + \beta_1 X^{FY}_i + \beta_2 X^{IP}_i + \varepsilon_i,$

where Y^{ID}_i	=	the number of invention disclosures (ID) in Fiscal Year i
β_0	=	an estimate for the number of invention disclosures immediately before the break point of the series (1990/1991)
β_1	=	an estimate for the increase in invention disclosures from one fiscal year to the next
X^{FY}_i	=	the difference between Fiscal Year (FY) i and Fiscal Year 1990/1991
β_2	=	an estimate for the change in the number of invention disclosures over the break point of the series
X^{IP}_i	=	0, when i ≤ 1990/1991
	=	1, when i > 1990/1991
ε_i	=	residual for fiscal year i

Table 24: Coefficients of Determination for Model 2

R^2	*Adjusted R^2*
0.917	0.911

Table 25: Sum of Squared Errors for Model 2

	Sum of Squares	*df*	*Mean Square*	*F*	*p*
Regression	61298.5	2	30649.2	143.5	<.001
Residual	5554.7	26	213.6		
Total	66853.2	28			

Table 26: Parameter Estimates for Model 2

Parameter	*Estimate*	*Standard Error*	*t*	*p*
β_0	40.6	6.0	6.73	<.001
β_1	2.5	0.6	3.84	.001
β_2	54.4	10.8	5.06	<.001

The coefficient of determination, given in Table 24, indicates that the model accounts for 91.7% of the variance in the number of invention disclosures reported annually. The adjusted coefficients of determination indicates that the second model's fit is still better than Model 1 when the degrees of freedom are taken into consideration (R^2=0.911, R^2=0.829 for models 1 and 2 respectively). The F-test of the model was significant at the 0.01 level which also suggests that the fit of the model is very good indeed. However, the model fit can not be properly interpreted until the diagnostic checking is complete. The regression diagnostics for Model 2 are summarized in Table 27.

Table 27: Regression Diagnostics for Model 2

Characteristics Expected of the Residuals	*Diagnostic Checks*	*Violation*
Normal distribution	• Shapiro-Wilk test of normality provided no evidence that the errors are not normal, W = 0.81, p = .979	No
Constant variance	• Variance of the residuals before and after the breakpoint (136.8 and 291.9 respectively) differed by less than a factor of 10, therefore heteroscedascity is not a concern (Chatterjee et al., 2000)	No
Independence of each other	• Durbin-Watson test for autocorrelation indicated that first-order autocorrelation is present: d=0.861< d_L(2,29,.05)=1.27 (Chatterjee et al., 2000) • The presence of autocorrelation suggests that the relationship between time and the annual counts of invention disclosures has not been adequately captured by the model • In the scatter plot of standardized residuals versus fiscal year end, shown in Figure 12, the residuals display a decreasing trend before the breakpoint and an increasing trend after the breakpoint • This pattern suggests that the slope before the break point is too high and the slope after the break point is too low	Yes

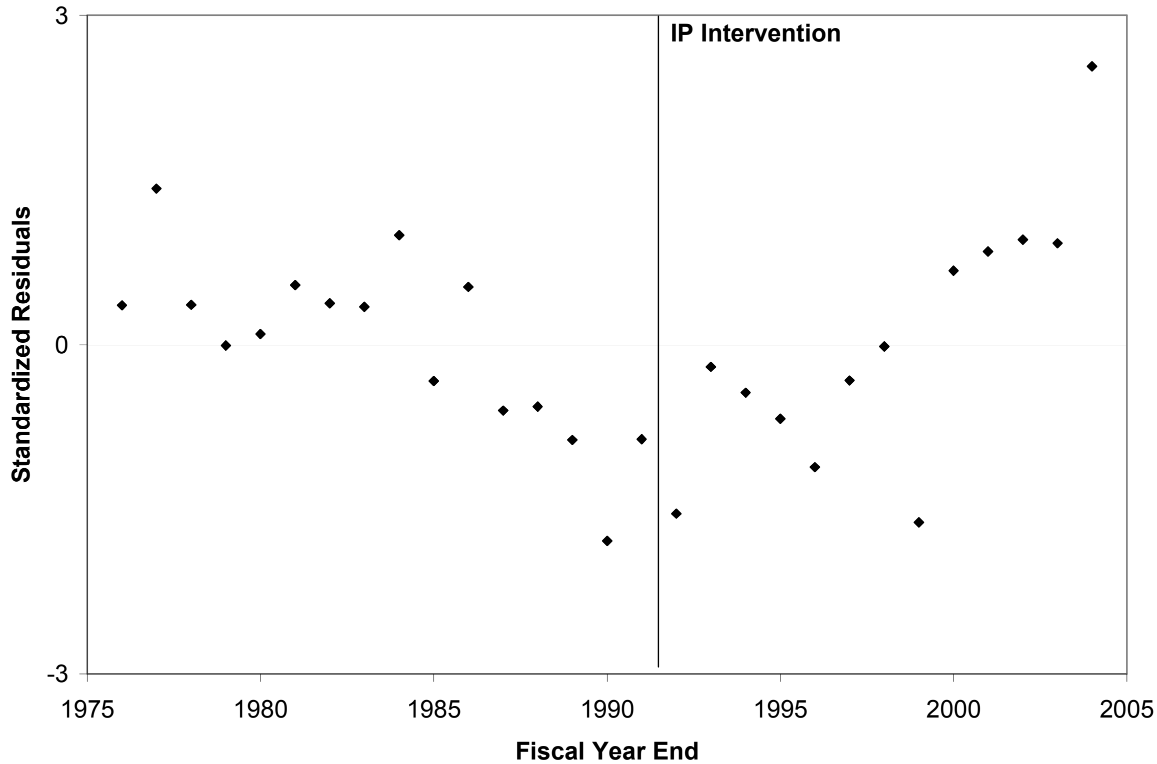


Figure 12: Scatter Plot of Standardized Residuals for Model 2 versus Fiscal Year End

The second model has only one violation, compared to the two violations observed with the first model. Therefore, comparing the two models on the basis of fit is a reasonable next step. The increase in the adjusted squared multiple correlation terms from the first model (R^2=0.829) to the second model (R^2=0.911) suggests that the second model has more explanatory power than the first model, even taking into account the larger number of parameters in the second model. Since Model 1 can be obtained as a special case of Model 2, an *F*-test can be used to determine if the increase in explanatory power is significant (Chatterjee et al., 2000). Chatterjee refers to the model with fewer parameters as the Reduced Model (RM) and the other model as the Full Model (FM), and summarizes the test's hypotheses as, "H_0: Reduced Model is adequate", "H_1: Full Model is adequate" (Chatterjee et al., 2000, p. 63). The *F*-statistic is calculated using Equation 3.

Equation 3: *F*-test for Comparison of Models

$$F = \frac{\dfrac{[SSE(\text{RM}) - SSE(\text{FM})]}{p-k}}{\dfrac{SSE(\text{FM})}{n-p}},$$

where SSE(RM)	=	the Reduced Model's Sum of the Squared Errors
SSE(FM)	=	the Full Model's Sum of the Squared Errors
p	=	the number of parameters in the Full Model
k	=	the number of parameters in the Reduced Model
n	=	the number of observations
F	=	a ratio that has an F-distribution with (p-k, n-p, α) degrees of freedom, where α is the significance level of the test

The *F*-test is significant at the .05 level, F= 25.6 > F(1, 27,.05) = 4.21 (Hill & Lewicki, 2005). Therefore, Model 2 fits the time series significantly better than Model 1.

Model 3

This model, specified in Equation 4, assumes that the policy intervention did not have an immediate impact on the number of invention disclosures per year but it did have an impact on the rate at which the number of invention disclosures changed from year to year. Estimation of the model parameters yields three important tables of data that summarize the model: Table 28: Coefficients of Determination for Model 3, Table 29: Sum of Squared Errors for Model 3, and Table 30: Parameter Estimates for Model 3.

The coefficient of determination, given in Table 28, indicates that the model accounts for 91.5% of the variance in the number of invention disclosures reported annually The adjusted coefficients of determination indicates that the third model's fit is still better than Model 1 when the degrees of freedom are taken into consideration (R^2=0.829, R^2=0.908 for models 1 and 2 respectively). The *F*-test of the model was significant at the 0.01 level which also suggests that the fit of the model is very good. However, the model fit can not be properly interpreted until the diagnostic checking is complete. The regression diagnostics for Model 3 are summarized in

Table 31.

Equation 4: Regression Equation for Model 3

$Y^{ID}_i = \beta_0 + \beta_1 X^{FY}_i + \beta_2(X^{FY}_i * X^{IP}_i) + \varepsilon_i,$

where Y^{ID}_i	=	the number of invention disclosures (ID) in Fiscal Year i
β_0	=	an estimate for the number of invention disclosures to expect at the break point of the series (1990/1991)
β_1	=	an estimate for the increase in invention disclosures from one fiscal year to the next
X^{FY}_i	=	the difference between Fiscal Year (FY) i and Fiscal Year 1990/1991
β_2	=	an estimate for the change, at the break point, in the rate of change in invention disclosures from year to year
X^{IP}_i	=	0, when $i \leq 1990/1991$
	=	1, when $i > 1990/1991$
ε_i	=	residual for fiscal year i

Table 28: Coefficients of Determination for Model 3

R^2	*Adjusted R^2*
0.915	0.908

Table 29: Sum of Squared Errors for Model 3

	Sum of Squares	*df*	*Mean Square*	*F*	*P*
Regression	61141	2	30570	139.2	<.001
Residual	5711	26	220		
Total	66853	28			

Table 30: Parameter Estimates for Model 3

Parameter	*Estimate*	*Standard Error*	*t*	*p*
β_0	44.5	5.50	8.09	<.001
β_1	2.33	0.68	3.43	.002
β_2	6.51	1.32	4.92	<.001

Table 31: Regression Diagnostics for Model 3

Characteristics Expected of the Residuals	*Diagnostic Checks*	*Violation*
Normal distribution	• Shapiro-Wilk test of normality provided no evidence that the errors are not normal (W=0.98, p =.874)	No
Constant variance	• Variance of the residuals before and after the breakpoint (126.6 and 248.6 respectively) differed by less than a factor of 10, therefore heteroscedascity is not a concern (Chatterjee et al., 2000)	No
Independence of each other	• Durbin-Watson test for autocorrelation indicated that first-order autocorrelation is present: d=1.05 < d_L(2,29,.05)=1.27 (Chatterjee et al., 2000) • The presence of autocorrelation suggests that the relationship between time and the annual counts of invention disclosures has not been adequately captured by the model • There is a downward trend in the second part of the scatter plot of standardized residuals versus fiscal year end, shown in Figure 13 • This pattern suggests that the model fits the second half of the data series less well than the first half	Yes

The third model has only one violation, compared to the two violations observed with the first model. Therefore, comparing the two models on the basis of fit is a reasonable next step. The *F*-test is significant at the .05 level, $F = 24.2 > F(1, 27, .05) = 4.21$. Therefore, Model 3 fits the time series significantly better than Model 1.

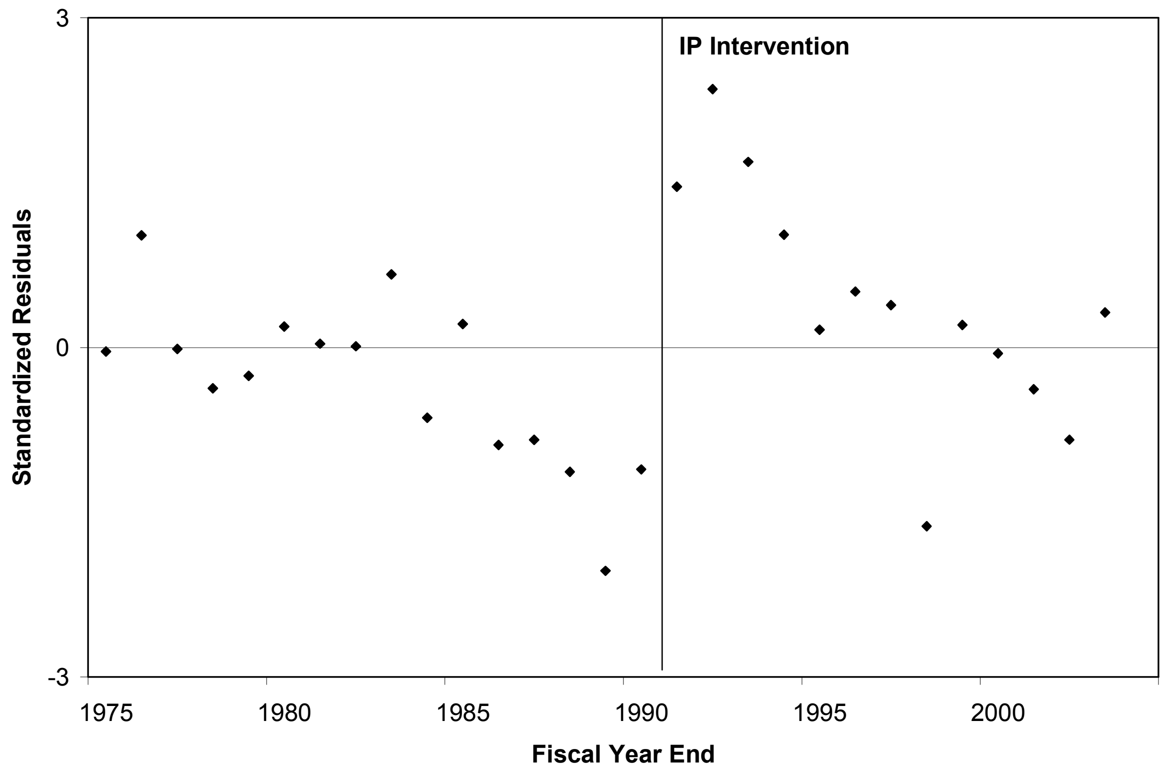


Figure 13: Scatter Plot of Standardized Residuals for Model 3 versus Fiscal Year End

Model 4

This model, specified in Equation 5, assumes that the policy intervention had both an immediate impact on the number of invention disclosures per year and an impact on the rate at which the number of invention disclosures changed from year to year.

The coefficient of determination indicates that the fourth model accounts for 96.6% of the variance in the number of invention disclosures reported annually. Comparing adjusted coefficients of determination shows that Model 4's fit (R^2=0.961) is better than Model 1's fit (R^2=0.829), even when the model's different degrees of freedom are taken into consideration. The *F*-test of the model and the *t*-tests of all of the parameters were significant at the 0.01 level which also suggests that the fit of the model is very good. However, diagnostic checking must be completed to verify the fit of the model. The regression diagnostics for Model 4 are summarized in Table 35.

Equation 5: Regression Equation for Model 4

$$Y^{ID}_i = \beta_0 + \beta_1 X^{IP}_i + \beta_2((1-X^{IP}_i)*X^{FY}_i) + \beta_3(X^{IP}_i*X^{FY}_i) + \varepsilon_i,$$

where Y^{ID}_i	=	the number of invention disclosures (ID) in Fiscal Year i
β_0	=	an estimate for the number of invention disclosures per year immediately before the break point (1990/1991)
β_1	=	an estimate for the change in the number of invention disclosures per year over the break point
X^{FY}_i	=	the difference between Fiscal Year (FY) i and Fiscal Year 1990/1991
β_2	=	an estimate for the increase in invention disclosures from one fiscal year to the next prior to the break point
X^{IP}_i	=	0, when i ≤ 1990/1991
	=	1, when i > 1990/1991
β_3	=	an estimate for the increase in invention disclosures from one fiscal year to the next after the break point
ε_i	=	residual for fiscal year i

Table 32: Coefficients of Determination for Model 4

R^2	*Adjusted R^2*
0.966	0.961

Table 33: Sum of Squared Errors for Model 4

	Sum of Squares	*df*	*Mean Square*	*F*	*P*
Regression	64554	3	21518	233.9	<.001
Residual	2300	25	92		
Total	66853	28			

Table 34: Parameter Estimates for Model 4

Parameter	*Estimate*	*Standard Error*	*t*	*p*
β_0	26.9	4.6	5.9	<.001
β_1	44.3	7.3	6.1	<.001
β_2	0.6	0.5	1.2	.239
β_3	5.9	0.7	8.3	<.001

Table 35: Regression Diagnostics for Model 4

Characteristics Expected of the Residuals	*Diagnostic Checks*	*Violation*
Normal distribution	• Shapiro-Wilk test of normality provided no evidence that the errors are not normal (W=0.95, p =.138)	No
Constant variance	• Variance of the residuals before and after the breakpoint (61.1 and 115.3 respectively) differed by less than a factor of 10, therefore heteroscedascity is not a concern (Chatterjee et al., 2000)	No
Independence of each other	• Durbin-Watson test for autocorrelation provided no evidence that first-order autocorrelation is present: d=1.92>d_U(3,29,.05)=1.65 (Chatterjee et al., 2000) • The scatter plot, Figure 14, does not appear to have any obvious trends • The absence of autocorrelation suggests that this is the first model that has adequately captured the trends in the time series of invention disclosures	No

The fourth model has no violations, compared to the two violations observed with the first model. Therefore, comparing the two models on the basis of fit is a reasonable next step. The F-test is significant at the .05 level, F= 47.4 > F(3,25,.05) = 2.99 (Hill & Lewicki, 2005). Therefore, Model 4 explains for the time series significantly better than Model 1.

The only indication that the model does not appropriately model the data is given in

Table 34. The increase in the number of invention disclosures from year to year prior to the break point (β_2) is not significant at the .05 level (p=.239). Therefore, the next model will omit this term.

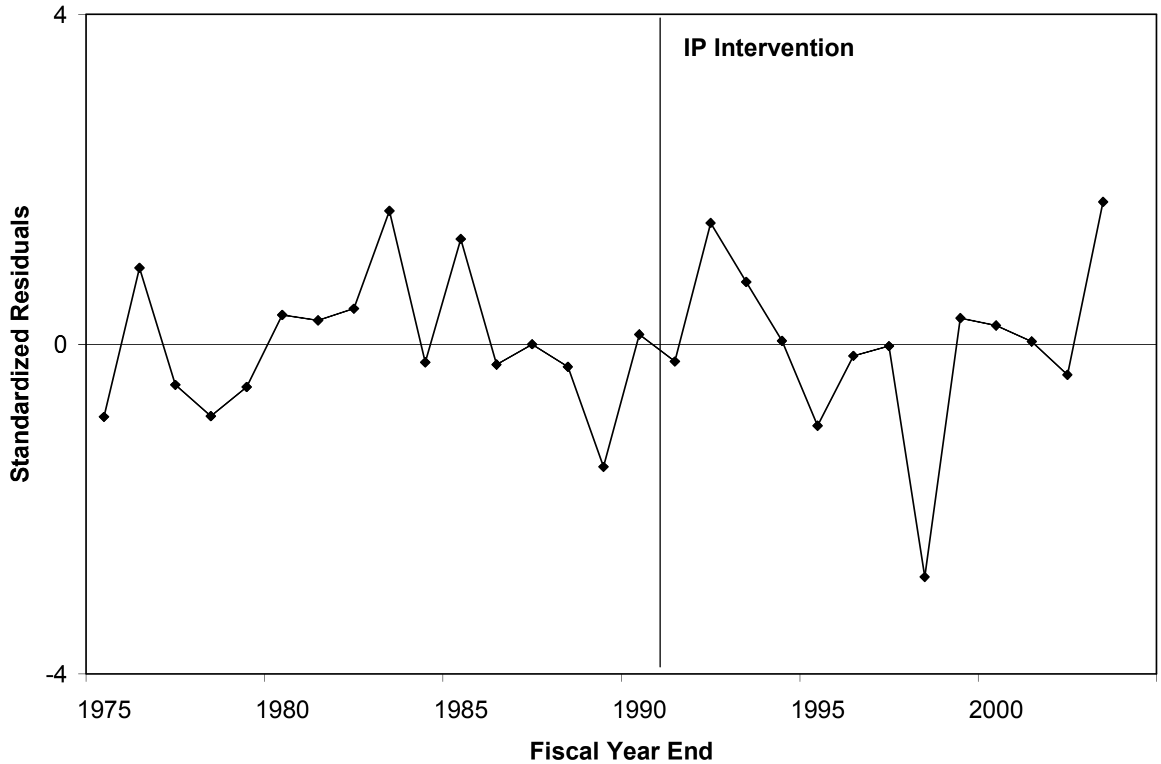


Figure 14: Scatter Plot of Standardized Residuals for Model 4 versus Fiscal Year End

Model 5

This model, specified in Equation 6, assumes that the policy intervention had both an immediate impact on the number of invention disclosures per year and an impact on the rate at which the number of invention disclosures changed from year to year. Furthermore, this model assumes that there was no change in the number of invention disclosures from year to year prior to the policy intervention. Estimation of the model parameters yields three important tables of data that summarize the model: Table 36: Coefficients of Determination, Table 37: Sum of Squared Errors for Model 5, Table 38: Parameter Estimates for Model 5.

The coefficient of determination, given in Table 36, indicates that the model accounts for 96.4% of the variance in the number of invention disclosures reported annually The adjusted coefficients of determination indicates that the fifth model's fit is still better than Model 1 when the degrees of freedom are taken into consideration (R^2=0.829, R^2=0.961 for models 1 and 2 respectively). The F-test of the model and the t-tests of all of the parameters were significant at the 0.01 level which also suggests that the fit of the model is very good. However, the model fit can not be properly interpreted until the diagnostic checking is complete. The regression diagnostics for Model 5 are summarized in Table 39.

Equation 6: Regression Equation for Model 5

$$Y^{ID}_i = \beta_0 + \beta_1 X^{IP}_i + \beta_2 (X^{IP}_i * X^{FY}_i) + \varepsilon_i,$$

where Y^{ID}_i	=	the number of invention disclosures (ID) in Fiscal Year i
β_0	=	an estimate for the number of invention disclosures per year before the break point (1990/1991)
β_1	=	an estimate for the change in the number of invention disclosures per year over the break point
X^{IP}_i	=	0, when i ≤ 1990/1991
	=	1, when i > 1990/1991
β_2	=	an estimate for the increase in invention disclosures from one fiscal year to the next after the break point
X^{FY}_i	=	the difference between Fiscal Year (FY) i and Fiscal Year 1990/1991
ε_i	=	residual for fiscal year i

Table 36: Coefficients of Determination

R^2	*Adjusted R^2*
0.964	0.961

Table 37: Sum of Squared Errors for Model 5

	Sum of Squares	*df*	*Mean Square*	*F*	*p*
Regression	64420	2	32210	344.1	<.001
Residual	2434	26	94		
Total	66853	28			

Table 38: Parameter Estimates for Model 5

Parameter	*Estimate*	*Standard Error*	*t*	*p*
β_0	22.2	2.4	9.17	<.001
β_1	49.0	6.2	7.92	<.001
β_2	5.9	0.7	8.18	<.001

Table 39: Regression Diagnostics for Model 5

Characteristics Expected of the Residuals	*Diagnostic Checks*	*Violation*
Normal distribution	• Shapiro-Wilk test of normality provided no evidence that the errors are not normal (W=0.95, p =.138)	No
Constant variance	• Variance of the residuals before and after the breakpoint (70.0 and 115.3 respectively) differed by a lot less than a factor of 10, therefore heteroscedascity is definitely not a concern (Chatterjee et al., 2000)	No
Independence of each other	• Durbin-Watson test for autocorrelation indicated that first-order autocorrelation is not present: d=1.84 < d_U(2,29,.05)=1.56 (Chatterjee et al., 2000) • The scatter plot, Figure 15, does not appear to have any trends • The absence of autocorrelation suggests that this model that has adequately captured the trends in the time series of invention disclosures	No

The fifth model has no violations, compared to the two violations observed with the first model. This means that Model 5 can be compared against Model 1. The F-test is significant at the .05 level, F= 91.8 > F(2,26,.01) = 5.53 (Hill & Lewicki, 2005). This is strong evidence that Model 5 fits the time series significantly better than Model 1, which supports the hypothesis that the policy intervention had an effect on the number of invention disclosures reported annually.

The absence of any violations of the assumptions underlying regression analysis also means that the tests of significance of Model 5 and its parameters are valid. These tests were all significant at the .01 level, as shown in Table 37 and Table 38, which is strong evidence that the model fits the data very well. Therefore, the parameter estimates for this model are meaningful. These parameter estimates indicate that prior to the policy intervention there were 22.2 ± 4.7 inventions disclosed per year. Immediately after the intervention, the number of disclosures increased by 49.0 ± 12.2 and continued increasing from year to year by 5.9 ± 1.4 disclosures per year. There is no question that these effects are substantial when compared to the pre-intervention disclosure rates. Therefore, the policy intervention had a significant and substantial effect.

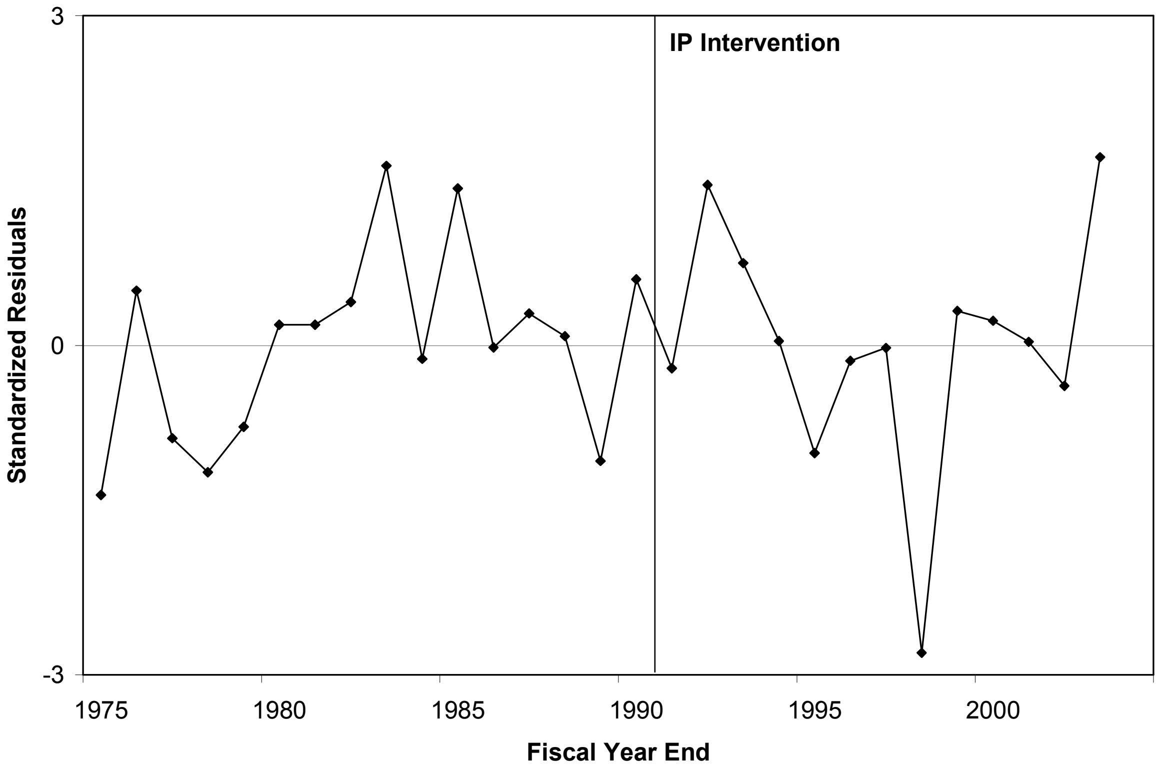


Figure 15: Scatter Plot of Standardized Residuals for Model 5 versus Fiscal Year End

Reviewing the Need for Transformations of the Data

In the Exploratory Analysis, the data were visually inspected and it was determined that transformations of the data were unnecessary. This section reviews that decision by assessing whether or not a Box-Cox transformation would have yielded substantially better fit.

The Box-Cox transformation for a positively-valued time series is given in Equation 7. Note that the transformation has no effect on the series when $\lambda = 1$. To assess the impact that a Box-Cox transformation would have on Model 5's fit, the Root Mean Squared Error (RMSE) was calculated for values of λ ranging from -3 to 3 using SPSS syntax made available by York University (2005). As shown in Figure 16: Box-Cox Transformation Results, the RMSE is minimized at 8.95 when $\lambda = 0.80$. This minimum is only 2% smaller than the RMSE generated by fitting the untransformed values (9.16). Therefore, the Box-Cox transformation does not create sufficient advantage to be worthwhile in this case.

Equation 7: Box-Cox Transformation (Hipel & McLeod, 1994, p.951)

$$Y_i^{(\lambda)} = \begin{cases} \dfrac{Y_i^{\lambda}}{\lambda}, \lambda \neq 0 \\ \ln(Y_i), \lambda = 0 \end{cases}$$

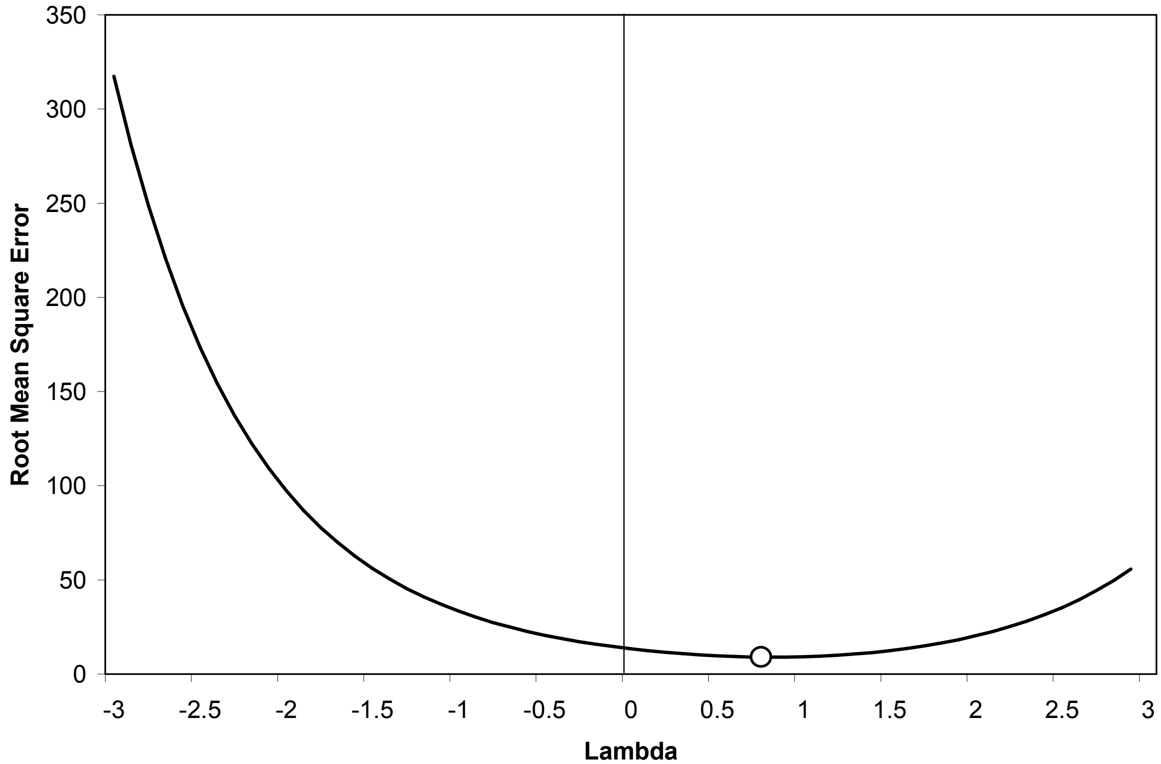


Figure 16: Box-Cox Transformation Results

ARIMA Modeling

ARIMA models were not the first choice when investigating the interrupted time series because the use of an ARIMA model typically requires at least 50 observations and the time series of interest contains only 29 observations (Montgomery & Johnson, 1976). To verify that ARIMA models could not be usefully applied to the time series, SPSS DecisionTime, version 1.1, was used to investigate the time series. This program allows the user to specify interventions and then it will automatically search out the most significant ARIMA model. This tool was used to quickly assess whether or not ARIMA modeling of the intervention would be fruitful. Testing of the simple intervention model showed that significant ARIMA models of the intervention are not achievable.

Non-Parametric Tests for Trend Detection

Non-parametric tests, or tests that do not assume that the data of interest have a specific distribution, can be used to test for the existence of trends within the data. In this case, the Mann-Kendall trend test for non-seasonal data was used to confirm the existence of a significant change in slope when the policy intervention went into effect. This test, specified by Equation 8, determines whether or not a time series has a statistically significant monotonically increasing or monotonically decreasing trend. The test was coded in SPSS syntax because it is not available as part of the standard functions for version 13.0. The syntax is included in Appendix C. The test was applied to separately to the time series before and after the policy intervention. The series before the policy intervention has a positive trend but it is not significant at the .05 level (S=31, p=.0876). The series after the policy intervention was found to have a positive trend that was significant at the .05 level (S=55, p=.0004). This confirms the significance of the change in level immediately after the policy intervention.

Equation 8: Mann-Kendall Test Statistic (Hipel & McLeod, 1994, p. 864)

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_j - x_k\right), \qquad \text{where} \qquad \operatorname{sgn}(x) = \begin{cases} +1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}$$

Appendix D

SPSS Syntax for Mann-Kendall Trend Test

The Mann-Kendall Trend Test is a non-parametric test that detects the presence of monotonically increasing or decreasing trends in time series data. It was used the in assessment of the time series of annual invention disclosures at the University of Toronto. Since the Mann-Kendall Trend Test isn't included as a function in the basic installation of SPSS, version 13.0 for Windows, the following script was written in order to implement the test.

```
* Mann-Kendall Trend Test
* Make sure data of interest is in first column, ant that there is no other data in the file

SET MXLOOP =9999.

MATRIX.
GET W/VARIABLES = all/FILE=*/missing=omit.

COMPUTE IND=0.
COMPUTE N =NROW(W).
PRINT N.
COMPUTE SZ=(N*(N-1))/2.
COMPUTE SGN=MAKE(SZ,1,0).
COMPUTE S=0.

LOOP K = 1 TO N-1.
    LOOP J  = K+1 TO N.
        COMPUTE IND=IND+1.
        COMPUTE F=W(J,1)-W(K,1).
        COMPUTE SGN(IND,1)=0.

        DO IF F>0.
            COMPUTE SGN(IND,1) = 1.
        ELSE IF F<0.
            COMPUTE SGN(IND,1) = -1.
        END IF.
    END LOOP.
END LOOP.

LOOP L = 1 TO SZ.
    COMPUTE S=S+SGN(L,1).
END LOOP.

COMPUTE VAR_S=(N*(N-1)*((2*N)+5))/18.
PRINT S.
PRINT VAR_S.

COMPUTE Z=S/SQRT(VAR_S).
PRINT Z.

END MATRIX.

* End of script for Mann-Kendall Trend Test
```

Appendix E
Vignettes from Study 3: Qualitative Investigation of Faculty Inventors' Experiences

This appendix contains vignettes from interviews in Study 3, the qualitative investigation of faculty inventors' experiences. The participants had been University of Waterloo faculty members prior to the interviews or were senior University of Waterloo faculty members at the time of the interviews and all of the participants had had experience with university-industry interactions. In order to broadly investigate the faculty inventor's experiences, participants were selected who had engaged in patenting and licensing, spin-off company creation, doing contract work for industry, and who had moved back and forth between industry and academe. Some of these activities were successful from the participant's perspective and some were not. The vignettes were constructed to convey a rich picture of these individual perspectives on these experiences and related issues.

The vignettes are organized thematically using the following five over-arching themes: 1) university-industry activities; 2) university environment; 3) rewards and reward systems; 4) attitudes; and, 5) career decisions.

Theme 1: University-Industry Activities

This theme explores attributes of the technology transfer activities and other university-industry interactions in which the participants were involved. This top-level theme is further divided into six themes: 1) opportunity recognition & catalysts for technology transfer; 2) participants' roles in technology transfer activities & relationships with spin-off firms; 3) time demands; 4) learning and identification of mistakes; 5) success factors; and, 6) outcomes.

Opportunity Recognition & Catalysts for Technology Transfer

There was a lot of technology that I ended up developing: in research papers and also in the filing cabinet. I saw that there was a lot of technology and I started thinking, 'What happens now? How do I get it into practice.' I offered it to companies but they did a marketing study and the volume of the business was too small. So then I ended up considering, 'What do I do with this?' I met a guy with a technology transfer support organization and I told him that I had tried to transfer this technology and the companies were not interested. He said, 'Look, I could find you some venture capitalists' and he did.

[I knew there was a market for the technology because] being a technical person, I go to conferences, I go to trade shows and so on. I see which direction the technology is going and which direction the markets are going. But the answer to your question is I didn't know. My gut instinct was telling me that it would be important to this industry because then they can have a faster manufacturing line. That doesn't take an Einstein to figure out.

Some people in the research group decided that they had enough of working within the university. They wanted to go out and try new things; they were all going to go out and get big jobs. We recognized that these people were very bright and they had a bit of an entrepreneurial bent to them, so we suggested we would finance a company, set them up in business. We passed around a hat and that's exactly what happened. Nothing actually left the university in terms of intellectual property. The company went off and developed the technology independently of us, except, obviously they had all this knowledge. Also, they had the knowledge in our group that that they could tap into. It was a cooperative venture; we did some things, they did some things. The groups gradually diverged but we were still working together on various projects.

I never planned any of it. I mean it happened to me, in the sense that I worked with really interesting people. I worked with one colleague in particular and he had these ideas, which were pretty exciting at the time. I don't claim that I did anything in one sense; what I did was follow these other guys. What they were doing was exciting and my talents helped them a little bit so it went well.

With one of the major issues in my research area, we all know that it causes many problems but how you treat that in an applied science sense is not always so clear. There're all kinds of specific research problems and issues that arise out of it and you have to determine which ones you're going to attack, which ones should be the highest priority. One of the things we did a lot of in those days, we had a good set of contacts, some relatively formal groups and some more informal, with whom we would thrash out this problem. We would try to come to a resolution by saying, 'Okay, this is by far the highest priority. We'll work on that problem, provided we can find someone to support us, provided we can find good graduate students, and undergraduates to work on it.' We had a large number of projects right from the early days on through to now. I think one of the key issues here is, not only, being able to identify those problems, prioritize them, having a plan of attack for them, but also having some kind of a perception of what the problems will be in the future. As a researcher, you want to be on the front end of the wave, not the back end of the wave. And, in our field, economics of what we do are critical to developing the technologies.

The catalyst for the start-up was a business person familiar with the industry. He approached our research group and said 'Why don't we start up a company?' We very naively said 'Okay, let's go ahead and form a company.' We went out and tried to get contracts. Like many start-up companies, you have a business plan, a potential set of clients and we did marketing. In fact we got our first contract, when I met an old buddy who I'd worked with years and years ago, a chance encounter and he said, 'Well, what are you guys doing here?' and we said 'We started up a new business, we're trying to get some work.' And he said 'I've got a project. I need some design work done.' So we said 'okay' and that was our first contract. It wasn't big, and it was a happenstance thing. So sometimes in marketing you can have a very deliberate marketing program, but launched our small company. We kept getting contracts, a number of small contracts and then larger contracts.

After struggling for the first five years, we wanted to think it was time to quit. That missionary period: having to go through that, still not seeing the real developments until that period was over. It's the length of the thing that's frustrating. Trying to get the financing is very difficult and things don't always, not necessarily financially, but other things don't progress as you expect them to. It gets very frustrating at times and you just have to see it through. You have to make sure that there's, well I don't know how you do this, but you hopefully have some sort of light at the end of the tunnel. What got us through was faith in the product, faith in what we were doing. We knew, having looked at the market, that there was a need.

We decided that the project was too important not to get involved in. We didn't know whether there would be any interesting research in it but we were pretty sure we could contribute to it whether it was just a straight development effort or what. As we started working on the problem, we found that it wasn't merely an application of existing technologies; it really needed new technology to be developed. During the project, as we were developing new ideas and implementing new ideas, we were also exposed, through conferences and through visitors, to people who wanted to use the technology.

The tools we had developed seemed like the basis of a company or of a business plan. And so a few colleagues and technical staff members and I together decided that we would form such a company. We talked to the other people who were involved in the project and everybody agreed that this would be a good thing but only a few of us became the principals; putting together the company with only private investment. The investors were all people who were involved in the project. The idea was that the company could be the commercial outlet for these tools. We didn't want to just to be a distributor of technology developed in the university, so the idea right away when we set up the company was that it was going to have its own development staff as well. It would start with our tools but it would develop them further as they needed more tools, do what ever they wanted. So they were going to have their full-time development staff, not necessarily research. We would continue to do research and the idea was that we would complement each other. Research that was done in the university could be transferred to the company; improvements that the company made would come back to the university so the research group would deal with the most recent versions, to go forward. That was the principle, with which the company was formed

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I had a student take on an applied project and found that the theory needed to be advanced to solve the problem. The thesis was a very successful thesis. And the problem then was to get it published. I wasn't thinking of anything commercial yet. I was in my normal mode, get the student through the thesis and crack the whip and get something published. But where do you get something published like that? The application-area journals rejected every paper because they didn't understand it. We finally got it published in one journal. I don't know what kind of review it got. I don't think there was anybody who could review it very well. At that point in time we decided, I guess because of the fact that the solution worked, that it might be worth patenting.

Participants' Roles in Technology Transfer Activities & Relationships with Spin-Off Firms

When we set up the one spin-off, I was a faculty member. I'm allowed one day of consulting a week. Ok. How do I use that? Well, I use my consulting by helping to run the spin-off. For instance, we ran courses for them. We were teaching the users. We would run those courses; all of us would contribute and give lectures. I used to visit a major user site once a month and talk about this stuff to a class of people. That was my contribution. I didn't get paid for it, except travel expenses. In the other spin-off, I spent time developing new ideas, new ways of doing things with their technologies. I wasn't the only one; I'm just giving you an example of how different people contributed. Everybody chipped in, in various ways. Some people got paid, some people didn't. For example, I had a full-time job at the university and so I was very well paid there. Other people, their full time job was at the spin-off and they got paid there, so they might get paid to give a lecture. The idea was we were building something that was a legacy for all of us.

I served as a tie to the university, as a technical representative. After several years, the company was really on its own in the business sense. It had a lot of internal technical expertise. There was a lot of interest in ties with other corporations and it didn't need its close ties with the University of Waterloo, in the same way. It went off on its own. Over the years, I have been an occasional consultant to the spin-off and I've got a very good relationship with lead technical staff at the spin-off. In fact we have just now started a new contract funded by government to do some research where the spin-off is the corporate partner. We've maintained a good relationship.

My personal view on how the company grows and my relationship to it [as a founder who remained in the university]? I never felt proprietary ownership of the company. I never felt that I needed to be in control of the company, which I think was healthy for me. I view the company's growth a lot like raising a child: starting very small and nurturing it, playing an advisory role with it as it gets a little older, being cut off completely for a couple of years because the company thinks it can do a lot better without you, and then slowly recognizing where you can contribute and you come back in to play and the relationship gets re-established on good terms. And that's sort of very much the way that my work with the company has worked. And it's been fine with me. I mean I think that if I wasn't going to give up my university position then the company's not going succeed if it's going to depend on the university to sustain it or to depend on me to sustain it. Furthermore, the company should choose its partners based on what's good for the company. So when the company feels that the university has something to offer it should work the company and when the company feels the university has nothing to offer or a different university has something better to offer, or something. If it's going to grow it should feel free to do those things. I was happy to let it. Other entrepreneurs that I know are much less willing to give up what they started.

[My role was] giving guidance and advice, and high-level marketing in the sense of making presentations with large-scale proposals or projects. Because of my involvement in research and professional practice issues, I had a higher profile than the university members who left to join the university had, so I made presentations, I gave seminars. I did really long-range marketing, plus technical guidance too, because I have a large role in the development of much of the technology that the company markets.

Any organization, once it's set up, takes on a life of its own. It goes in its own direction. You can only influence that to a certain extent because things are differently because they're in a different space than you are. They diverged, there's no doubt about that. Even when we owned them, they were diverging because they had to. Having said all that, a number of us still have very close relationships with the company. Some of the senior management used to work with me, so we've known each other a long time. The other aspect of this is that I go and try ideas on them periodically and say, "Hey, what about this?" They do support our research, sometimes providing tools and sometimes cash and sometimes decision making. I often talk to the people at the spin-off in support of our work in past. Whether they will want to in future, I don't know. We'll see what we're doing.

We gave a series of lectures on campus. They were one or two day seminars to which we'd invite local industries. A lot of their people would come. We would talk to them about our technology and what it would do and an overview of the field and they would in turn tell us things that they were doing. We got feedback … you have to know what products people want; see what they liked, what they didn't like. The contacts and the networking are very important.

The technology that we developed was very broadly applicable. When somebody in computer science or engineering solves a problem they typically solve the more general problem then the specific one. It's not just the one problem that you're trying to solve but rather you solve the more general one. That was recognized early on. As soon as we started developing the tools, we recognized that it was going to be applicable in a number of industries. The disappointing thing was that whenever somebody came along for a demo to see what we were doing, we would tell them about the project, show them what we could do and try to explain how it could be used. They all said, 'this is very exciting but it doesn't apply to us.' People just could not see the applications. The spin-off struggled for the longest time. The biggest struggle was trying to find ways to show that the technology was applicable more broadly. One of the first things we did was develop demonstrations of some of the uses. We did some other things, within the university, to show that we could do it but also because the company needed it. They needed things that they could take on the road. If they were going to industry A, they had to show examples from industry A, and if they were going to industry B, they had to show examples from industry B because people can't translate from some other application to their needs.

At first potential users do not understand what the invention is all about. They don't understand the need. So, there's a bit of missionary work to be done: Why pick this particular technology versus another and that makes us better for techies then for high level people, but then high level people don't listen to techies. That's what our experience has been. I'd say there were maybe three or four years where we were doing missionary work. Where we were going out and talking to executives, getting them to take the time to get the ideas through without going into the very heavy technical side. It's not that they can't understand it's just that they're busy with other things but there's an intermediate stage which has to be achieved, I think. They have to know enough about the technology: what it will do and what it is from the point of view of what they're going to have to invest in it. Then they understand it and then they can appreciate it and promote it. But there is missionary work especially in this area that had to be done.

I'm not quite entrepreneurial in the same sense that some other people are because I don't have the business interests in working with the company and getting it going. I thought it was a good thing. I was definitely interested in seeing it happen but I was not the one to figure out how to make a company work and I was not about to give up my job here in order to get into the company, either. So, it was definitely a little more remote a relationship with the company. Some of my colleagues really invested their time in the company and took ownership of it, had very much of a personal interest in making the company work.

Time Demands

One of the biggest challenges is being able to manage your time. I'm very conscious about that. I was getting paid by the university; that was my primary job, so I had to put in the time required to do my job at the university. In other words you can't sacrifice university time for the start-up. What I did in the company was really extra time, quite often early morning work from 6 a.m. to 8 a.m. or evenings, a lot of evenings, weekends and stuff like that. You find the few hours that you don't have to be at the university, as a faculty member and a university administrator. Also, your research projects that need attention here at the university, and your students that need attention. So, you have to be pretty careful in how you manage your hours.

I attended meetings regarding proposals on projects. We wrote a lot of proposals, spent a lot of time working on proposals because that's the way you're going to get a good majority of your contracts. They aren't going to walk in the door. You have to write proposals and they have to be well written, they have to be directed to the client's problems. Sometimes these would be unsolicited proposals, other times they would be in response to a request for proposals and you work them both. Cost estimating on these things is absolutely critical, because you're not there to lose money. So I worked a lot on proposals and made presentations. I spent a lot of long hours, night hours, weekend hours and so on.

Probably a couple of days a month is right, [as an estimate of the amount of time I spent working on the spin-off as a founder who remained in the university]. I think I went to the spin-off once a week, for technical meetings; that would be once a week for a couple of hours. It was like consulting: you're hoping that you get some insights into your research or teaching. I was being compensated for it, I think… Even if I wasn't getting a consulting fee I was certainly earning money by putting time into the company because I owned a share of it. I think it is like doing consulting for any other company. It has to be balanced with everything else and you have to get good things out of it. I was interested in the research area; there were definitely research challenges. It's a consulting opportunity like other consulting opportunities but with a company that actually cares or, at least, that's going to listen to what you're saying and that was very good.

I could say that the university should allow you time to develop these ideas [to encourage technology transfer] but, I think, that if you feel strongly about the idea then you will find the time. I actually kept track of my time. And I made sure that I spent forty hours a week at the university, at the university work. I did a lot of traveling so that meant weekends and evenings and things. But I made sure that I didn't feel like I was ripping the university off. And still it can be done. I worked forty hours a week at the university; I had a huge number of graduate students. I worked for the company probably twenty to thirty, sometimes forty extra hours a week. So it was a fairly tiring time. It was hard physically, it was hard mentally.

Learning and the Identification of Mistakes

I think I was a little bit of elitist, at the beginning. That ended up hurting me. I was looking down on understanding the law. Later on, when I was hit hard, then I said, "Oh! You have to understand the laws, you have to understand how it works," because it can be legal and it can be very unfair. But it was too late, you see? So that was a mistake I made. Now when I enter into agreements with respect to the business, I look at the legal aspect. In other words, I say, "Ok, suppose the worst scenario happens here, what are effects on the company, what are the effects on the individuals?" because the other person will not operate fairly.

There seem to be two kinds of businesses in the technology world. In one kind of business is you've got a good idea and now you have to figure out who would ever want to buy it and why. So you have to create a market place. That's hard. The other idea is they absolutely need this product because if they don't have it, their business will be destroyed. The spin-off was really constructed on, amazingly enough, not satisfying a need but creating superior products that we hoped would sell in the market place. But we did sell them at the market place. Some of the stuff is best of breed in it's particular niche. The spin-off was acquiring large customers, who could see the value of what we were proposing. We were getting to the point where we were creating a market place for the product because enough people were saying, "Hey, this is good stuff, and we can see that it would help us do our business better."

The way I look at it is that you have to learn from your mistakes and not make the same mistake the second time. I was lucky because I had multiple chances at setting up companies. The first one started, lasted for a couple of years, didn't do anything and died. I learned from that one that it's important to choose your partners correctly but nothing much came of that. In a later spin-off, I was learning how to set up a company and doing all that on the side as well as working at the university. All the things we were doing in the lab were quite exciting because we were able to get patents on them. In those days, people in my field were not patenting, it was not considered important to patent stuff. It was sort of fun because I started to realize that it was pretty important. If you're going to commercialize something, patents are pretty important things. That was fun. Looking back on past experiences, there were lots of mistakes I made. I don't think I've made any of the same mistakes in this spin-off. I've made some others, maybe, but at least I learned enough not to make the same mistakes again. That's part of the fun, I guess. Anyway, I've enjoyed it.

I made mistakes. I didn't really pay attention or have a good understanding of agreements I entered into. Later on, when I realized what it meant … it was terrible what I had signed and it came back to haunt me. I signed an agreement with no out, the investors were controlling everything. I lost the ability to develop the company the way I wanted to develop it. It led to a lot of issues, especially when the company started to be profitable. They wanted to dip into that money but I wanted that money to put it back into the business. It was painful. The mistake I made is that I didn't really understand the investment process. Instead of trying to understand it before I got into it, I assumed that if it's legal, it's also fair. So I learned that one the hard way.

If I had to do it again, one of the things I would certainly consider, is moving the company into the U.S. in a much earlier stage so that it would have access to the grants that are available in the United States for company development. There's nothing in Canada that matches. IRAP grants are small and, at best, do forty percent of the total cost of the project. Whereas, in the U.S., you can get SBIR grants that are up to seven hundred and fifty thousand U.S. each and there's no matching funds required and you can have two of those going at the same time. That would change the whole structure of a new high tech company.

I never thought about the market when I started. I just thought, I'm out to design a better mousetrap than ever was before. The failure was because of not understanding the market and how the market works: the industry managers and their mindsets. A newspaper did a write-up of the concept, and from the response we knew that end-users were interested. The mindset of the managers was the reason for the barrier there... If there's anyway you could test the market earlier on, I'd do it.

I discovered that this product had to be picked up by one of the existing companies to be successful. It is a difficult market, there's not doubt about it: very niche, very narrow market and established. The number of manufacturers in the market hasn't been going up. Each one is fighting each other for his share of the market whatever it is and it's a decreasing market.

The springboard for establishing our initial company was some of the research that my students had been doing, and work that I had done. We had some things that we could go out and sell. Of course, once you get contracts to do this, then you learn a lot more; you develop better technology and so it's an ongoing process. If you don't do that you're going to be taken over by the competition real fast.

Industrial research groups are not as open to new ideas as they might be. They have their own proprietary stock and they don't want that disturbed. So it was hard in a lot of cases to break through. They would listen to a company but not to new researchers who were intruding on their turf already. Even if you got through with some of those technical groups, their management wasn't with them. You don't go to technical people because you're wasting your time. We learned it the hard way. We did that lots and lots. It shouldn't have to be this way but you have to go around and go to the top over technical people's heads. Get their people interested, they could say to a research group, 'OK, now you look at this.' Then it works. But if you just go to the research group, believe me it doesn't work.

Success Factors

I knew the Canadian representative for one of the largest companies in the industry. I had worked with him on a project for two years before he went to work with them so I approached him to take this design back to the company and ask, "Is it of interest to you? Do you want to license it?" They came back very arrogantly and said, "If it wasn't designed in-house, it's not worth looking at." According to him, those were the words that came back to him, "We're not interested in anything else."

We had hired an outside president for the company. I was still full-time at the university in those days. We hired an outside president and he expanded the company to meet a sales forecast that never came to be. We almost went bankrupt, this was after he was gone of course but nevertheless we were able to pull through that and turn it into a profitable company again.

The spin-off company rented space from my department and they were pretty good about it. There was at least once where we were substantially behind in our rent because we had no money. They just kept sending a bill and adding the months and you know sending another bill and adding a month. Of course, when we did get some money we paid them off. But they were pretty good about it. I didn't feel any pressure at all.

Being plugged into what others do is extremely valuable to any researcher. In fact, sometimes I think we don't realize how valuable it is to have these contacts, to know what is going on in many other countries. If you have contacts, it saves you an inordinate amount of time. And it's not just saving time. Quite often, if you have these contacts, you can send somebody an e-mail and say, 'Hey Joe, can you tell me who's done this or who's done that on problem X?' When I really sit and think about it, my career has benefited immensely by having all these different contacts. Not just the graduate students that I've had, but also people that I've met and worked with in different countries. In other words, it's a leveraging and reinforcing mechanism.

[Publications have helped me develop contacts] hundreds of times and it also leads to recruitment of students. It is a factor in students becoming aware of your work, from Canada or other countries. It leads to agencies wanting you to look at some research problems. If they are aware of you and your work, then certainly they're going to come to you. I've had all kinds of examples over my career where people say 'Would you look at this?' I've seen an enormous number of different problems that have come from, not even just within Canada, but abroad.

The aspect of my background that made it easier for me to help with the business was my experience giving estimates for research and consulting projects. When you do an estimate on a research project or contract research, it just strikes you that this is a three hundred thousand dollar project. Literally within minutes you kind of make that kind of rough estimate. Then, when you do the detailed pricing, if you're way off that, you have to ask yourself why. It's kind of a test of reasonableness, in the sense that when you price things out in detail, you should come out with what your gut feeling was to start with. Experience teaches you, I think, that you should have a kind of a gut feeling for the scope of the project, not just the work to be done but also what it should be costing.

I've never consciously thought of myself as an entrepreneur but when I look back at the things I have done in the private sector and in the academic sector and so on, I guess I have been an entrepreneur. I haven't been an academic that hunkers down and works in depth on a particular problem. I've worked on a very large number of problems, ranging from a hard-core experimental type of work to very soft-sided work that is more economics and socially-oriented. I like working on specific technical problems but I also like to cover a very wide range of problems and interests. I have a large amount of interest in what goes on, politically, economically, socially and so on not that I have any great ability to participate in that. I try to keep aware of what's going on in the financial world and other things like that and I think that's helped me in trying to understand the impacts and the relevance of a large amount of things that I do in research.

The other thing that's important here is that the co-founders of the company, we knew each other well. We had a similar philosophy on how the business should be run. My cofounders are very good in our field and I think we also had a kind of an unwritten understanding that we would try to make sure that we had a consensus on our decisions, not that we ever wrote that down or anything like that. We'd better make sure that if we're making decisions to buy equipment, to take on different jobs and this sort of thing, that we had a reasonable consensus on it or that we talked it out. You're not always absolutely unanimous on everything but, once we made a decision, we'd all go along with it. There wouldn't be any sour grapes. It's kind of like a cabinet, I guess, where you have to show some solidarity. If you can't go along with it, then you need to resign.

One of the biggest difficulties is making a transition from half a dozen people to 15 people to 20 people to 50 people and so on. When you start out you have big meetings to decide whether we should buy two pencils instead of one pencil. Then you finally realize that you've got to go beyond that. It's not just the management, a lot of your employees can't make that transition from where you're very heavily involved in all the details of buying new fixtures and furniture and all that sort of thing to making the jump to managing a bigger organization. We were very fortunate in that the people who left the university and who were really operationally running the business, were able to go through those various levels. They were very conscious that they had to do that, because we made a decision fairly early on that we wanted to grow. We saw a lot of opportunities. In the early days, the managers were in on every aspect of the product, then they'd say, 'Here's the general scope, here's what we want', and so on. It wasn't a set of very deliberate steps, but it grew and the managers were able to keep going to different levels of the organization, realizing that they could not micromanage stuff. There's an old saying 'the devil is in the details.' Of course, it's in the details but you have to hire people that you can trust to take care of the details. We hired some very good people and, like any organization, we had a few disasters. Those people, sometimes they're very good at doing a detail task and you have to put in a back corner, otherwise you just have to say 'I'm sorry, the fit just isn't there.' We've had some very bright people that didn't fit in.

Nothing came to us easy. I mean, we really had to work very hard for it. We had to work hard, day-by-day or quarter-by-quarter or year-by-year in order to beat the competition and get our products in a state where they are highly differentiated. The two reasons for success: one is we pay attention to detail and the other thing is we stay on the problem long enough to solve it. When I commercialized the first important component of our technology, we stayed on it for more than five years and we have technology now nobody else has. At the moment, competitors do not have the patience to develop or to perfect a product's technology. That differentiates us from others. We stay on the problem once we identify that this is really what we want to do. This is the problem we want to solve, we understand the problem and we know that it is going to help us, then we stay on it.

We considered getting investments from venture capitalists very briefly but I think the venture capitalists really are just loaning you money and expecting a big return on it. We were more interested in going in with a larger partner, which had additional technical capabilities in other areas. The company that we partnered with had a very good accounting system, which we needed. It was a big help to us, to get that on line. It was also a good fit. They were not in the area that our core expertise was in. They were in other areas so it was a very complementary thing.

The first thing is to know the market. Know what your customers want. You have a wealth of knowledge that they are going to use on their behalf but you have to know what they want. One of the main problems is the communication problem when you're trying to talk somebody from a different mindset and they tell you about what they're doing; often what they're describing and what you're thinking that they're describing are two entirely different things. It takes a while to get to know exactly what it is that they're talking about and then have them know what you're talking about. I think that's one of the things to do is see how your interests mesh. It's an iterative process usually but I think that's one very important thing to look after. And the reason I say that is I have a colleague who wants to commercialize a product. The product that he has is one that no one wants and he has tried to commercialize for ten years or more. I frankly told him, 'Look, you have to modify this so that it will be what people want.' He hasn't been too receptive to that. That's the second thing: Deal with the right people. He turned this over to a lawyer to commercialize; he doesn't know anything about it. He can't talk to the people who might want the product and so it's gotten nowhere.

[Venture capital wasn't available so] we were forced to be self-reliant. After awhile it became part of our culture to be self-reliant. We didn't need the infusion of capital from outside. The company itself made money and grew as needed. Now, you would get the opposite argument that you can't make a great company that way; you need lots of infusion of capital to build this, that and the other thing. Yes, we are weak in some areas, but we are gradually overcoming that. And the question is do you want to build again a great company over which you basically have no control. If venture capitalists come in and take a large percentage of what you have created in order to give you a large infusion of cash, are you that much farther ahead? You can argue that, "I'm a billion-dollar company now. I only own one percent, but that's not bad" but if you owned twenty percent or thirty percent of a fifty-million dollar company you are just as far ahead. There's a very interesting balance there. It's not clear that having large amounts of money and giving up a significant amount of what you created is a good thing to do. I have seen companies where the people who started the company have lost control of it because the people who built the business and constructed it had a totally different goal set than the people who invested in the company without an interest in the business.

I came from a company town. The most logical route was to go into industry where I spent years doing all sorts of things. I was introduced to all types of processes but it was really a long grind as far as getting involved with all these aspects of an integrated manufacturing company. And so one spent three months in one area, three months with the next and then on to the third, generally on shift work, so that one got a real grassroots feeling of how one made the products and really got involved with the people who were actually making these products. I suppose I was also making them myself. At the same time, night school made it more interesting to find out what was going on. And from there, I had scholarships to go to university and from that point onwards I stayed doing a normal degree and then to a Ph.D. So, that's the evolution. I came into the university very much from an industrial background as opposed to a continuation of high school. And I think it was helpful because I think I wanted to know a little bit more of what was going on, more of the fundamental aspects of problems I worked with in industry.

My feeling very strongly is that technological transfer is carried out more between people than it is through papers. When the government talks about technological transfer from the university to the society the main conduit for transfer is through the people that the university graduates. It's not the papers that the faculty writes. And many university researchers have never been out of the womb. They've gone through university, they've done their Masters' degree, they've done their Doctorate degree, they've done their post-doctoral work. They've got a faculty appointment and they are professors. So that they really are sometimes quite, well, I wouldn't say ignorant, but haven't quite had the experience out in the industry. The co-op environment forces university professors to deal with more mature students, from the point of view of having been out in the world. All you have to do is interview a student in a non-co-op program and they're different as night and day. The primary difference is that the student who has been out in the co-op world will not always believe you unless you have some legitimacy. They've been out there. They say, 'Well that's fine but that's not what I experienced. That isn't the way the world works.' They're more mature from that point of view. And, if the professor has to interact with students in a design and development environment, in project work and things like that, it can condition the faculty member. They learn from it. It's a continuous feedback loop despite the university.

The licensee recognized that they needed access to a component of our technology so they hired somebody to work over there to bring the technology to them. I advertised for somebody to do that and a graduate student here applied for it and went to work for them in order to help transfer the technology to them. While he was there, we had lots of communications back and forth of, where he was saying, 'Help! I need to do the following task and I don't know how,' or something or other. We'd try to work on the project here for a while and eventually send him some way that he could make it work. So that was one of the, one of the first little pieces of technology transferred along these lines with this particular project. It was done in the way that's most effective, which is by having a person, who knows how the technology is going to work.

It was clear that this company was losing money a lot faster than it was ever going to make it. One of my co-founders used to talk about the j-curve and the problem is that the down part of this j-curve was going to hit zero before it got a chance to turn around and start going up. It was clear that we needed new markets and a new direction. A person was hired to manage the company; this person seemed to have a lot of skills and a lot of ideas about how to make the company grow. He put together some reasonable business plans, and seemed to have the right kinds of contacts and so we all decided that this person should become the president of the company and the previous president would move to being chief technical officer or vice-president in charge of technology or something like that. The new person was going to be the business leader and really push the company forward to its next stage. He was very keen on establishing some research relations with the university and establishing some ties with some other companies and getting some government funding. He knew about how to get government money for small companies and worked on that. After awhile he got a few government investments, into the company, and then went to private investors and we had the first external private investor in the company

Outcomes

I feel that I contributed quite a lot to the university but at the same time I feel the university contributed to me. It's mutual good feeling. I feel that my graduate students benefited. A student that I met with at a conference last week, he is an executive with a big technology company. If I didn't interact with industry, I wouldn't have given him a good project, good leadership and good advice so he could achieve what he achieved with his Ph.D. thesis. I think, overall, that my students, my Ph.D. students, also benefited from my activities. That's how I feel.

My sabbaticals have been deliberately involved with industry because I like very much to have that application side. All the sabbaticals have been involved more with industry or government labs where I'm removing myself a little bit from the university atmosphere. The general theme is to get involved with ongoing work which is already in place in these institutions. In other words, I'd like to know more of what they're doing rather than imposing what I have done as my own dedicated research. Obviously, the fundamental side of what I know is of value to the companies. And so I think, there's a welcome for someone who can come in and help to understand some of the things, which are going on in industry or in the government labs. But I always like to get involved with ongoing research. So, there is this, I guess, combination of help both ways to bring in a different view from their aspect and from my aspect to look at what they're doing too. So, there is this, I hope, synergism going on there.

I was conditioned to the possibility of tech. transfer, fairly early on, and always interested in working on solving real-world problems. I found it exceedingly exciting to work on a problem that people cared about. The research project that led to the spin-off was exceedingly stimulating because we had early users of the technology who had lots of ideas about what they wanted us to do and we had lots of ideas about what the technology could do. Therefore, we were exceedingly compatible.

It's been an interesting life; the years have gone by extremely fast. If one asked the question 'Would you do anything differently?' I would do a thousand things differently but I don't have any regrets from what I did. It's been a very interesting life. I've had a lot of fun and I'm very proud that I've been recognized for it by a number of things, which researchers don't normally get like prestigious awards for having a social impact and things like that. I never set out to be recognized that way but you take pride in what you've done. I take pride in what I've accomplished in an academic sense and take pride in the students that have worked with me. Your legacy really is as much in the students that have worked with you as anything going. A lot of stuff I've written and produced, research results, they have meaning, in the short term. Some of it is relatively long-term if it's fundamental but students last a little bit longer than that stuff.

A lot of the interactions with industry have given me ideas that I could use to recruit and enthuse graduate students to work on problems. When you do projects you see all kinds of additional problems that need to be solved or that could be solved. It provides a goldmine of problems for graduate students to work on. I also take pride in the fact that the research internally and projects and consulting and so on, have helped me immensely, in writing my book. When you have knowledge of what goes on in different countries around the world and what other researchers and practitioners are working on in different areas, that's pretty valuable if you're going have a book that is comprehensive. I take pride in my book because it's been received quite well.

[Industry partners are likely to employ people who can make sense of my publications] An awful lot of my students have gone to work for an employer, like a consulting company, because the company has begun to know the student through the work. If the student is good and they've got a position, it's in their interest to employ that student. And that's been very successful. Even within the local area, we have quite a number of our former, mine and other colleagues, former students, who have done extremely well. They're CEOs of companies, they're senior engineers with different organizations, and they're within academia and so on.

I'm really proud that I surrounded myself with smart people at the spin-off and that we are able to compete internationally. I'm also really proud of our technology; our technology is leading-edge.

When I was doing a lot of pure research, especially in my graduate lectures, I'd be putting out ideas. The interaction and the comments and the feedback from the students gave me a lot of research ideas. I think, by talking about what I was doing currently, I was helping these students. Also, there was an undergraduate student many years ago. I'd taught him second-year linear algebra. Later, he was working on his thesis and he needed a lot of linear algebra and he turned around to me and said to me, 'Why didn't you tell us that this is important stuff?' And I said, 'What do you think I was trying to do?' I think I was a better teacher for knowing how it could be used as well as knowing theory. I think that makes for a stronger teacher, having this balance.

I always felt that one of the most satisfying things was the number of people working at the company. These are Canadians who have good jobs, they're taking home money, they're paying taxes. It's good for the Canadian economy, it's good for everybody. And that's one of the satisfying things.

[The benefits of university-industry interactions are] two things: interesting problems and how to modify what we were doing so it would be more in the line of what people wanted. I like to do something useful. Don't we all want to feel that we're being useful. Isn't it a criticism of professors that they sit there in their ivory towers, they do nothing for society and they take all these resources. Why are they wasting their time on research when they could simply do teaching?

If we count off the contacts with industry which have been generated through sabbaticals and also meeting people of similar interests in conferences, I've developed very good relationships with these industrial applications. For instance, I had a student who came from a country in Europe to finish his thesis. The work he's been doing has been with developments from Company XYZ and his degree is from another country in Europe. So, it's becoming more of an international network as opposed to a University of Waterloo network.

We did field tests with the product and one of the test users was so in love with the invention that he didn't want to give it up. We took this as a supreme compliment.

I took on a commercial project that made my research more easily shared and used within the research community. At the time, I didn't realize how important it was going to be... not from a financial point of view because it only brings in a modest amount a year. It gives you a certain prestige or stature in the community that you're working with, far more than I thought. I get people coming up to me and they don't comment about any of the many papers I've published, they comment on that project. In fact, it sort of gave me a shock... I didn't realize the impact it does make on the community until the first conference after and I really got it right in the face, which was nice. It was a very nice pleasant feeling but I wasn't expecting that.

My one project is an extreme case of something which is nothing in terms of, say, a journal publication. On the one hand, you've got these high-tech publications, and on the other, the low-tech aspects of taking a simple design and adapting it for use. I've had very beautifully inscribed letters from users, thanking me and that sort of thing. I've been on the local news, [laughs] and so on. And that, in a way, is rewarding. But it has nothing to do with the other side of the university as far as high-tech is concerned.

Another thing about those seminars, you met people and they met you. So even after the seminars were over, they had a contact with you. So I would hear from them, they'd phone me up and say, 'Who should I talk to about this or this.' You'd get a network established. It's a different network than you get when you go to a conference. That very often is the internal network of academia. It doesn't reach out beyond academia in many cases.

The research project that led to the spin-off is the activity that I'm most proud to have been involved in. The spin-off activity is probably lower because I value the research and teaching aspects of what I do higher than the commercialization. On the other hand, I recognize the importance of the commercial activity, in contributing to the community, having it pay back the university in many ways through hiring of people from here and through direct funding back into the university, through research contracts and through donations. Those things are very, very important contributions.

The dissatisfaction here is that this a design that people could be using. I'm not worried about the money involved; I'm not even thinking about that. I'm just thinking here is a design that people could be benefiting from but it's not out there now because of the myopic view of industry. I'm bordering on anger…

Theme 2: University Environment

This theme explores aspects of the university environment that appear to influence technology transfer activities. This top-level theme is further divided into four themes: 1) peers and group norms; 2) academic leadership; 3) university culture; and, 4) experiences with Technology Transfer Support Organizations (TTSOs).

Peers and Group Norms

The thing I liked about our technology transfer was that was that we had developed a theory that was needed for the technology. There's a problem with culture, you know at a university, some people disapprove of technology transfer, doing something useful, something applied because they think it's trivial. Putting together the facts, that can be trivial in the context of theory, together to solve a problem can be an amazing intellectual accomplishment. I think some people are a little too smug. They think that well if you're doing something applied it can't be very intellectually challenging. I think that's wrong. It's snobbery when people want to think that their work is above application.

There were a few people in my department who felt that any connection with industry was wrong; that it meant that you were not a real researcher or a real scientist. But it ranged all the way to a few people who were very interested in doing this with industry and keen and enthusiastic. At least one colleague was active and doing that kind of thing. So reactions ranged all the way from some people who thought you shouldn't have anything whatsoever to do with industry, to others who were quite supportive; it was the whole spectrum there.

The graduate students benefited and the university benefited because we put a lot of money into the university. Financially I was not doing too badly because I did consulting for significant pay. Because it was coming through the university, people could see the amounts. According to a Professor of Economics at Princeton University, a professor may inherit lots of money, he may marry lots of money and he may spend lots of money, but he's never, never supposed to earn lots of money. It is un-academic. That sentiment was still at the university. We used to live at the university, we didn't have any other life apart from the university. A lot of us only interacted with other professors at the university. And, my colleagues used to say, in the form of a joke, that we were prostituting academia by being involved with industry. When I was working on my start-up, I got pot shots from my colleagues: that I was getting rich at the expense of the university and that type of thing. It was not a good situation for me.

No [my colleagues didn't give me a hard time about making money by investing in the spin-off]. I think people thought that I owned a lot more of the company than I did. The average person might have thought that I made a lot more out of it than I actually did. But I haven't gotten that sort of negative feedback or concern or anything else.

[My colleague's reactions] run the full gamut from very supportive and encouraging to others that have a sense of envy. There's a sense of envy sometimes, but I guess that's not unique to a university. When I received an important award in recognition of the social value of my work a lot of colleagues were very congratulatory. It's not that I'm going around looking for that but it's encouraging. So there are people all across the university that congratulate you on achievements, and that's nice. There're a few, unfortunately, that make snide remarks, 'He's not deserving of it,' but that's their problem, not mine. There a few people who are envious, but, you know, nobody who's ever succeeded has ever had entirely unanimous support. The other part of that is that, in the applied areas of research, contract research is a big part of our research funding here. I try to take on research projects where I don't feel I'm competing with the private sector. Sometimes the people that are expressing the desire to be pure and not do research that is 'tainted' believe what they say. Sometimes, there's a certain degree of envy. I've heard people in other areas of the university sometimes, "Some of those engineers over there are going around getting rich; going out and doing consulting and making millions of dollars and everything else." It isn't true, it just isn't true. Any money I've made, I made by risking my money. I probably could have made as much putting it into GICs in the bank, you know, which is pretty risk free. It's an argument that I've heard many times, but I think that I can defend what I've done.

Colleagues didn't care, it didn't bother them. A few colleagues also had had the opportunity to have research projects with the company and it's viewed as being generally good. Hiring our students is viewed as a good thing. It enhances the reputation of the university. That's viewed as a good thing. I think more people see the general benefits and appreciate them, rather than being annoyed at some people making money from it. I haven't seen that as a problem. And I haven't noticed it as a problem with other companies either.

[My colleagues were] almost all completely supportive. I've never gotten back any negative feedback, I don't think. If there was negative feedback it was mild enough that it didn't scare me [laughs]. I think people were pretty supportive. At that time, other companies had been spin-offs of the University and it was viewed as being a good thing by almost everybody, so it wasn't new for most people. I think that it was viewed as part of the Waterloo culture, the Waterloo advantage and I think it's still viewed that way now. I mean that new employees, new faculty members see that there is this potential to be able to take your ideas and commercialize them and benefit from them.

Academic Leadership

It perhaps wasn't explicit but, implicitly, there was very good support here by the senior administrators. One of our presidents was a very externally-focused person. He had a lot of contacts. It's not that I ever went to him and said, 'What do you think of me doing this?' but you sensed there was a strong encouragement of taking the initiative. Also we had deans that were superb. Certainly the few times I ever did go to sort of chat with them about internal research initiatives or external activities, they were entirely encouraging. In other words, you never felt that you were being held back, that you shouldn't go out and do things. And one of the vice-president's of research, even to this day, whenever I see him he asks about the company. You sensed that he was very supportive of technology development here being transferred to industry and public sector, being commercialized and so on. I would say that he was a very strong encouraging influence. We had another president for awhile who was also a very fine fellow. Again you sensed that you had this implicit mandate to go ahead and do things. I think that basically we had a good environment here.

[The support for the spin-off] was on all levels: it was the Chair at the time, the Dean at the time, the VP at the time. Everybody was supportive right off the line in the university hierarchy.

I didn't cost the university anything during the first years of the start-up even though I was still teaching a couple of courses a year because the start-up was paying my university salary. I still had Ph.D. students and I was still bringing a lot of research funds to the research group. If I had left it would have messed up the students. So I ended up staying at the university and trying to figure out a way to make it work. I reached an agreement with the dean that I would not suffer if I paid my salary even if I didn't teach four courses. When I retired the dean argued that I hadn't been a full-time employee at the university because I didn't have a full course load during the time I worked on the start-up. Therefore I was not entitled to the full-time benefits for that period. I was short-changed on my pension. That was not the understanding that I had with them. I felt that the dean was doing this to penalize me because he did not approve of technology transfer. If a university official, like the president, asked him he would say he supported it but he was penalizing anybody who was involved in it. He would find ways to prevent you from getting certain benefits or charging your company the full increment of your salary. Apparently the penalties I got were really small compared to some of the penalties for other people. We started comparing notes and we found out he was doing it to all of us, not just to one individual. Our officials were not prepared to support technology transfer. They could see the benefits which would accrue to society and were prepared to support it but they wouldn't get involved themselves because they were afraid that they would be tainted by getting involved with business.

I don't think we had one chairman, in the time I was there, that felt you shouldn't be doing technology transfer. We always felt that we had some support there. Even the basic researchers seemed OK. I've always had a very positive feeling towards my department.

We really tried to set an organization up within the university and so we had meetings with university administrators. I remember one day the Vice President of Research said, "Why don't you just set this thing up outside the university?" I said, "Well, there certainly would be less red tape and that seemed to be a good idea." And I said to him, if we set this up outside the university, I would pledge that I would not use resources of the university for our personal use. That was a very significant moment because it was almost a sigh of relief. I didn't want to rip the university off. I wanted the university to have every opportunity to participate if they wanted to but it became obvious that there were so many problems that it would have been better for us to do it ourselves. All of us in the start-up breathed a sigh of relief, when they said, "Why don't you take it outside?" That was a famous moment.

University Culture

In the early days there was almost a revolution of young people. It was an era that fostered this, "You can go out and do anything you want." We became much more conservative later on. I don't have the capability to be able to really interpret it well but obviously we knew what was going on. There were occupations, there were protest marches, there were all kinds of things going on. As researchers, a lot of us were on the sidelines saying 'Gee, what's going on?' I think you were very conscious of what was going on, but you really couldn't understand it. In fact I think the radicals and protesters themselves didn't understand it. So yeah, it was an interesting era. Very much different than we have today. I'm not sure how much that impacted what we did but maybe the entrepreneurial open spirit we had at that time may have been part of it, either caused by it or going along with it. I really don't know. But the fact is it was an era that was very amenable or conducive to doing what you wanted, whether you wanted to be a radical, a protester, or whether you wanted to be an entrepreneur, establishing research programs or whatever you wanted to do. It was sort of a different era than today.

Before I worked at UW, I worked in a research environment where we were not allowed to really explore our potential. The management and the environment really were not conducive to really exerting yourself. Some of the other researchers felt that the other new guys and I were undermining them because they didn't want to push themselves. At the beginning, they used to come and talk to us one by one telling us that we ought to be careful not to hurt ourselves by working so hard. Later on they started unplugging our experiments. All we wanted was to get in and advance the field. We didn't care about getting brownie points or getting a high salary or whatever.

Waterloo was very different. There was a lot of excitement. A lot of trying to build something and that was very exciting; it was a very exciting period. There were no bounds on what we could do at UW. The dean at that time said, "Put this faculty on the global map" and that's what we did. He was promoting research excellence, good research published in good refereed journals. He provided the leadership. He indicated that you were contributing to the advancement of the field. We worked very hard to put the faculty on the academic map. The working environment was completely different from the environment I had had before. There were no bounds; you could produce as much as you could and not only in research. We started modernizing the undergraduate programs. We started developing undergraduate laboratories, so we improved the undergraduate program and the graduate programs. We started publishing in highly-respectable journals, refereed publications. After a while, my research group at the University of Waterloo was well-recognized internationally. So that was quite a fulfillment. I miss the excitement of that time. It doesn't exist now in the present environment of the university. There was an involvement whereby you were building something and that excitement, it was a fantastic excitement.

In the early days, Waterloo was moving and growing very quickly. And I was invited to come here and see what was going on and look at the possibilities, you see. When you think about Waterloo in those days, it was the darling of the, the Ontario governments with its new co-op program. And it was moving very, very quickly indeed. And anyone I suppose less than, younger than thirty, had, had a lot of sense of it could go a long way with all this encouragement. It was an exciting time. In retrospect, it was a gamble, it was no question because it was feeling its feet. And I suppose in those days, you know, being younger and perhaps less conservative, it was worthwhile giving it a go, there was nothing to lose.

Waterloo itself is an entrepreneurial place. We did many, many things here in the early days. For example, there was a new technology out there and people desperately needed to know about this. So we actually went out and taught courses. That's in the days when if a brochure came on your desk, it was rare as opposed to today, you just throw it in the garbage because there's so many of them. We went on the road to all sorts of places and taught courses. We raised a huge amount of money, all of which went into resources for research on campus. That was my first real experience being an entrepreneur.

An entrepreneur is someone who has interesting, exciting ideas and they want to make them real someway and get them out to individuals. The University of Waterloo, we wanted to sell the ideas that we had, we were a clear choice to go to school, an interesting place to go to school. We had good people here, we have good students here and we wanted to convince the rest of the world that Waterloo is not a bad place. And it looks like we've succeeded. That's what I mean by entrepreneurial. You're excited about what you're doing and want other people to be excited about it and participate too.

The university isn't as entrepreneurial as it used to be, which I think is a shame. I guess there were always people around here who weren't entrepreneurial per se, they were here to teach and just do research. I teach and do research too but I get excited about my ideas and I try to sell them to other people.

UW had a very entrepreneurial spirit. I don't mean that so much in a commercial sense, but in the sense that people were enthusiastic and energetic. We didn't realize it at the time but there was very little bureaucracy here at that time. Bureaucracy grows as an organization gets older, like creeping fungus. If we wanted to do something that made sense and we could talk our colleagues into it, the attitude was, "Sure, let's go, get on with it." We had a dean who was very highly supportive. You could walk into him with an idea and he'd say, "Well what's holding you back? Go ahead." I think there was a lot of trust too in those days. The trust was primarily internal, like from the dean to the chair of the department, the administrators trusted you to go out and do something useful and they gave you literally free rein to do it. We were kind of unaware of it at the time but looking back, this attitude and enthusiasm and encouragement were very influential in the growth of this place. And obviously the people you attract to that kind of thing; you attract younger people who have energy and enthusiasm.

I think Waterloo had some very remarkable people. Ralph Stanton, who started the math faculty, for example. He had graduates that he also taught in Portuguese and Physics. He had the largest Portuguese library in Canada. This is not your typical man on the street. There were those sorts of people around, some very clever and innovative people that made the University of Waterloo what it is today. [Resistance to doing work with industry] came to the university later. There were a lot of innovations and things that people would try. Then we got bigger, maybe we got successful. I don't know what you would call it. We became established. That innovative spirit, a lot of it died. What is the last major innovation in a sense of starting a co-op program or something like that that you know that's happened at this university?

Experiences with Technology Transfer Support Organizations (TTSOs)

At one point the start-up was partly owned by a government-funded technology transfer support organization (GTTSO) that wanted to sell their shares and get money for it. At that time, foreign investors were interested in buying technology companies. I was not prepared to do that. The GTTSO was pushing for it and I was not prepared to sell because I wanted the business to grow. I later found out that the person I dealt with at the GTTSO had a personal incentive which was based on return on investment. He had personal incentive to see the technology sold rather than be built-up in Ontario.

We went over to the Technology Transfer and Licensing Office over here at the university and we talked to them about a patent and how do we go about it. And they sat down with us and we said okay, 'We'll carry the ball for you on this.' So the university really came to our aid, there's no doubt about it. And they did all the correspondence with their patent lawyer and they started the patenting.

The most frustrating part in the whole thing was this patent, reading over all the details from the patent office. The patent office response said that a completely different technology with a different use had the same capability. I almost went down to Washington and said, 'Who's the guy who wrote this thing? [laughs] Let me strangle you... [continues laughing] How stupid can you be?' That was the most frustrating part. I was a bit disappointed with the university's patent lawyers. All they did was take the patent office reply to the application out of one envelope, take a look at it and send it back to us, saying, 'You come back with your counter arguments.' Meanwhile, while charging another $7000 or whatever it is.

I have had extremely limited contact with the Technology Transfer and Licensing Office. I don't mean to sound really negative on this but I have to be honest. Quite frankly, I felt that the amount of bureaucratic or administrative support you get can be more constraining than it can be helpful. I think those offices are probably more conducive to the young faculty member who really doesn't know how to go out and license or commercialize his or her idea. I think that for more experienced faculty members, they're probably not that much help.

The university's equity stake in the start-up got transferred into a technology transfer support organization (TTSO). After the equity was sold, it appeared that the money didn't go to the university … it stayed in the TTSO. I was very upset at finding out that the money did not go to the university. I did not do a proper accounting when I gave that equity to the university. I did not sit down and say, "This share is worth so much." I just made a good gesture. If it was for value added, I wouldn't have given them so much. So when the equity was sold and the money did not accrue to the university, I was very upset about it.

The Technology Transfer Support Organization (TTSO) was almost useless when it came to helping with the new company. As it turned out, they weren't actually part of the university but they tried hard to make people think they were. They wanted to own a piece of the company. We almost ended up in a lawsuit by the time that was over because they claimed about half the value of the company by giving us access to an engineer to help us with the product development. It turned out later on that that engineer had never been to university, he wasn't an engineer at all. He had a high school diploma and had worked at a local company to do some high tech stuff but they were billing him as an engineer. We discovered when he made some suggestions for our product that were completely unphysical, he didn't understand the science of the way the product worked at all. I had to get a lawyer and break that off.

I think the University of Waterloo's policy in giving the professor ownership of, of intellectual property is a good one. Most Canadian universities don't act that way, so that's a big positive in my mind for the University of Waterloo.

When we first started developing technology in the lab, I approached the university for help with the patenting. The way things work at the University of Waterloo, if the university helps with the patenting then they expect to own something. In other words, they paid out money, so they expect to get a return on it. That makes sense. As it turned out, I visited the technology transfer office and they looked at the technology and said, "No, we don't think the university should put in any money into that technology." I went ahead and had the patent put in without their help.

I applied for these patents and some of them started to issue. When I started to apply for patent number two, people knew that we were applying for another patent. At that point in time, the university said, "We'd like to help you with the patenting of this one." I said, "You didn't help with the first one. If you start helping with the second one or the third one, then you start getting ownership but the risk was in doing patent number one." I didn't ask them for help with the second or third patents or any of those because I felt if they were unable or unwilling to help with the first one, they shouldn't be able to buy in later after most of the risk has been done. They agreed with that.

When the university refused to help with the patent, it was because they did not see a way to license the technology, and most university technology transfer people are focused on licensing. They don't understand that there are a lot of technologies that are not licensable. My technology is a perfect example of one. In the early days, we tried to license this technology and we could find nobody who even knew what it was all about, let alone was interested in licensing it. I think the problem is that if you came up with a new chemical process and you take that to the licensing office, they'll go down to the chemical industry down the road and say, "Do you want to license this process?" The chemical industry may say, "Yeah, that, that looks really great, we'll license that." But if you're doing something really new, there is very often nobody out there who will license it. From my experience, one of the major problems is the technology transfer office is thinking about licensing only. The idea of the professor starting his own company is a waste of time. The professor doesn't know anything about business and therefore it will fail. Certainly that was the case when I started my spin-off. There was nobody out there who even understood what our technology was, let alone was interested in licensing it. Even if there had been somebody out there who understood what the technology was, we would never have found them. I think this is a major problem in technology transfer. In the U.S. it's not nearly such a big problem because there it's quite common for professors to start companies. The SBRI grants are set up to fit that situation exactly and they've been very successful. There's no equivalent granting agency in Canada and the technology transfer offices in Canada don't expect that to work. They may have changed by now. I don't know but I doubt it. They understand licensing and they don't understand letting a professor start his own company. It's not just at the University of Waterloo; I've talked to technology transfer officers from all over and they all talk about licensing. That seems to be their focus.

I don't think we would have been able to commercialize the technology through the university because our technology is really a management system. It's just not a type of product or service that you can realistically market out of the university. That's not to say that the university's bad or anything, it just isn't the type of thing that you could have done. Other products and services could be.

Working with the TTLO just wasn't feasible. We would have been too constrained. That's not a knock against them, it's just the type of thing that they're not really set up to do. They're more set up to take an inventor's idea and help in getting the patents and the licensing, etc. I'm not saying that they're well set up to do that, but they're more … You know, I'm really not aware of what the university really has to help inventors in that sense.

Those people over in the Office of Research, and possibly in the TTLO, really have trouble living up to the expectations that professors have because they're also burdened with all the bureaucracy they have to deal with. I'm not questioning their motivation. They're pretty good people, they try hard, but they’re committed but they’re understaffed, I think. I don’t think there’s any lack of motivation but sometimes there’s demoralization, which is natural when you get overworked and understaffed and pushed. Let’s face it, faculty members can be bloody boorish and demanding, at times. You know, if you talk to any of the administrative people, they sometimes get yelled at by faculty members who act like little children. There’s no excuse for that at all. Just not on.

After the first project failed, I didn't go to the Technology Transfer and Licensing Office to try to get a patent for the second project because I couldn't really see the market. We did the market test on our own and it failed. I thought, ‘I don't think the Technology Transfer Office would like it, especially with our experience with the first failure.’ I had gone to the companies and said, ‘Look. I’ll give you the design as it is now. I’ll sign it over to you.’ If it had gone ahead, I would have gone to the Technology Transfer people at that point in time and got them to come in on some legal document but it never did get to that stage unfortunately.

[The university support through the technology transfer office] certainly was valuable but… There’s a place here where we’re talking about candour and now I’m kind of against the barrier. I think that if the university is going to do something like have a technology transfer office, the staff there should not expect some portion of the companies which are being developed. Universities should hold equity positions. I have nothing against that. But the individuals representing the university shouldn’t. A lot of the businesses that went through that process were [allegedly] asked for a percentage, a share of the business, by an individual who worked in the technology transfer office. I don’t think that anybody regrets giving money to the university. But you have somebody who probably is on the university payroll also acting as an individual for a share of the company… There was a lot of resentment from a lot of companies, people among those companies… And some people just avoided that office completely.

We built a couple of test units. I made the measurements myself and it worked as predicted. People were interested in it. I presented the results to the trade association. They thought it was great. Because I was so busy, I turned to the university, who would develop and license things developed in the university. So, I gave them the rights to the invention and verbally I told them, “Under condition that you do not license to Company A,” whose management I had come to distrust. To me, they were dishonest. The university came back to me, I forgot how long later, weeks or months later and they said, “We have licensed the invention, we have an exclusive licence with Company A. ” So the licence gave Company A an exclusive contract to manufacture the invention. It made quite a few of them based on what I was telling people, by my reputation. We started calling up how they were working, and they weren’t working. And our first thought was that a particular critical component had failed. I had the university call Company A and ask about that component and they responded, “Oh, that component’s too complicated to put in. It’s not included…” So Company A had had manufactured this thing incorrectly, they didn’t work and within two years, the idea was dead.

Theme 3: Rewards and Reward Systems

This theme contains vignettes related to rewards and rewards systems related to technology transfer activities. These rewards systems are elements of the university environment; they were captured in this top-level theme because of their importance with respect to this thesis. This top-level theme is further divided into three themes: 1) Intellectual Property (IP) policies; 2) financial rewards; and, 3) other reward systems.

IP Policies

IP policies range across the country, from the UBC model to models like Waterloo, which is probably the most generous of any university in Canada; the IP belongs to the researcher although the researcher can make a deal with the university. I think that if the university-owner model were applied right across the board to every bit of IP developed or every product or research product or service, it would work fine for some. Others, like our type of thing, it just doesn't work. It wouldn't be practical. I'm not sure how other university-owner institutions operate but, I think there has to be some flexibility in that. I can see that if you use your university resources, you get research funding that comes from the university or the university provides the environment and covers a lot of the overhead, they should get a piece of the action. But, I think, Waterloo's attitude, and again it's not explicit, is more that if I become successful, then there's an expectation, or a hope, that you will be generous in turn by providing endowments to the university. And I think, like that's personally the model I prefer. In fact, I contribute to an endowed chair. It's a model that would hopefully generate just as much income for the university as the other model where the university owns the IP because there's a marketing cost associated with that too, that may or may not pay off.

It is claimed that Waterloo had generated, I'll say, twenty-two percent of the spin-off companies in this country that have spun off from universities. That's a phenomenal record. So you have to ask yourself, what is it that, that's happened. I would sort of define a spin-off as any company that sort of came out of the creative juices of some individual, whether it was a professor or student or whoever, that caused them to go off and start an organization up. I think we've been so successful because I think one of our key features here is the intellectual property policy, which basically says, "You create it, you own it." Other institutions have much more complicated policies. There's an attempt to require that the university should share in the ownership. When that happens, the first thing that happens is you get into discussions as to who owns what. You know, if I have an idea in this office and then I rent a garage down the street and do all my work in the garage down the street, does the university have a share? I don't have any idea how you decide that. So, you don't want to even go there. I mean, can you imagine if I have an idea and then I go and try and sell it, and get into an adversarial situation where the university is challenging my right to have ownership of this idea? Because they paid me to have the idea didn't they? I mean, paid my salary. Did I have the idea in the shower? Did I have it in this office? I have no idea. This really complicates situations very easily. If the university just says, "You own them," it is has eliminated a lot of the complication. First of all, the IP policy's simple. It's a very good thing because frankly it avoids a whole lot of wasted energy on trying to figure out what make sense. The second thing is that universities then often set up corporations to exploit this IP. They hire people, some of these people are very competent, but, 1) they probably don't understand what it is they're selling in many cases and, 2) they don't have any passion about it. They're just selling something. You don't have the originator behind the idea, the person who said, "I think this is just terrific. I've just got to go out and make this happen." I think there's a real problem there. I think if you look at some of these corporations that have been set up to exploit university IP, they're not very successful. I could be wrong but that's my sense.

I don't know how it works in other institutions but the University of Waterloo says, "I own my invention." Now, I have to exploit it. I can exploit it myself or I can seek outside or inside help. If I wish to seek inside help, there are people at the Technology Transfer and Licensing Office, who supposedly know at least some of the questions and answers. There will be a fee for that service and I can pay the fee in different ways. I can pay cash or I can give a share of what might come out of this or whatever. There're mechanisms in place to allow me to acquire this information. Although what I know, I've just learned, that's all; we talk among ourselves and talk to lawyers when we need to. What you're suggesting is that there should be a formal structure at the university that manages this IP, manages its sales, etc. What I'm saying is that there could be a structure in place to provide certain services, which I can buy, but I don't have to buy. That's what we have here at Waterloo. I have personal opinions about how well the TTLO works but I don't want to comment because I've never used them. We've always gone our own way. We have enough collective understanding let's say. I think people that have intellectual property, have to have a passion for what they are doing. There're successes around here and those people had a passion for what they were doing.

If you're a university like Queen's where you have a very large history and a very eminent medical faculty, there're pharmaceutical products developed. Queen's, from what I understand, has a heck of a good amount of revenue from the patents and products that have been developed there. That's grown over time. I think it's more amenable to things like pharmaceuticals than it is to a software package, for example, because a software package isn't something that you could just take and transfer it. Plug it in somewhere to a commercial application. Who does all the upgrades on it? Who does the continuing improvement and redevelopment, which our company has to do, if you're going to stay competitive. The university is not set up to do that sort of thing, at all, unless somebody's giving me a contract to upgrade the package, and to do software maintenance, the university isn't equipped to do that either. So it's just a different type of animal, even though I think both are legitimate within the university environment.

[If UW's policy switched to university-ownership] I think we would lose a lot of future faculty members in the high-tech fields. I don't know that we'd lose current ones. We might. We'd certainly lose future ones. It's a big attraction for hiring. In most cases, would it make a huge difference in how things actually end up? Like who makes how much money from what? How much does the university gain? How much does the individual gain on the projects that get commercialized? Probably not because there's already a sharing between individuals and the university in various ways. A reasonable university would probably still try to encourage the individuals by actually paying them fairly richly for doing the commercialization and allow the same kind of activity to go on. So, in the instances where commercial activity takes place, my guess is it would be structured very similarly to the way they are now. I don't think as many would take place. Certainly, not in the short run, at Waterloo. I think that there'd be a big drop. What's worse is that, in the long run, the potential would go down because we would hire fewer entrepreneurial-type people. I'm absolutely convinced of that. It would be a very bad move for Waterloo.

The university was very helpful actually. The university has a policy that if you have some sort of intellectual property development it belongs to you. In return, I think people like to return something to the university because of that. It certainly is an incentive thing and I think that's an oversight that other places that haven't done as well. I know places that have tried to develop research parks and they end up just giving cheap rent or in this conflict… So I think that's a major thing at U of W. And also our president at the time, he was very entrepreneurial. And so the spirit was ripe for doing this sort of development.

Something that is very important at the university is that they do give the university professor ownership of the patents. I think that's very important and I think that should continue. Most universities claim percentage ownership and the problem with that is when you set up a company, the investors in the company don't see the university's ownership as being helpful. In fact, they see it as a very negative thing to have the university involved. The reason for that is because they know that, if the company needs money and investors are expected to pony up and put more money in relative to their stock ownership, the university will not do that, they never will. And so they don't look upon the university as being a useful partner. I don't think most people at the university realize that.

One of the things that Waterloo has done, that I think is a catalyst for what's happened to Waterloo in terms of turning out new companies, is that Waterloo has encouraged people to put the results of their work into practice. And they've done that by allowing the people who do the research to own the results of the research. And that's the only university in Canada, I believe, that has that rule. At all the other universities, either the university owns the intellectual property or the university will share the intellectual property with the investigator. In our case, it didn't make any difference because we didn't take intellectual property from the university to set up the company. All of our intellectual property had already been published in the literature and we just wanted to see it applied in the best possible way. But, I think the feeling is that it's part of what the university wants us to do. And you then go the extra step and see it applied.

If you're going to do a lot of extra work, if you're going to do the eighty hours a week to get something going and the university owns ninety percent of it, whatever you produce, then you lose incentive to do it. And it's not only the money, it's control. You know that you worked your buns off and in the end it doesn't matter because if the university owns the technology and they decide that you're not going to use it in that way and then everything you worked for could be destroyed in a moment. I mean, if you do it, if you own it, then you're responsible for it for better of for worse. If you make a mistake, then you suffer. If you do well, then you see things grow. You don't have that other ownership body out there who really controls what you're doing and has the ultimate say in what you're doing. It's also pride, I think, and you do something because you want to see it flourish.

The most important [way to foster academic entrepreneurship], is the one I mentioned. That the intellectual property rights reside with the researcher. The sense of ownership… it's more, "Is this a part of you?" You're reputation is on the line. It's your idea that's on the line. So it's more a sense of ownership, I think, than pride.

The downside of the current policy is making sure that everybody is signed in and gets included if they should be included and that we really know who owns what, at the time. I think it can be addressed better. I think that Waterloo could put some more effort into making sure that everybody works early on to establish who owns what. If something gets developed, making sure that the developers are all included and that everybody knows who is a developer and who is not, early on.

So that worked very well and because of the early success in being able to license a few universities through the university, we could see that there was a potential for a spin-off. Because of the inventor-ownership policy at Waterloo we were able to see a future for us in putting in the extra effort needed, at the end, to make this work.

The university policy of inventor-ownership is supportive of this spin-off formation. It means that the individuals have the option to put more effort into something with the potential payoff to themselves, as opposed to the university dictating that whatever the individuals do, the university has the right to decide how things happen with it and therefore you're always subject to the university's whims: whether or not something can be commercialized in the way that you think it should be or could be. My guess is that the company wouldn't have started if the intellectual property was university-owned. Who within the university would have said, 'Let's do it?' And how would the university have convinced us, the people who actually did it, that we should do it on their behalf? We did it because we wanted to do it and we didn't have to ask somebody for permission.

The IP policy says that inventors don't legally owe the university anything but I think there's been moral obligation, felt by many people who have started companies, to pay the university back. In some senses, there's an investment back into the university, that's where some of this moral obligation comes in. It's not just paying for activities that happened but it's rather paying back the university so that the university can start other new activities. It's more of a forward-looking moral obligation rather than a past payment of debt kind of obligation.

Financial Rewards

Everybody who worked on the research project that was the basis for the spin-off was given an opportunity to invest. I had reasonable access to money, so I was able to invest without risk. In other words, if the money disappeared, it disappeared. I wasn't going to cry. Well, I'd cry but not very much. So we were all in this together. We continued to do our research but we invested in a little company that was just starting up. We were always very careful to make sure that we always did our job at the university and we followed the policies and rules at the university very carefully. It wasn't the case that it was all very well orchestrated because you can not ever create the perception that working at the university is a way to get rich because it isn't. There's nothing wrong with making investments. We all do that. It's called the stock market, bond market or whatever. If we can work together so that we both win, that's a good thing to do, which is what happened. So, I want to be very careful how one says that because it can be very easily misinterpreted.

It's not money. I don't think that was ever the motivating factor. If money was the motivating factor, I would have just stayed in consulting and done straight consulting. It's the fact that you can see something grow, you can see a place where your other students can move to do really meaningful and exciting work. And there are lots of things that are more important than the actual financial rewards. There are two ways of being rewarded, at least two ways. One is financial and the other one is the good feeling of seeing something flourish. Certainly financially: it was fair. I felt fairly rewarded. Financially it was fine. Not like a dot-com where you make many millions of dollars. It was very rewarding in terms of seeing something grow and flourish and do well in Canada. It still gives me pride when I go to a trade conference or go to a conference where I see people talk about what they've achieved using our products. Especially to trade conferences, where every year, there'd be a huge number of presentations of people who had done work with many different applications. And it's all done with products that I played a role in bringing to the point where it can be used. So there is a pride and it's a 'feel good' that you've done something to make the world a little bit better place.

I'm not worried about getting any recognition for this. I've received international awards, national awards and career awards for the things I've done so another one's not going to make any difference to me. I guess I'm more interested in having satisfied users, just to talk to them and say, 'How are you finding it?' and have their eyes light up and them say, "It's the greatest thing since sliced bread." If, afterwards, I made a little money that would be a benefit but that wasn't a certainty at that stage of the game. In fact, if it was money that I was interested in I might have taken a different route. I would have short-circuited some of the things to get to the answer quicker. Instead, I was determined that this wasn't just going to be a design out there that looked better, I was going to analyze the problem in the most rigorous scientific way to show that my solution is better than anything out there.

I think in academia, you can create real serious problems for yourself if you talk about making money through technology transfer. Academia does not celebrate wealth. That's crass, that's commercial. They celebrate other things, they celebrate publications, they celebrate good teaching, they celebrate honours: The Order of Canada, Fellow of the Society of Canada, and that kind of stuff. There is a different set of criteria by which they measure success. You can be poor as a church mouse but, by God, you've got three hundred publications. Now, is that good or bad? I'm not going to comment. It's all where you stand.

When entrepreneurs outside of academia, make it big, they expose it. Like an entrepreneur friend of mine and his Ferrari. In that culture that's one of the marks of success. Counting wealth in an academic institution is, in my opinion, not smart. You don't see me driving up here in a Rolls Royce. I own a modest car, I mean it's a nice car, but it's a modest car. I don't own a Ferrari, I'm not interested in one and all that stuff. I can let people know where I'm coming from if I have to, if it's important for some specific reason, but no you don't want to shout your wealth in an academic institution. You're just asking for trouble because a lot of academics are 'poor'. Academics are fairly well paid on the average, better than say, the average working man by quite a bit. They're paid to do mostly what they want to do, which is explore and have fun but I don't really mean to play around. I mean there are very serious scholars that are doing the work they want to do. They're not working in an office making twice as much money, but hating every minute of it. They're doing what they want to do. A lot of them will retire with a comfortable pension but they'll never have a lot of money. So, it's best to leave it alone. You can create envy, jealousy, etc. You can create that anyway in any society. I don't wish to say universities are any different or any better or worse than any other society.

When I say I am not interested in money, all it means is that I'm not interested in accumulating personal monetary worth. I'm not interested in that but it doesn't mean that I don't know how to create it. They're two completely different things. I was never interested in trying to accumulate one million dollars, two million dollars, ten million dollars, fifty million dollars. That's not what I set out to do. I was more interested in and I still am interested in how to get the company to grow. Now the company has to be profitable. If the company is not profitable it will not create more technology. I'm interested in technology. If you look at the core values of this company you'll find that our aim is to create better and better technology but to do that you need money, therefore you have to be profitable. And I know how to look after a company to make sure that it is profitable. But I'm not personally interested in a lot of money. There is a limit on how much I can eat, there is a limit how much I can wear, there is a limit on how much I can travel. Those needs could be satisfied, not with millions, but maybe with thousands. So that's two different things you see? Of course, I was always interested in providing comfort to me and to my family and I still am, but it doesn't mean that I'm interested in, in money. I like to be comfortable, yeah. I like to have a warm house; I don't want another cold house. I could afford to have a house which is 200,000 square feet with swimming pools and extravaganza and all that. I'm not interested. I'm interested in comfortable clothes. For example, the shirt I'm wearing probably cost $30 or $40. If I was interested in money, I would get a shirt which cost $400 or $500. I got a present, an Armani shirt which cost $400. But I really don't need a $400 shirt. You see the difference?

You have to have some motivation for the people doing it. I don't think the commercialization always happened as much without that incentive. People will just pursue their research. Why do people, who are just doing pure research, who aren't doing commercialization, why do they publish in journals? There are three reasons. First, they want to let their colleagues know what they're doing, and they want to be able to read what their colleagues are doing. The second thing is it's publish or perish, right? And the third is you don't get research money unless you publish. These things would happen but not to the extent that they happen without the monetary incentives. Also, we did a lot of research as part of our jobs but we also spent a lot of time that wasn't the university time pursuing these things.

One of the early investors in the company wanted to put money in the company. Unlike everybody else, he didn't want to have a share of it. We forced him to have a share of it. As far as he was concerned, putting money into the company is guaranteeing future employment for himself. He's an expert in this area. The company will know that he's an expert and they come to him when they want him because they'll know that he's the best in what he does. And, just having one more company in Waterloo who hires people is a good thing for him, personally. That's why he invested. Part of me says that about the company with respect to the university, too. So having started it off, having it grow and now having it be as successful as it is… I think it's a great thing for Waterloo. I'm proud of what happened with it and proud of my role in it.

Other Reward Systems

A number of years ago a graduate of my department made a career out of offering seminars for people in industry; they'd be one day seminars or weekend seminars. We went to large Canadian technology companies or he would gather a bunch of engineers from around Toronto together. Now the point was, I could do this because by that time I was a full professor, so it was no skin off my teeth. But I sat on many promotion committees, and certainly when it came to the question of rank or promotion for a junior professor, an assistant or associate professor, that activity would count for nothing. Now that activity was a way of transferring stuff out of the university environment because we were doing studies on technology development. We published them in journals and things like that but nobody we ever ran into ever read any journals on it. I've never run across very many industrial R&D-types who spend very much time reading journals. But if you gave a seminar and charged them $500 or something for the seminar and took them off to some place to talk about it they'd come. But that's not a method of dissemination that universities used.

I think the university really has to compartmentalize and say to researchers, "Look, not only do I pay attention to somebody who's producing fundamental work but I also like to reward those who are doing applied research: the guys taking the research and applying it to solve particular problems in the society. It's not that it has to be high tech, but the standard has to be of considerable level. Also, the university has to identify good teachers. It's no good just to say, "Oh, he's a good teacher." If he's a good teacher, he has to come up with techniques and facilitate much better transfer of knowledge from him to the student. The university has to compartmentalize that expertise and not to expect everybody to develop in all directions. Most of the universities are not doing it. We talk about the University of Waterloo. They could have the luxury to say, "I'm going to compartmentalize and I want to reward individuals who are really good fundamental researchers, reward individuals who are applied researchers, and reward good teachers. They're not doing that because it takes a lot of effort at the top level to put this process in place. They'd have to work with the faculty association because immediately when the faculty association sees that the university's trying to change things, they assume that they're out to screw them, you see? So you'd have to basically work carefully with them and you'd find that the faculty association would be cooperative because they'd realize that it's something which is good for them and it's good for the university. It's good for the individuals. But it's a lot of work to do that and come up with processes.

The answer [to how to promote university-industry relationships] is like a lot of things, in my view. The most you can do is create an environment. I think whenever there's a big plan where government throws in millions of dollars and a centre of excellence is set up and five industries are brought in here and ten universities come in here and they produce a big program. To me, those things almost always fail. I think what has to happen is that there has to be encouragement and there has to be an environment, which fosters entrepreneurial things. I think people have to start off on a one-on-one basis working at a low level and then see things grow. I believe in bottom-up, not top-down. You only set up a big structure to handle something, which is already working. You don't set up the big structure first and then try to plug people in to make it work because it's just a scramble for money and there are fights. The motivations are all wrong.

I think the answer is you just create an environment which facilitates these sorts of things. You encourage it verbally and then you let the individuals try to fulfill those goals as best they know how. And that will be different for everybody. I think they should be encouraged to take risks. That's a huge, huge part of it. That people are allowed to do things, which are risky without hurting their reputation and career within the university. You should be allowed to fail, that's part of research. The way we do research in the universities tends to be you're rewarded for the things you succeed at, which is very unfortunate because some of the things you don't succeed at are the most important issues that exist and you should be allowed to fail and try again, and fail and try again, and still not be marked down because of your failure. It's very hard because the university, like everybody else, tries to quantify us. So your advancement through the ranks depends on successes, your pay depends on successes. So it's hard to allow people to take risks.

It's very difficult, I've found, for practicing engineers and practicing engineering academics to drink coffee together. They're operating on different incentive systems. If I'm out in the practice of engineering and I'm out there starting to develop a product my future lies in the success of the product. If I'm an academic my future lies in the success of publication. Those are different and facing in opposite directions, quite often. Academics get frustrated because the practicing person isn't really interested in coming to a conclusion and the academic isn't really interested in the fact that this is going to be a product and we have to take into account a number of other considerations that are outside of my field of expertise and so it's hard for them to work together. You have to set up a situation where they work together and the difficulty is both organizations, the academic organization and the industry organization, don't set up incentive programs to have them work together. And industry is always resenting having to pay money to their practicing people to go off and do a lot of brainstorming or, 'If we let them spend too much time with this bunch of academics they'll get to be too theoretical'. It costs them money. It costs a lot to take an engineer out of his environment and send him somewhere for a week because you lose all that productivity and you lose all of the people that they relate to in your organization or out because there's a hole that week. And similarly university departments aren't very amenable to see a faculty member going and spending a week at a company. What's he doing? Where're his students? So it's very hard.

There is a certain onus on those three parties, industry, academia, and government, to set up rewards systems that encourage the coming together of academia and industry; that don't discourage it. That's particularly true in universities where you have applied faculties like engineering and architecture and things like that. Now in Germany or in Europe it's not nearly the same problem because the institutions that teach applied stuff are not embedded along with the pure researchers so they can have their own rewards system. The one thing that happens within a university system you see is that you get all these different faculties: arts, health studies, environmental studies, engineering, science and mathematics. And the only common ground they can talk about is publication. So at the university level, publication becomes the fundamental measure; everything else is secondary to it. Then after publication comes teaching and there's a commonality here that they can get at. But when you get to an architectural faculty member who designed a new museum, how do you relate that to what the historian has done? Design activity is not a common thing to all departments and all faculties in universities, so it doesn't count. Ask any architectural faculty member how hard you have to fight to get the fact that you've designed a building that was built recognized within academia as a legitimate reason for being promoted.

I think there are different rewards you know. Applied math and science students are rewarded by the phenomenon, 'Look, Ma, what I built!' Whereas pure math and science students very often are rewarded by the Eureka phenomenon, 'Now I understand!' Well, for a lot of applied students, understanding something isn't the end of it. How do you apply it? To what? Build what? That's why many of those students, once they graduate, get somewhat alienated from the university. The university's rewards system isn't involved in this sort of, 'Look, Ma, what I built!' sort of thing. It's, 'Look, Ma, what I now understand.'

Theme 4: Attitudes & Motivations Regarding the Role of the Professor

This theme captures information regarding the participants' attitudes towards research directions and the role of the professor and/or the university in society and some descriptions of those aspects of being a professor that they do or don't enjoy. Therefore, this top-level theme is further divided into two themes: 1) attitudes; and, 2) job elements and job satisfaction.

Attitudes

I personally feel our job is to really act as a dictionary or a lexicon as far as industry is concerned. In other words, there're a lot of things we do here, which I don't think are understood by industry. Maybe we're using the wrong terminology. There's got to be someone, maybe like myself or someone who we're teaching, able to translate what we're doing to be understood by and be used by people in industry, you see. We can do all sorts of wonderful things but I guess the important thing is to use them. In many respects, that's really important thing. We can do all this work and really what does it mean? The thing is only any good if it's useful.

Faculty members have three basic jobs within the university: research, teaching and service. If you had something that could be exploited, for societal good and maybe for your benefit as well, and it does not conflict with those other duties, please do. I know a bunch of guys who got together and said, "We've got some neat ideas here," and started up a company. I didn't see them let down on their academic duties and at least one of them holds a prestigious research chair and is very well-known in his field.

[That there is a problem of maintaining objectivity in research when doing contracts] is probably truer in the pharmaceuticals field than it is in my field. I'm sure the medical and pharmaceutical types are subject to a lot of criticism because they are 'bought by Pfizer' or whoever. We get some of that too. You know, if I did a project for a company, the nuclear industry would accuse me of being bought by the hydro-electric industry. I'm exaggerating a little bit, but the fact is that the best thing you can do is try to maintain your objectivity, let the chips fall where they may. We've done projects for lots of large companies and we get criticisms that we've been bought off by one or the other, but I think we can defend every piece of research we've ever done for them in the sense that we absolutely let the chips fall where they may. We don't falsify results. If you do that, you're going to be found out. So you cannot compromise your integrity. You're subject to criticism, there's no question about that.

[The applied side of the sciences is] a great source of interesting problems. James Watt developed the steam pump and, because they wanted to make these things work efficiently, they started thinking about pressures and measurements and ultimately we got not just the steam engines but the Second Law of Thermodynamics. Gauss, a great mathematician, started looking at applied astronomy; always looking up at the stars. Think about how much we've learned about physics because people are interested in astronomy. Applications feed the theory and theory feeds the applications. It seems to me there's got to be that interaction.

I argue both for the pure and applied. I think in a university I'd want that sort of balance. I often find myself arguing with advocates of pure research on one hand and their opponents on the other hand and I have arguments with both of them. [laughs] We need some sort of middle ground.

If you're doing something that is very technically-oriented, you're going to attract different people. They're no less bright, but their interests are quite different and they want to be doing applied stuff and they don't really care about the theory as long as it appears to work, it seems to be good in a lot of practical cases. But you can't advance it unless you know the theory. The better thing is to have them both in balance. Then you get the cross fertilization.

If you get to be at a point where you're just a minion of the industry then what will happen is you will gradually be shifted from fundamental research to being a product designer because product design is the thing that industry wants. It wants a product you can sell. The researcher wants to generate new information that people can use. A lot of universities couldn't even care whether it's useful. It's just new information. They're the two ends of the spectrum. If industry dominates it will be up at this end all the time. If the university dominates you're down here all the time. So our faculty's role is to act as an interlocutor between those two things.

I think that university should be doing work, which, if it sees application, it will be five to ten years down the road. You're not aiming at next year or next month. So it's not the short-term goal that you should be pursuing it. It's the long term goal. It's to light the path so that you or other people then can do the applications in the future. If you're just doing bread and butter things, you're not really learning. You're not advancing state of the art, there's no research component to it. It's no good just having a scientific problem. You solve it and then you publish a paper and that's great. Now you have to really try and take it to the next step. Is there a way I could modify this technology or develop it a little bit further such that it can solve a specific problem somebody has? And that problem could be a small problem or large problem. Then you adopt it or change it a little bit further to solve another problem, then it starts growing.

There isn't any technology or research output which, if it's properly identified and properly understood, couldn't solve problems which will be a benefit to the society. It doesn't matter what technology it is, it could even be in the arts. It could be a person who is helping with speech therapy for kids. She's coming up with techniques and those techniques are technology. If it's properly understood and properly documented, that technology can be used in a different area to solve another problem elsewhere. It's good for the society. It's good that it displaces old technologies and introduces new technologies and then it also introduces new jobs and so on. So, it's a good solution for the society and for the country. People think that technology has to be technical, but not necessarily.

There's too much focused research, mission-oriented research. If you make it too narrow I think it's going to choke off things because you could specify a certain goal, if that's all you're after you may or may not get to it. And when you get there it may or may not be as important as you thought before. But if you have the flexibility to go in the direction and the inclination to apply what you're doing then I think having a greater flexibility has a much greater social value in the long run.

Job Elements and Job Satisfaction

[The best part about being a professor is that] I get to do what the hell I like. I enjoyed the acting part of teaching and I enjoyed having all these bright people around to sort of discuss and argue with and being able to maintain that. But just freedom is the thing. You can't price that. You don't make as much money; if I had been out in industry, I could have probably made quite a bit more but I was working with some really neat people. My colleagues are really neat people, a lot of fun. We had no idea of what was going to happen when we invested in this company. We took a chance because it seemed like an interesting thing to do and we had some good ideas and very clever people. You have to enjoy what you're doing. I can't say I enjoyed absolutely every minute of it, but damned near. We worked hard but we worked hard because that's what we liked to do and that's nice.

My board of directors advised me that I had to let go the research; had to let somebody else run the research of the company and I did. I let it go but I didn't give up trying to stay with the technology: going to conferences, understanding it, I'm just not doing hands on research. Sometimes I miss it, so whenever I have to give a talk about technologies, I sit down and I research. I enjoyed it very much, you know.

I don't like the bureaucracy that goes along with some of the research contracts and projects. I mean who does? Particularly, now that our university's become more bureaucratic over time… That's the way things are, so I probably spend much more time than I want to on dealing with the financial services people and so on, keeping track of accounts and stuff like that. Doing all the paperwork that goes along with research contracts. That's the drudgery of it. I don't think I'm unique in that sense. I don't think anybody likes that kind of thing.

I think it is a beautiful subject. There's a certain beauty to the logic. But it's very hard to explain to people who don't know the field.

[The best part of my research day is] trying to come up with ideas that make sense. The question I always have is, "Why?" I think a lot of people follow the trend. I quite often don't do that because I look at it and I can see problems with it. For example, in some things, we really haven't advanced because the technology is just as complicated as before. And that's great for job security, but it seems to me it's wrong. So I'm very much for simplification.

I think it is being my own boss, to a certain level that I get to choose what I want to do. Not all the time, not every day, not every hour of every day but generally being able to set my own goals and my own agenda and my own timetable. I like the interaction with the students. I like the interaction with other profs, working with them. I think that those are the major attractions.

I like working on projects with colleagues. I like the belonging to a lot of organizations. I'm on committees; I chair different things and so on. I think the attraction in working with colleagues is that quite often you're plowing new ground, in the sense that you're solving new problems. As applied scientists that's what we like doing, you know. I like the diversity of the projects that I work on too, rather than working on project after project within one particular area. One of the advantages you have is when you have a lot of experience, is that you have a way of attacking problems. Even though you may not know a heck of a lot about the area, you hopefully are smart enough to know where the pitfalls are, and smart enough to know that somebody else has probably worked on this problem before. You find out what has been done, so that you don't reinvent the wheel. You know, it sounds simple, but it's probably experience that, if anything, teaches you that.

[The best part of doing research] can happen when I should be sleeping or off and on during the day when I'm into something. My wife is very understanding so if I go into a deep concentration she knows what's going on. It can happen any time I guess. It's frustrating [laughs] and very satisfying, both. I can't explain why that is but for example you're lying awake at night when you know you should be asleep and you're going through calculations where you're doing a theory or something. I've always tried to take time to do outside things that I've enjoyed apart from my university work and I sometimes feel I'm cheating on that, to do research.

In my first year of undergrad, I was taking a course that I really liked. And I was studying for it in a library with a whole bunch of other people. We all had exams at the same time, starting at one o'clock and I was there about twelve. And at two-thirty I looked up and the place was deserted. I'd been concentrating so much on this material that I had no idea that anything had happened. Everybody got up and went. So I had to go and track down the professor and he gave me an oral examination on the spot and, of course, since I was concentrating on this material there wasn't any problem. [laughs] You know I lose myself in things like that.

Theme 5: Career Decisions

This theme includes excerpts related to two aspects of career management: 1) work/personal life balance; and, 2) mid-career change.

Work/Personal Life Balance

My wife really raised our kids. I didn't spend as much time with the kids. My wife was also a professional but she decided not to work and then she looked after the kids. She looked after our life. We went to the theatre and we went to concerts but I have no idea of where she'd get the tickets. The kids' birthday parties and all that, I was there when they happened but I did not set them up. I used to work during weekends for the university. There are trade offs. If it wasn't for my wife, a smart woman, I could have never have achieved what I achieved.

[The long hours at the university and spin-off didn't affect my personal life] too much because, fortunately, my wife is very understanding. Her full-time job is at the house, and when a lot of this was going on, the children were in high school, so it wasn't a big problem with having little kids at home. They were a very supportive family, so it really wasn't a problem, thank God.

It is a big factor. My wife is an unbelievable person. She's just always been supportive. We've tried to be supportive of each other. Yes, there were demands. But, the reason I mention this, I had a colleague involved in another technology transfer. His wife wasn't that supportive and ultimately it tore the marriage apart.

I had an understanding family, they're great. My wife has been so good to me over the years. She's allowed me to work sixty, seventy hours a week, and kept the operation at home going, and kept our kids happy and well adjusted and did a terrific job.

Mid-Career Change

I did design work on a consulting basis for different companies. It was very lucrative. I was also doing consulting through the university and we used to do the some of the consulting through that. So money was not a consideration, it was not the motivating factor at the university. The motivating factor was to innovate and that was quite exciting.

I wasn't sure whether I would be able to continue being able to innovate as I got older. So when I looked at those who really innovated at a much higher level than I did, they were in their twenties. So I felt that I would not be able to innovate at the same rate I used to innovate before. I thought that as I get older my work will become incremental. Therefore, I should try to develop the technology.

I was not interested in consulting because there is no scope for leverage. If you trust your technology to a company then you can't have it multiply and create more technology and more jobs and so on. You can't see the results. At my start-up, you can see it.

I enjoyed being a prof. I like teaching, I enjoy undergraduate courses, I liked being able to do my own research and decide what I wanted to do and so forth. I enjoyed being a professor, I was just there too long. It would be very nice if after twenty-five years, you could automatically look at going into another, another job but the way the pension plan worked at The University of Waterloo, you were locked in. They tell you when you're going to retire and you really don't have any choice. I would have left earlier if I could have taken my money out of the pension plan. I just felt I needed to do something else. The way the situation works now they really have you tied up to age sixty-five. If you could go between fifty and fifty-five, then during the time you were a professor you could, you could plan your life and say, "Okay, at age fifty or age fifty-two or whatever, I'm going to start a company and try and commercialize the technology I've developed in the lab, or I'm going go and work at NRC, or whatever. But they won't allow that. You're stuck there until they let you go. The early retirement penalty at the University of Waterloo is so large that you really can't consider leaving more than five years early, at age sixty, and that's already too late for a second career. I feel very strongly that they should allow people to leave at, say, age fifty so they still have time for another career. But that's not the way it is.

[I started the spin-off] because it's fun. It's exciting and I really enjoy it. It's a real challenge and it's different as well. One of the problems of being a university professor is there's two possibilities: you can be a university professor and after about twenty years you've done everything that you can do as a university professor and then you can become Dean or you can become Chairman or you can get involved in University administration in some way. That's a common thing to do but I was on the back end of a hiring bulge. Most of the administrative positions of the university were not open to me because there were a lot of people in that bulge right ahead of me. I saw my opportunities would lie in companies and I liked that.

[I enjoy technology transfer because] it's a challenge. The main thing is the challenge. The other thing I liked about it is: imagine the stupidity of it, if I had spent all these years working at the University of Waterloo on this technology and had not started the company. All of the value, the commercial value and the research would have just been lost because nobody else would have done anything. It's not the kind of thing that you can license because there's nobody out there who wants to license it. I felt that, if I could use it and develop real products and have some effect on science by developing those things, it would be great fun to do and I wanted to see it done. Otherwise you write your papers and the papers get published in journals and five or six people read the paper. Then the paper is there, forever stuck between the pages of that journal, and it doesn't mean anything. To a large extent, I felt that it was a way that I could make the results of my research a lot more meaningful and useful, and I could generate some jobs for people. I find it a hell of a lot more fun than just going and teaching classes every day. Teaching classes was great for the first twenty years but after you've done it for twenty years it gets pretty boring. I can't imagine how people could stay and just keep doing the same thing over and over and over for all those years. It would drive me nuts.

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