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Technology Transfer and Innovation Policy at Canadian Universities: Opportunities and Social Costs

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Knowledge Synthesis Report on Leveraging Investments in Higher Education Research and Development to Stimulate Innovation

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Executive Summary

This report, supported by a Social Sciences and Humanities Research Council (SSHRC) Knowledge Synthesis Grant, critically examines the role of universities in transmitting knowledge in the forms of technology transfer mechanisms, intellectual property agreements and other knowledge diffusion policies. In reviewing and synthesizing the recent literature on the topic, we seek to provide some initial evidence-based policy recommendations in order to generally strengthen Canada's innovation ecosystem and more specifically to maximize the return on the nation's investment in higher education research and development.

While much attention has recently been given to innovation policy, the evidence suggests that Canada's innovation performance has declined relative to other developed nations. Understanding Canada's performance in this area, and how it can be improved, is crucial because greater flows of knowledge from academia to various receptor communities will facilitate the development of new goods, programs and services. Such improvements carry the potential of not only enhancing productivity in order to strengthen economic performance, but also to improve overall social welfare. Our review suggests that while Canada's universities can play a central role in the nation's innovation infrastructure, more attention needs to be given to the relationship between academic activities (such as scholarly research, teaching, training and service) and the diffusion of the benefits of these activities through the broader society. These relationships need to be conceptualized in a broader manner than has been the case. While much of the traditional literature recognizes this link between research and innovation, it is often framed in terms of technology transfer and commercialization. The creation of intellectual property, licensing activities, the establishment of new business entities and other legalistic categories have been the principal outputs for purposes of the evaluation and measurement of overall innovation policy.

Our review of the literature suggests that while technology transfer and commercialization (and their corresponding legal devices) are an important component of innovation policy, a broader and more holistic approach is also needed in order to recognize all of the potential societal contributions flowing from educational institutions. For example,

“technology transfer” might be thought of as a component of the broader concept of “knowledge diffusion,” which is dependent neither on the subject matter being limited to “technology” nor the method of distribution being limited to a “transfer” (a legal term of art involving an exchange of value between a transferor and transferee). “Diffusion” in a broader sense might take on other forms including the dissemination of research findings through publication, the training of “highly qualified personnel” (HQPs) or the direct provision of service to the community on the part of academic personnel by way of consulting and other forms of engagement.

Recognizing some of the inherent tensions that may exist among these various knowledge dissemination functions is crucial to developing a broader and more holistic approach to innovation policy.

In terms of methodology, this report is based initially on a review of the literature conducted in selected databases and additional sources as indicated in Appendix A. The literature was then reviewed for relevancy and refined, resulting in the entries reflected in the bibliography.

The results of the review are presented first in terms of the range of what are generally referred to as technology transfer policies evident in Canadian post-secondary institutions. These include patent policies, licensing arrangements, spin-offs and other transfer methods. A more specific discussion on the role of patents follows which examines the usefulness and limitations of patents as an indicator. The particular problems of the anticommons and patent thickets are considered as they pose potential constraints on innovation through the over-protection of intellectual property.

The review closes by identifying some of the limitations of this study, gaps in the existing research, and suggestions for areas for further research. We present the overall implications of our synthesis as well as policy recommendations following the introduction.

I. Introduction and Context

Although the issue of innovation policy has attracted significant attention in Canada, the country's actual innovation performance has declined relative to other developed nations (Canada, 2011; STIC, 2011). A central component in Canada's innovation ecosystem is the transfer of knowledge from academic institutions to other receptor communities including industry and government. This knowledge synthesis grant report aims to enhance knowledge flows stemming from university research with the aims of better leveraging public investments in research and development (R&D) and strengthening Canada's innovation ecosystem. This report examines the role of universities in transmitting knowledge in the forms of technology transfer mechanisms,[2] intellectual property (IP) agreements[3] and other knowledge diffusion policies. It also examines the usefulness of patents as indicators of university innovation and the potential problems that may arise from the overreliance on patents as a means to encourage university innovation.

Improving Canada's performance in the area of innovation is crucial for a number of reasons. First, greater flows of knowledge from academia to receptor communities[4] facilitate the development of new goods, programs, and services, and enhance productivity all of which help strengthen economic performance and social welfare. Several recent reports have emphasized the importance of improving collaboration between Canadian universities and industry (Canada, 2011; STIC, 2011; OECD, 2010), and the government has expressly committed to strengthening university linkages with both industry and the public sector in its 2007 science and technology strategy (Canada, 2007, p. 46). Although Canadian universities currently do over $1 billion in research contracts for private sector and another billion in partnership with the non-profit sector (Munroe-Blum, 2012), Canada ranks near the bottom of OECD countries with respect to the proportion of businesses collaborating with universities to undertake R&D (Canada, 2011, p. 2-16). Furthermore, R&D funding to universities still lags far behind business sector investment in

[2] Technology transfer mechanisms primarily include university run technology transfer offices (TTOs) and technology licensing offices (TLOs) as well as spin off companies.

[3] Intellectual property agreements usually deal with ownership of patents, but also includes other intellectual property rights such as trademarks and copyrights.

[4] Receptor communities for university research include industry, government, and the non-profit sector. They also include other researchers who will cite and build on research.

R&D (Canada, 2011). Canadian universities and teaching hospitals generated only 1613 commercialized inventions in 2008 according to Statistics Canada (2010, p. 20). While these institutions filed 1791 patent applications, only a total of 346 patents were granted, representing a drop of over 20 percent from the previous year's total (Statistics Canada, 2010, p. 21). Although commercialized research resulted in revenue of over $53 million for Canadian universities and hospitals, the total value of contracted research undertaken was just less than $2 billion (Statistics Canada, 2010, p. 17 and 24). However, it is important to note that the low return on contracted research in terms of commercializable outcomes does not mean that universities do not play an essential role as institutions for innovation and research. Universities play an invaluable role in conducting basic research and the development of theory in addition to applied R&D efforts. Furthermore, commercialization of university research represents only one of many was that knowledge is generated by universities and diffused to the public. Still, given the nation's poor innovatory performance, it is crucial that the knowledge diffusion from Canadian universities be strengthened.

While Canada's universities can play a central role in the nation's innovation infrastructure, more attention needs to be given to the relationship between scholarly research, innovation, commercialization and technology transfer. Recognizing some of the inherent tensions that exist between these functions is crucial to the development of a coherent innovation policy that will act as a framework for harmonizing economic development and improving social welfare, while at the same time recognizing the special roles that universities as a knowledge nexus that connects researchers, industry, government, the non-profit sector, and the broader community. At the outset, we believe that Canadian innovation policy lacks such a coherent framework which is capable of taking diverse and sometimes disparate goals into account.

II. Implications and Recommendations

Our general conclusion is that Canada's innovation policy lacks an overall framework that is both holistic and inclusive and which also takes into account the various roles that need to be played by post-secondary academic institutions, government, private industry and the non-profit sector. Closely related to this lack of overall framework is an over-reliance on particular types of indicators as well as a narrow approach to the broader process of knowledge diffusion.

Much of the literature on "technology transfer" is focused on quantitative measures that are preoccupied with counting discernible artefacts (the problem generally described as "looking under the lamppost"). Without losing the importance of "technology transfer" as a component, we would favour more thinking about the broader concept of "knowledge diffusion." Knowledge diffusion includes, but is not limited to, technology transfer (see p. 9). In order to better appreciate the full range of the diffusion of university research, a broader range of innovation indicators should be examined (see p. 25).

The literature is overly focused on certain disciplines, and a broader approach is needed. While a focus on medicine, biotechnology, natural sciences, and engineering is understandable, more attention needs to be given to the potential contributions from the social sciences, humanities, and education (see p. 30).

The more limited notions of technology transfer that dwell on the creation of discernible artefacts can be broadened to include non-commercial and social impacts, including open access models of knowledge dissemination. Furthermore, rather than examine technology transfer through legalistic categories, research should focus on the functional characteristics of various diffusion mechanisms (see p. 23 and 30-31).

More attention needs to be placed on human factors—that is, the role of human capital as a valuable output of academic work in its own right. This would include giving more expanded attention to consulting by faculty members and other engagement of academic personnel in government, the private sector, and non-profits. In terms of teaching and training, the development of Highly Qualified Personnel and related areas of placements and co-ops needs to be incorporated into the discussion of knowledge diffusion policies (see p. 23-24).

While patenting activities will remain a key component of a commercialization strategy, a balanced approach is needed that recognizes the potential for negative social costs resulting from the over-protection of intellectual property. The potential problem of patent thickets and the anticommons needs to be incorporated into institutional and public innovation policy discussions (see p. 28).

A clearer definition of "spin-off" is needed. The Tri-Council funding agencies, in coordination with the federal government, should develop a taxonomy for classifying spin-offs to improve measurement and research on this important means of technology transfer (see p. 18).

Given the importance of innovation in the medical and biotechnology sector to the health and wellbeing of Canadians, more study is needed as to the effectiveness of CIHR's Commercialization and Innovation Strategy in order to assess how successful it has been in achieving its objectives (see p. 21).

Recommendations in terms of areas of areas for further study are provided in the last section of this report.

III. Methodology

Several graduate and law student assistants at the University of Western Ontario conducted the literature searches and identified relevant papers up to 23 April 2012. While our search protocol was informed from readings related to conducting systematic reviews in medicine, our search cannot be construed as comprehensive or exhaustive due to the short timeline of the project (Grimshaw, 2010, p. 14-17; Eden, Berg & Morton, 2011, p. 81-154 and 265-280; The Lancet.com, 2011). The list of resources searched is tabulated in Appendix A. The selected databases included broad topical indexes (e.g., *Scopus* and the *Web of Science*), subject specialized (e.g., *SciFinder* and *Compendex*), legal (e.g., *Legal Trac*), government-information based (e.g., *Canadian Research Index* and *PAIS International*), and newspaper databases (e.g., *Factiva*). Search strategies were primarily keyword based and made use of truncation and proximity operators. The search terms were identified from the literature, used by a specific database, and by subject experts on the research team. Searches were limited to English language materials only and a publication date range of 2000 to 2012 was imposed.

Additional published and unpublished materials were identified by manually searching the reference lists and footnotes of relevant reports, by browsing the table of contents of key journals (e.g., *Research Policy* and *Journal of Technology Transfer*), and perusing the websites of relevant associations (e.g., Association of University Technology Managers). We employed both Google and Google Scholar to undertake an extensive but targeted gray literature search focusing on reports from Canadian universities and conference proceedings. The identified literature was systematically reviewed by a minimum of two Library and Information Science doctoral students to determine inclusion in the final report. Finally, research materials were organized using *RefWorks* bibliographic management software. The results of the searches were then synthesized to write the report, and all cited materials have been listed in the bibliography.

IV. Results of the Knowledge Synthesis on Canadian University Technology Transfer Policies

This section of the report outlines the results of the knowledge synthesis on Canadian university technology transfer policies. It begins by examining the scope of technology transfer policies at Canadian universities and also discusses specific mechanisms and the uniqueness of the medical and biotechnology sectors.

A. The Range of Canadian University Technology Transfer Policies

In Canada there is considerable range in the technology transfer policies of universities. At the outset it is crucial to note that technology transfer policies form only a small subset of the full range of means through which knowledge generated by university research is diffused through society at large. The Knott and Wildavsky (1980) scale for measuring knowledge transfer includes seven different categories of activities that transfer knowledge ranging from the transmission and presentation of research by faculty to those outside of academia on one end to involvement in business and commercialization on the other end of the scale (1980). Policymakers should not simply limit their analyses of university innovation to technology transfer mechanisms, and instead use the broader concept of knowledge diffusion and the Knott and Wildavsky approach in particular given its frequent use in literature on the subject of university innovation (Landry, Amara & Ouimet, 2007, p. 566). While we recognize and stress the importance of considering the role of universities as knowledge diffusers not simply technology transfers, this section of the report focuses on technology transfer policies, which in turn reflects the tendency for literature in the area to approach subject in a more focused but limited manner.

Technology transfer policies are connected to intellectual property (IP) policies in general at the post-secondary institutional level for which, note LaRoche, Collard, and Chernys (2007), there is no nationwide policy standard. Rather, each university has its own IP policies *sui generis* (LaRoche, Collard, & Chernys, 2007, p. 139), typically through faculty collective agreements but sometimes, in cases where collective agreements may not apply, through individual faculty contracts. Additionally, an IP culture has evolved in Canadian universities that resembles the environment of the United States, where academic institutions have, since the passage of the

1980 *Bayh-Dole Act*, increasingly sought greater ownership and control of innovations borne from university research (Eisenberg, 1996; Rosell & Agrawal, 2009). Insofar as IP in Canada is dealt with as a matter of technology transfer, post-secondary institutions have over the last two decades moved toward the establishment of special IP-related offices, most notably Technology Transfer Offices (TTOs, described below), to facilitate innovation and commercialization of research. According to the Statistics Canada's 2008 Survey of Intellectual Property Commercialization in the Higher Education Sector, 88 percent of Canadian universities were actively engaged in intellectual property management through IP offices (Statistics Canada, 2010, p. 10). In addition to legal mechanisms and bureaucratic structures within universities, Sá and Litwin (2011) report that government has become more intensively involved in facilitating university-industry technology transfer relationships, particularly with small- and medium-sized businesses, so as to prevent potentially marketable discoveries and applications from going through a kind of "valley of death" (p. 432) that they might have faced had they not been supported through government initiatives. The "valley of death" is the mid-point in the process of transforming university research into a viable business in which a promising technology is past the point where it can be researched and developed by a university but before it can attract commercial capital to allow for product development, production, and marketing (Niosi, 2008, p. 6). Overcoming this "valley of death" is a recurrent theme in recent literature on improving university innovation in Canada (Niosi, 2008, p. 6; Sá & Litwin, 2011, p. 432).

Researchers of university technology transfer to the private sector have commented on how the literature in this field, particularly in the last decade, has grown appreciably (Landry, Amara, & Saïhi, 2007). Analyses in the early 2000s were focused on the evolution and effectiveness of structures within universities such as Industry-Liaison Offices (ILOs). Perceptions by the academic world and industry of these offices have been studied, such as Fisher & Atkinson-Grosjean's examination of how ILOs have been perceived skeptically as conduits through which capital is introduced into university culture (2002). ILO staff were seen to deal with defining intellectual property policy, contending with the conflicting cultures of academia and industry, and reckoning a sense of intellectual property and innovation as a public good, all the while being regarded as "Janus-faced" (Fisher & Atkinson-Grosjean, 2002, p. 453) in that academia saw ILOs as too aligned with industry, whereas industry perceived them as too aligned with academia (2002). Considerably more skeptical is Armbruster (2006), who views the industry-connected, entrepreneurially-oriented university as a "failed idea" (p. 1) that ultimately disappoints the expectations of both academia and industry and erodes scientific commons.

The literature has more recently diversified to look at TTOs as institutional apparatuses of knowledge translation and synthesis. McAdam, Miller, McAdam, and Teague (2012), writing from the United Kingdom, pick up on earlier commentators and note that TTOs are continually challenged by the differences in culture between academia and industry, that technology transfer to the private sector has not become any easier or more effective (p. 57), and that TTOs need to "engage a plurality of stakeholders and to accept that their performance measurements will be more commercial and with shorter delivery timescales" (p. 66). Bubela and Caulfield observe in their qualitative study of 20 personnel from various Canadian TTOs that such offices were generally misperceived by stakeholders as revenue-generating structures within universities rather than as promoters of knowledge creation as a social good, and that current metrics of the effectiveness of TTOs need to be reconsidered (2010). Focusing specifically on the Canadian context, Rasmussen (2008) notes that TTOs are connected to federal government policy on stimulating the transfer of knowledge and technology to industry, and that TTOs are an aspect of two types of government objectives: improving universities' capacity to make their research more commercialized and the development of specific commercialization projects within universities (p. 513). However, TTOs are seen as instruments of a bottom-up approach to knowledge and technology transfer (Goldfarb & Henrekson, 2002), rather than as something emanating from government.

The various studies of Landry and his research colleagues reveal that academics engage in a variety of formal and informal knowledge transfer activities, and that a "complementary set" (Landry, Saïhi, Amara, & Ouimet, 2010, p. 1387) exists between publication, patent creation, spin-off development, consulting, and other informal practices (p. 1396). Earlier work done by Landry and his research team revealed that academics were more active in transfer activities of non-commercial knowledge rather than commercial knowledge (Landry, Amara, & Ouimet, 2007), which could have ramifications for TTOs with respect to focusing on the sharing of non-commercial knowledge (2007, p. 586). Bekhodja and Landry observed that academic activities related to a researcher's strategic positioning with respect to knowledge transfer are influenced by a variety of factors such as research budget, university localization, the degree of radicalness of the research, the degree of willingness for a particular university/researcher culture to take risks, and the researcher's publications, and that academic collaborative behaviour leading to knowledge transfer does not result from a particular view of return-on-investment or transaction costs (2007, p. 309). Additionally, a "degree of mistrust" (Bekhodja & Landry, 2007, p. 324) may exist amongst university/business/government partners, and that adopting a culture of risk-taking may not mitigate mistrust.

The literature refers to a 'virtuous cycle' (Landry, Saïhi, Amara, & Ouimet, 2010), or a relationship that exists between the publication of research and its transfer outside the university. Publications produce knowledge, which subsequently generate "informal transfer activities" (Landry, Saïhi, Amara, & Ouimet, 2010, p. 1397) that improve academics' knowledge about the private sector, which in turn allows academics to be involved in patent development, spin-offs, and consulting (2010). These activities then contribute to further publications, and so on. Van Zeebroeck, van Pottlesberghe de la Potterie, and Guellec observe the same type of cycle; they note that the development of patents does not reduce the quantity of subsequent publications (2008, p. 253). However, an inverse relationship has been observed—by Landry, Saïhi, Amara, and Ouimet—between the academic activities of teaching and publication, in that an increase in teaching brings about a decrease in publication, and vice versa (2010).

Other strands in the literature explore knowledge transfer through not through TTOs or sets of academic social and professional practices but through an investigation of actions or characteristics of university groups and even individualistic behaviour. Troshani, Rampersad, and Plewa (2011) consider the matter of optimal characteristics of universities that foster greater technology innovation and transfer, such as technological competence, accountability, accessibility, and communication (p. 88). At an individualistic level of analysis, Eder, Fier, and Grimpe discuss the mobility of scientists and its effects on publication: greater mobility of scientists between a home country and a guest country constitutes a "catalyst for excellence" (2011, p. 800) and that both home and guest countries benefit from scientist mobility in terms of publications and knowledge transfer (2011). Hoye and Pries explore a sub-section of Canadian engineering, science, and mathematics academics known for 'repeat commercialization,' and who initiate a disproportionate amount of commercial activity at their institutions (2009).

According to their study, repeat commercializers accounted for 80% of innovations brought to market (2009, p. 685). Individuals who often engage in commercialization are voluminous publishers (Hoye & Pries, 2009), though they operate in a kind of "grey zone" (Crespo & Dridi, 2007, p. 79) in which tensions exist regarding intellectual property ownership and conflict of interest issues (2007). The finding that those who frequently undertake commercialization and commercial partnerships publish at higher levels is particularly important because it suggests that linkages with industry do not result in a dampening of traditional academic knowledge flows.

Finally, repeat commercializers have active relationships with industry (Hoye & Pries 2009). Linkages between researchers within universities and outside partners are a particularly important factor for improving knowledge flows (Landry, Amara & Ouimet, 2007; Crespo & Dridi, 2007). These individuals are seen to have an ability as well as a desire to commercialize their research, and Hoye and Pries recommend that institutional knowledge transfer policies and programs be geared so as to facilitate this academic population (2009). Another important finding is that universities may have to provide greater incentives to faculty members to commercialize their research findings, as a researcher's unwillingness to assist in commercialization can impair knowledge flows (Hoye & Pries, 2009).

The literature on Canadian university technology transfer policies is quite broad, reflecting the general heterogeneity of practices and policies in Canada. While numerous mechanisms exist to facilitate the diffusion of knowledge from universities, patents as a technology transfer mechanism represents a significant part of the literature and are discussed in the following section.

B. Technology Transfer Through Patents

Research into university technology transfer has also specialized and become more sophisticated over time (Landry, Amara, & Saïhi, 2007) to focus on specific instruments of translation, such as patents and spin-offs (Landry, Amara, & Rherrad, 2006). Unlike in the United States, Canadian universities do not have a uniform patent policy with both university-ownership and inventor-ownership models existing at different universities (Robinson, 2006, p. 398; Ketis, 2011). For inventions 22 percent of Canadian universities have university-ownership policies, while inventor-ownership policies are more common making up 42 percent of university IP policies (Statistics Canada, 2010, 16). Rarer are joint-ownership models where both the inventor and university retain ownership rights (Robinson, 2006, p. 398). As of 2008, 17 percent of Canadian universities and teaching hospitals had no policy on ownership of inventions (Statistics Canada, 2010, p. 16). University-ownership models are found at the University of Saskatchewan, McMaster University, Memorial University, McGill University, l'Université de Montréal, University of British Columbia, University of Guelph, University of Ottawa (Robinson, 2006, p. 399). Conversely Queen's University, Simon Fraser University, University of Alberta, University of Calgary, University of Manitoba, University of Toronto, University of Waterloo and University of Western Ontario, require researchers to disclose inventions that they intend to patent; however, inventors still retain ownership rights (Robinson, 2006, p. 400).[5] Robinson suggests that mandatory implementation of uniform patent ownership policies interferes with contractual freedom:

> The policies currently in place are the result of negotiations between university researchers and the individual universities to satisfy the particular concerns and conditions of that university. Therefore, not only does this interfere with free collective bargaining, it also straitjackets universities into mandatory intellectual property policies that may not address the needs or concerns of the particular university and the prospective industry partners (2006, p. 405).

In their discussion of patents, Van Zeebroeck, van Pottlesberghe de la Potterie, and Guellec note that fostering academic patents does not result in poorer quality patenting in other areas (2008, p. 251) and that there does not seem to be evidence to suggest that academic patenting has a detrimental effect on scientific production by academics (2008, p. 252). As well, there does not appear to be evidence that patenting as manifest in anticommons has a deleterious effect on subsequent scientific production (Van Zeebroeck, van Pottlesberghe de la Potterie, and Guellec, 2008), though questions do exist as to whether academic patents affect the timeliness and extent of disclosure of research (2008, p. 254). Indeed, Chavez (2010) notes that the potential for patenting a particular research result attracts external investment and funding, and that a connection exists between external/industry funding sources and increased generation of research results (p. 204). It is also important to note that while numerous concerns over university patenting exist, patenting is preferable to secrecy, which is antithetical to the

[5] Note that Ketis (2011) helpfully summarizes the ownership of intellectual property in Canadian universities in one convenient table.

university's role as a mechanism for knowledge diffusion (Robinson, 2006, p. 329). Further discussion on the relationship between patents and innovation is contained in Section V of this report.

C. Technology Transfer Through Spin-offs and Licensing

With respect to spin-offs as knowledge and technology transfer mechanisms, Landry, Amara, and Rherrad look at why these are created by some university researchers and not by others (2006). They hold that a set of resources complementary to both academia and industry need to be mobilized by researchers to launch spin-offs (Landry, Amara, & Rherrad, 2006, p. 1611) and that university spin-offs are likely to increase as researchers have greater access to grants such as those from NSERC and university-industry partnership programs (p. 1611). As well, spin-offs are more likely to be formed when researchers have greater intellectual property and social assets, expertise and years of experience in consulting and research, and access to the large research universities and larger laboratories (Landry, Amara, & Rherrad, 2006, p. 1611). Another possible factor in spin-off development may involve a sort of conservatism from industry, which Chavez (2010) noted might be more keen to invest in spin-offs already developed than fund wholly new spin-off initiatives (p. 205). Landry, Amara, and Rherrad (2006) contend that spin-off development may be less likely when researchers have increased financial resources from private companies, as this is seen to channel knowledge directly to the funding companies rather than to spin-offs; they observe that spin-offs are seen more in the computer sciences and engineering, and this is corroborated more recently by Kenney and Patton (2011), whose research suggests that spin-offs are more efficiently developed in universities that have inventor-ownership intellectual property policies rather than those with institution-owned frameworks.

Kenney and Patton (2011) cite the University of Waterloo (UW)—the "sole North American pure inventor ownership university" (p. 1109)—as a model of effective spin-off development, and that governments wishing to stimulate university invention commercialization and entrepreneurship should follow such a model (2011, p. 1100). Bramwell and Wolfe suggest that Waterloo's "magical" catalysis role in the creation of regional high tech start-up and spin-off companies is due to its international reputation for strong science, math, and engineering programs and the tradition of inventor as owner, in addition to the impact of the co-operative education program on the selection of faculty interested in applied research and the provision of R&D support to local firms (2008, p. 1179). Alternatively, Bathelt, Kogler and Munro caution that the idealized model of UW as an entrepreneurial research university and its role as "one of the key examples of strong technology transfer with its surrounding economy" has been over-stated by the media and in the academic literature (2011, p. 482). Indeed, the three researchers' study found that the UW's strongest connection to its regional spin-off firms was in the provision of qualified graduates (p. 482). The importance of a steady flow of highly educated graduates from UW (ie. human capital) as a source of skilled talent for local high tech firms was also highlighted by Bramwell, Nelles and Wolfe (2008, p. 108). Mike Lazardis, the founder of Research in Motion (RIM) and a former UW chancellor, also emphasized the importance of students in a speech he gave at a conference on commercialization organized by *Research Money*: "Commercialization happens when we educate the next generation of students with the latest cutting-edge technology and the latest techniques and processes. [...] Students drive innovation in our companies. Students are the most prolific, most efficient, most practical form of commercialization" (Smith, 2005).

Finally, Wigglesworth (2002) commented that one of the positive outcomes of the IBM Centres for Advanced Studies (CAS) program, a model that brings together academic researchers with IBM product developers, is the recruitment and high retention rate of former CAS students for employment at IBM (p. 870). Some CAS students who opted for careers in academia instead have subsequently gone on to encourage their graduate students to also participate in the CAS program (Wigglesworth, 2002, p. 870).

University spin-offs face unique problems that could render them inefficient instruments of technology transfer. A significant issue is that these spin-offs are highly influenced by university professors and graduate students. While these professors and students may be highly competent in their academic research, they often lack sufficient knowledge in corporate and managerial matters. For this reason, Niosi (2006) argues that spin-offs may be hindering the commercialization process, and that the technologies might be better left with larger established companies (p. 457). There is a need to study the effectiveness of spin-offs with that of existing companies (Niosi, 2006, p. 456).

Yet the ability to effectively assess university spin-offs is hindered by several factors. A fundamental issue being that while university spin-offs are acknowledged as being an important part of technology transfer, there is little clarity on what exactly such a company is. There is little consistency throughout the literature about the definition of a university spin-off (Bathelt, 2009, p. 520). At one extreme, some define university spin-offs as undertakings arising directly from university research, and at the other extreme some studies cast a wider net and include any firm created by a university graduate to be a spin-off (Bathelt, 2009, p. 522). The lack of a consistent typology limits an understanding of spin-offs and their contribution to innovation (Bathelt, 2009, p. 520). Because of the lack of clarity on defining what constitutes a spin-off impedes analysis of this important mechanism and metric for technology transfer, the Tri-Council funding agencies in coordination with the federal government should develop a clear taxonomy for classifying spin-offs that can be used by the government, granting agencies, universities themselves and researchers to improve understanding of the role spin-offs play in diffusing university research.

Vincett's study (2010) argues that spin-offs, at least in certain areas, are significant economic contributors. A fairly narrow conception of a spin-off was applied here, including only first generation non-medical natural sciences and engineering (NSExm) spin-offs that received funding from the NSERC. Companies founded by graduate students later in their careers were excluded (Vincett, 2010, p. 743-744). The study specifically analyzed the effect of spin-off companies on the Canadian GDP to measure the impact of academic research in Canada. Comparing these impacts with the amount of government funding given, demonstrates that academic spin offs in these fields more than justified the government's contributions. The economic impact to Canadian GDP from NSExm spin-offs was approximately 3.3 times the government funding (discounted to 1998, the benchmark year). If the benchmark year used is moved backwards to 1980, the return increases to 4 (Vincett, 2010, p. 744). In terms of tax yields, the study estimates that these spin-offs will return approximately $1.30–1.55 for every $1 of research funding.

As a specific discipline, physics spin-offs stood out from the NSExm for generating a particularly high return on government investment. While the NSExm in whole returned 3.3-4 times the government investment, with physics spin-offs, those numbers increased to 4.3-6.5, depending again on the benchmark year (Vincett, 2010, p. 745). The tax yields arising from these spin-offs are approximately $1.65–2.50 per research dollar (Vincett, 2010, p. 743). This finding has particular relevance to policy matters because it defies the assumption that applied sciences are more profitable than basic science disciplines, such as physics and mathematics. Reducing work in the basic disciplines under the assumption that their work is too far removed from the market could actually be detrimental to the commercialization of academic research (Vincett, 2010, p. 745).

D. Technology Transfer Through Data Flows and Consulting

Patents, licensing and spin-offs are not the only means of technology transfer. Other important knowledge diffusion mechanisms are the flow of research data and consulting services provided by academic personnel. These mechanisms push up against the boundaries of what is traditionally considered to be technology transfer. Unlike copyright and patents, the state of Canadian law in regards to ownership of compiled or created university research data is unclear: "Data in its purest form, is not protected by existing intellectual property legislation. Data does not constitute an invention to be patented or an expression of an idea which can be copyrighted" (French, 2009, p. 9). Several universities including the University of Toronto, University of Regina, McMaster University and the University of Calgary have policies that govern ownership of research data; however, these policies do not provide complete answers or guidance as to the ownership and rights associated with data (French, 2009, p. 21).

Thursby and Thursby (2011) explore consulting as a knowledge transfer mechanism that operates between universities and industry and acknowledge that little research has been conducted on the significance of consulting on knowledge transfer. Private consulting with faculty members is mainly done outside the sphere of university technology transfer protocols and policies (Bercovitz & Feldmann, 2006, p. 178) and possibly because the private sector may be close-mouthed, even in confidential surveys, about revealing the identities of consultants and the nature of consulting work with which it engages (p. 609).

Agrawal & Henderson (2002; as cited in Chavez, 2010, p. 24) suggest that university faculty may overestimate the significance placed on consulting as opposed to patents and scientific publications. Other studies done in 1990s conclude the opposite, such as the survey done by Cohen, Florida, Randazzese, and Walsh (1998; as cited in Thursby & Thursby, 2011, p.

609) in which R&D managers indicated that consulting yielded more technology transfer from universities than patents and licensing, as well as Mansfield (1995, p. 63; as cited in Thursby & Thursby, 2011, p. 609) in which faculty members considered their consulting to have stimulated new research ideas. Bercovitz and Feldmann (2006) argue that the lack of clear findings on the role of consulting may, in fact, represent an *underestimation* (p. 178) of the role of the university in technology transfer. What is known, however, is that consulting can take the form of either direct consulting to businesses or consulting to non-profit organizations (Jacobson, Butterill, and Goering, 2005, p. 316). Using consulting to improve knowledge flows is particularly useful in the health services area (Jacobson, Butterill, and Goering, 2005, p. 316) as well as in the social sciences, humanities, and business, where knowledge diffusion tends to be manifest in less traditional modes of technology transfer. While consulting offers an important mechanism to improve returns with respect to innovation, institutional intransigence to consulting on the part of universities may fetter the number of academics willing to undertake consulting opportunities (Jacobson, Butterill, and Goering, 2005, p. 317).

E. Knowledge Transfer Factors in the Medical and Biotechnology Sectors

One aim of this knowledge synthesis report has been to identify discipline specific factors that contribute to differences in technology transfer practices and policies between academic disciplines. However, through the course of the synthesis, it has been determined that the literature is highly concentrated in the medical, biotechnology, engineering, and natural sciences fields with less frequent reference to mathematics and computer science. In particular, references to technology transfer in the social sciences and humanities were lacking. Thus the following section focuses specifically on the medical and biotechnology sectors which did reveal unique disciplinary characteristics.

Technology transfer of innovative products from research institutions to the market is especially important in the medical and biotechnology sector. When innovation and its appropriate diffusion stalls or lags behind in this industry, it is not only the market that suffers, but the public health system overall. In the medical and biotechnology setting there are two prominent ways for knowledge created in the university setting to be transferred to the private sector and developed into useful products and services. The first is through licensing an outside organization to use this research in order to bring a new product to the market. The second is where investors fund a start-up company, with the sole objective of developing the technology. In the medical sector, when these pathways fail, the community loses the benefit of a valuable product that may have saved lives. Since most health focused biotechnology products are developed through university-based research, it is essential that universities have a clear strategy to ensure that innovations can be effectively transferred to the private sector and reach physicians and hospitals where it is needed (Centre for Intellectual Property Policy, 2005, 35).

There are many licensing ventures that are already taking place in this sector and the result of such collaborations have shown to be extremely beneficial to both sides, as well as the market overall. Research and commercialization in the medical and biotechnology industry tends to be challenging as there are often very high costs associated with development, and it can take years before inventions are ready for any type of commercialization. Collaborations between universities and biotechnology firms can help to relieve this burden and make the most of the resources available. Programs like the Ontario Centers of Excellence promote such partnerships in order to reduce the barriers of transforming ideas into marketable products (Levitte & Bagchi-Sen, 2010, 673). Recent studies indicate that this type of alliance in biotechnology increases productivity by allowing firms access to research and patented ideas in order to facilitate commercialization, and can also lead to higher quality research being produced from the university side (Levitte & Bagchi-Sen, 2010, 672).

While licensing ventures and partnerships have proved effective in Canada, commentary suggests that "debates continue over whether universities should license out their technology in such a way as to maximize their own revenues, or whether universities should simply act as a conduit to permit local industry to use the technology to create employment in the country" (Centre for Intellectual Property Policy, 2005, 3). One argument is that because university research is largely funded by the public sector, the best way for them to contribute is to make these materials available to other researchers and firms to develop them without restrictive licensing requirements (Gold, Bubela, Carbone, Gagnon, Srulovicz, & Joly, 2010, 2010, 4). However, this could result in research institutions favoring technologies that focus on promoting the public good, rather than more profitable areas that benefit the market overall (Centre for Intellectual Property Policy, 2005, 35). This rational drives other arguments that universities should be allowed to license out their inventions and generate lucrative revenues that will lead to more funding for research in the future. If this type of strategy is pursued it would require more investment in TTOs, so that universities have the resources to negotiate licenses that will result in high profits (Centre for Intellectual Property Policy, 2005, 35).

In order to improve technology transfer of research in the medical and biotechnology sectors and bring much needed innovations to the healthcare system, Canada needs to outline a clearer strategy for regulating the relationships between the universities who create the knowledge, and the industry firms who have the ability to transform it. Although CIHR has taken a leadership role in developing programs and policies for ensuring technology transfer in this area (Sá & Litwin, 2011, p. 430), such as the CIHR's Commercialization and Innovation Strategy (CIHR, 2005), more research is needed on the effectiveness of the CIHR strategy in meeting its own objectives.

F. Enhancing Technology Transfer at Canadian Universities

This section of the report has reviewed the scope of recent literature on technology transfer policies at Canadian universities. Issues revolving around the emanation of knowledge between the academy and the private sector are conceptually regarded in the literature as "technology transfer," which may imply a sense of linearity and point-to-point transmission, rather than a broader, more holistic, and more reciprocal sense of knowledge diffusion that encompasses the complexities of academic-industry relationships. The literature reveals that Canada lacks a nationwide policy on knowledge transfer. Currently, technology transfer is a matter of institutional policy from university to university.

The literature focuses on patents as a key aspect of technology transfer. Spin-offs and licensing are additional means of technology addressed in the literature. Less explored in the literature are research data flows and the role of consulting by academics as a means of technology transfer. Currently, literature on technology transfer focuses on the medical and biotechnology fields. The next section of this report expands the discussion on patents focusing on the connection between patents and innovation.

V. Results of the Knowledge Synthesis on Patents and University Research and Innovation

As the knowledge synthesis carried out in the previous section of the report has demonstrated, patents are an invaluable indicator of university innovation; however, it does not necessarily follow that the best mechanism to ensure increased knowledge flows from universities is to encourage greater patenting. This section of the report addresses the usefulness and limits of patents as indicators of university innovation. The first section examines the literature on non-patent indicators of university research and innovation with the aim of identifying the range of indicators policymakers must consider when attempting to measure increases in university innovation. The second section investigates the dangers of patents for inhibiting university research and innovation.

A. Non-Patent Indicators of University Research and Innovation

The OECD defines innovation as, "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD, 2005, p. 46). The OECD's definition of innovation is reflective of the fact that innovative outcomes can take a variety of forms, and also highlights the importance of using a variety of indicators of innovatory activity. Indicators of innovation have been well studied with respect to private firm activities; however, there is much less known about innovation indicators within the public sector. This disparity in knowledge persists despite the public sector's role as a source of innovation and contribution to the economy in OECD countries (OECD, 2010a, p. 90). In *Measuring Innovation* the OECD recognizes the importance of implementing a functional framework for measuring innovation, which would allow governments to better achieve goals such as improved public welfare, quality of life and economic successes (2010a, p. 90).

However, Canadian policy documents have taken a decidedly narrower approach. In the 2002 report *Achieving Excellence*, the government of Canada outlined its innovation strategy and emphasized the necessity of maximizing the commercial yield of publically funded research (Canada, 2002, p. 52; Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1586), and this goal was repeated in the 2007 national science and technology strategy where the government stressed that university research must be better aligned with private sector needs (Canada, 2007, p. 39). Following the 2002 policy goal, the AUCC committed Canadian universities to triple commercialization performance, (Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1587). A major source of statistical indicators on the commercialization of university research is Statistics Canada's *Survey of Intellectual Property Commercialization in the Higher Education Sector* which includes "revenues and expenditures related to IP management, spin-off companies (and equity held in spin-off companies), invention disclosures, patent applications, patents awarded, new licenses and revenues from IP" (Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1586). Citation analyses and university-industry or university-government collaborations are other useful metrics (Landry, Amara & Ouimet, 2007).

This standard, however, discounts other more indirect indicators which are still relevant, such as contracts, consortia and consulting (Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1596). The OECD also notes collaboration and open innovation as being trends in innovation which lead to increased access to information (2010b, p. 41-43). Grimaldi, Kenney, Siegel and Wright suggest that reliance on traditional measures of university innovation, such as those collected by the Association of University Technology Managers (AUTM), fails to appreciate the importance of more open models of technology transfer (Grimaldi, Kenney, Siegel & Wright, 2011, p. 1055), and Kenney and Patton note that alternative IP ownership models require greater research (Kenney & Patton, 2009, p. 1419). Assuming that the aim is for innovations coming from a public university to provide an overall benefit for society, and not just increase revenues for the university, more than IP revenues should be considered (Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1587).

Further, the role of university graduates should not be ignored. They are a main export of a university, and their skills and knowledge as learned at the university diffuse into society (Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1595). It is telling that the Government of Canada's 2006 Expert Panel on Commercialization explicitly noted that the key factor in successful commercialization is people (Industry Canada, 2006, p. 3). While we caution that commercialization of university research is only one of many means of improving knowledge flows, enhancing knowledge diffusion should focus on investing in individuals, both the academics and students who engage in such research. One approach to knowledge diffusion that specifically emphasizes the role of students is the Highly Qualified Personnel (HQP) training program that is part of the Networks of Centres of Excellence of Canada (NCE) (NCE, 2011, p. 35-36). The NCE's HQP program specifically ensures the training of the next generation of researchers furthering knowledge diffusion and strengthens the nation's research potential. Given the importance of individuals to innovation, it is crucial that policymakers specifically focus on the human elements of innovation and in particular to the training of HQPs.

As a measure of innovation, patent activity is common but often questioned. Patents activity is convenient because there are well documented databases generally available electronically to the public and can traced historically (Kleinknecht, Montford & Brouwer, 2002, p. 112). However, there are still significant weaknesses to patents as a measure of innovation. Patents have several crucial limitations: not all inventions are patentable, many innovations are never patented, some inventions are not patented because of their innovatory potentials but as mechanisms to fetter competitors, patenting behaviour various across industries and disciplines (Hasan & Tucci, 2010, p. 1274). The most basic flaw is that inventions that are not patented are overlooked (Kleinknecht, Montford & Brouwer, 2002, p. 112). Even excluding these other forms of innovation, a mere count of patent applications or patents granted may not be particularly beneficial. That measure assumes that patents represent commercializable or socially valuable work, which is not always the case (Langford, Hall, Josty, Matos & Jacobson, 2006, p. 1590). Some patents only reflect insignificant changes to existing technology, and some patents are simply strategic moves to prevent another firm from capitalizing on a piece of technology (Kleinknecht, Montford & Brouwer, 2002, p. 112). While patent citations may be used to assess the relative impact of a patent, Mortensen argues that that to make an unbiased assessment of impact, more is needed than a raw count of citations (2011, p. 9).

Another approach is to assess the entrepreneurial orientation of a university department. While much emphasis in recent years has been on commercializing innovations and thus making universities more entrepreneurial, little is known about how the entrepreneurial orientation of specific university departments might affect this process (Todorovic, McNaughton, & Guild, 2011, p. 128). One proposed approach by Todorovic, McNaughton and Guild is the use of a scale called ENTRE-U. ENTRE-U is essentially the modification of ENTRESCALE, a scale that has been shown to determine entrepreneurial orientation in private firms (2011, p. 128). ENTRE-U analyzes four factors: research mobilization, unconventionality, Industry collaboration, and perception of university policies (2011, p. 134). As a result, ENTRE-U is capable of predicting the spin-off and patent creation to come from university departments (2011, p. 133).

An intriguing report via blog post by Curtis (2010) reveals skepticism with current metrics that attempt to measure innovation and highlights a novel Canadian approach. Curtis discusses a “disconnect between TTO personnel and the government” (para. 5) in which government, influenced by the AUTM, sees an apparently straightforward path to innovation that is evidenced in tangible entities such as patents, licenses granted, licensing revenues, and the creation of spin-offs (para. 5), while TTO personnel consider matters such as advancing institutional public or social good and that current metrics fail to capture broader societal effects of technology transfer. Curtis discusses the example of the University Industry Liaison Office at the University of British Columbia (UBC) as an organization that is attempting to assess technology transfer and innovation in different ways, through multifaceted aspects of how the university’s social and academic missions are fulfilled in the short- and long-term (para. 7). Emphasis on both short- and long-term goals is particularly important as a narrow focus on short-term commercialization metrics will not necessarily result in the long-term building of capacity in industry and government to absorb future university innovations (Sá and Litwin, 2011, p. 432). According to Curtis, the UBC approach removes TTO personnel from a short-sighted agenda of translating immediately university research to dollars or numbers of commercial outputs (para. 7). More research is needed to determine the effectiveness of the approach taken by the University Industry Liaison Office at UBC in capturing a broader range of innovation indicators and the applicability of such an approach for other Canadian universities.

Finally, there is a fear that if we over rely on these proposed indicators of innovation, Langford cautions “we may get what we measure” rather than the end result we desire. While these indicators may be useful tools, it should be remembered that they are simply proxies for innovation and not the end goal in itself (2006, p. 1596). Innovation measurement is akin to losing one’s keys at night on a dark street and looking for them under the lamppost – not because the keys are necessarily under the lamppost, but because it is the only part of the street that has light. When assessing university innovation, policymakers must ask themselves if they are looking under the lamppost. If so, then they must endeavour to develop the means to not simply look where the easiest indicators can be found (such as statistics on the number of patent applications or licensing revenue) but develop more comprehensive indicators to better illuminate their key findings.

B. Anticommons and Patent Thicket Problems in University Research and Innovation

As noted in the previous section patents are only one of a range of indicators for university innovation. While they are a useful metric because of their quantifiable nature, excessive patent protection can limit university innovation. This section begins by briefly noting the theoretical contributions of Michael Heller and Carl Shapiro identifying the problems that may occur from the granting of too many fragmented exclusionary rights. The second part of this section includes a knowledge synthesis on the empirical literature on patent thickets and anticommons. It reveals that while a number of practical mechanisms inhibit the problems of overprotection from negatively impacting university research, there remains a danger of which policymakers should be mindful when attempting to increase university research and innovation.

Based on an analysis of commercial property in post-Soviet Russia, Michael Heller has identified a phenomenon known as the 'tragedy of the anticommons' where too many exclusionary property rights lead to the inefficient underuse of resources (1998). The anticommons problem is of particular importance to university researchers, particularly in the biomedical field, where IP rights on upstream innovation can fetter downstream research (Heller and Eisenberg, 1998).[6] While Heller's anticommons thesis provides an important theoretical insight as to how the overprotection of IP can inhibit university research, it is necessary to examine the empirical literature on the anticommons to determine to what degree university research is prone to anticommons problems.

A second related approach to examining the problem of too many exclusionary rights is advanced by Carl Shapiro who argues that the complex web of exclusionary rights has created a patent thicket. He defines a patent thicket as, "an overlapping set of patent rights requiring that those seeking to commercialize new technology obtain licenses from multiple patentees" (Shapiro, 2000, p. 119). In industries that produce complex products where innovation is

[6] With respect to research, the terms *upstream* and *downstream* refer to the sequence when innovations are known to occur. Upstream innovations occur early in cumulative research processes, whereas downstream innovations occur subsequently and are dependent on previous upstream findings.

cumulative, patent thickets dampen innovation. Although firms may be able to license IP rights, transaction costs decrease the effectiveness of licensing and act as a tax on innovation. Shapiro argues that business solutions such as cross licensing and patent pools are effective means for cutting through the thicket and may be welfare enhancing, but in turn these solutions raise antitrust concerns (2000, p. 129-30).

While anticommons and patent thicket arguments highlight the dangers of an expansionary IP regime, there are many practical considerations that may ameliorate the problematic dimensions of anticommons situations. Several empirical studies have found limited incidents of anticommons emerging (Cohen & Walsh, 2010, p. 14; Walsh, Cho & Cohen, 2005, p. 2003). Walsh, Arora and Cohen's empirical study of the biomedical sector revealed that although the preconditions for an anticommons exist, there are no major breakdowns in the industry's ability to continue research (2003, p. 297-298). Laboratory researchers frequently unknowingly infringe upon patents or believe that any infringement is covered by an exception for research (Cohen, 2005, p. 64; Standburg, 2009, p. 2254). Interviews with lawyers, scientists and managers in the biomedical field reveal that although initial searches may suggest that a particular project may involve many overlapping IP rights, the number of patents that actually have to be licensed is low if not zero (Walsh, Aurora & Cohen, 2003, p. 294). In some cases research may be done offshore as a method to avoid IP restrictions (Walsh, Aurora & Cohen, 2003, p. 324). Cross licensing of patents is a strategy often employed to quickly clear patent thickets; however, cross licensing can also be used to limit competition and the incentive to innovate (Jaffe & Lerner, 2006, p. 59-61). Patent owners tend to tolerate a degree of infringement based on the belief that such infringement may result in research that can add value to the patent and will generate goodwill with other researchers (Cohen & Walsh, 2010, p. 17; Walsh & Huang, 2007, p. 10). A study comparing licensing conditions in Japan, Germany, the U.K. and the U.S. revealed that while some difficulties do exist and overly complex negotiations cause some research paths to be abandoned, overall there is little evidence of anticommons problems (AAAS, 2007, p. 11-13). These findings mirror those of an Australian study that found inconclusive evidence that an anticommons exists and its authors could not even determine if the preconditions for an anticommons existed in the Australian biotechnology sector (Nicol & Nielson, 2003, p. 177-78 and 194-195). One OECD study noted that while the potential for anticommons exists, such breakdowns are rare and not a threat to innovation (OECD, 2002, p. 50 and 60).

While these studies have found weak support for Heller and Shapiro's arguments, there is empirical, experimental and anecdotal evidence to support their claims. A survey for the American Association for the Advancement of Science found 40 percent of survey researchers reported difficulties in obtaining rights to use patented technologies. Complex licensing negotiations were found to result in the abandonment of research projects, and anticommons problems were found to affect a range of disciplines as well as both academic and industry scientists (Hansen, Brewster, Asher & Kisielewski, 2006, p. 21-23). A survey of agricultural biology researchers in the south-west United States revealed that these academics felt that the protection of research tools through IP negatively impacts their ability to conduct research (Lei, Juneja & Wright, 2009, p. 39). Rosell & Agrawal (2009) report on a statistical analysis of the National Bureau of Economic Research patents database and note that an "increasing trend towards formal intellectual property protection was accompanied by a contraction in the breadth of knowledge flows" (p. 11). Studies on the potential emergence of anticommons situations in Canadian academic research are lacking and a primary avenue for future research.

In light of the empirical literature on anticommons and patent thickets, Eisenberg (2010) has revised the anticommons thesis. She posits that the burden of detecting infringement and the costs of suing for infringement limit the emergence of anticommons, but in situations where there is 'practical excludability' over research materials and data that are not necessarily protected by IP the risk of anticommons may be greater. Policymaker and university officials should pay specific attention to Eisenberg's insights to ensure that areas where practical excludability exist does not give rise to situations that dampen university research.

C. The Role of Patents in University Innovation

As indicated by the knowledge synthesis on technology transfer policies at Canadian universities, patents are an integral part of university innovation. However, the literature reviewed in this section of the report has identified two major limitations that arise from an overreliance on patents as both a means and a measure of university innovation. Patents are only one of a range of indicators of innovation. Though they are particularly useful for easy quantitative analyses, policymakers must ensure that they use the broadest range of innovation indicators to truly capture the variety of means through which knowledge is diffused by universities. Furthermore, an overreliance on patents as a means to encourage university research may produce dynamic effects that stifle future downstream research. More research is needed, specifically in the Canadian context, to determine what degree patent thickets and anticommons pose a danger to university research.

VI. Areas for Further Research and Research Gaps

This knowledge synthesis has identified several areas for future research as well as prominent gaps in the literature. An area of primary concern is that literature on technology transfer and Canadian universities is overwhelmingly concentrated on the natural sciences, engineering, and medical disciplines and is complimented by a smaller body of literature dealing with computer science and mathematics. More research is needed in the areas of the social sciences and humanities to examine what disciplinary factors affect knowledge flows in these areas. In a similar vein more research is needed on non-commercial university knowledge flows (Landry, Amara, Ouimet, 2007), which are more likely to occur in the social sciences and humanities.

Exacerbating the problem of the low volume of literature on technology transfer and in the social sciences and humanities, is what we believe is a discursive disjunction between disciplines in terms of their approach to knowledge diffusion/technology transfer. While this report, and in particular the search strategies used to inform the knowledge synthesis, have focused on literature relating to 'technology transfer,' we contend that the lack of results of literature in the social sciences and humanities stems not from the fact that such disciplines do not play an important role as knowledge diffusers, but rather that such diffusion is not framed as technology transfer. Given the discursive differences between disciplines in terms of describing knowledge diffusion/technology transfer, future research must be aimed examining knowledge diffusion not technology transfer, and more importantly, policymakers should focus on the broader notion of diffusion rather than technology transfer (one of its subsets) as a means of ensuring the important work by scholars in the humanities and social sciences is reflected.

One gap in the literature that was not anticipated was the lack of materials dealing with certain kinds of technology transfer and IP management. Specifically the literature is lacking with regards to the role of venture capital and non-disclosure agreements as means that encourage or inhibit university knowledge flows. Future research should address the role the venture capital and non-disclosure agreements play in Canadian universities.

One area of research that is sorely lacking, particularly in the Canadian context is discussion of the role of more open innovation models in diffusing university knowledge (Kenney & Patton, 2009, 1419). While the authors were previously aware of some Canadian examples of more open management of university IP, such professor Stephen Mann of UW who has freely disseminated a program for designing high quality violins (Mann, Playfair & King, n.d.), the literature search failed to discuss this and other similar examples. Future research should be aimed at exploring the role of open innovation paradigms in diffusing research done by Canadian universities. Concomitantly, researchers should also aim to address the degree to which anticommons in academic research exist in Canada, particularly as more open approaches to IP management can help mitigate such problems. In addition to more open innovation paradigms, future research should also aim to use new conceptual frameworks for analyzing technology transfer. For example Pries and Guild (2005) recommend examining technology transfer based on function (build, rent, sell) rather than on legal categories (patent, license, spin-off) (p. 471-72). Novel approaches to examining university IP management should help provide new insights into the range of Canadian university technology transfer policies and provide evidence as to how to strengthen the research output of Canadian universities.

The knowledge synthesis has identified several specific problems that merit further inquiry. Given the importance repeat commercializers play in diffusing the results of their research, more research is needed on such individuals as well as those who repeatedly license their discoveries for commercialization (Hoye & Pries, 2009, p. 684 and 687). While a focus on individual attributes provides one line for further inquiry greater research should also be directed towards examining the social practices that take place between the university and the private sector (Curtis, 2010).

Finally, the knowledge synthesis has identified two specific programs that require greater empirical examination. CIHR's Commercialization and Innovation Strategy and the approach UBC's University Industry Liaison Office to knowledge mobilization provide valuable case studies into Canadian technology transfer policies.

Although this knowledge synthesis has revealed many literature gaps and a great deal of heterogeneity both in the literature and on technology transfer in Canadian universities as well as in the practices and policies themselves, this report has found several important evidence-based policy findings that should guide Canadian university innovation policy and research. Universities serve an invaluable role in Canadian society as mechanisms for undertaking both basic and applied research, but most importantly as institutions that promote core civic values such as the importance of knowledge, discovery, and service to the public good. Evidence-based policy that aims to improve the diffusion of knowledge from Canadian universities is an essential cornerstone for improving the nation's innovation ecosystem in the 21st century.

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VIII. Appendices

A. Appendix A – Detailed Methodology

List of resources searched: **Academic Databases**
ABI Inform Global
ABI Inform Trade and Industry
Canadian Research Index
CBCA Business and CBCA Education
Compendex
EconLit
Forrester
Google Scholar
Hein-on-Line
Legal Trac
Lexis Nexis QuickLaw
PAIS International
Scholars Portal
SciFinder
Scopus
Web of Science
West Law
Newspaper Databases
Canadian Newsstand Major Dailies
CBCA Current Events
CPI.Q
Factiva
Google News
Lexis Nexis Academic
Library and Archives Canada - Indexes to Canadian News Papers
Google Searches
Canadian Univ. Tech. Transfer Policies
Canadian Univ. Tech. Transfer Policies
Anticommons and Patent Thickets
Non-Patent Indicators of Univ. Innovation

Other Materials
OECD Literature
Canadian Journal of Higher Education
Chronicle of Higher Education
Higher Education Policy
Research Policy
Research Money
Journal of Technology Transfer
Association of University Technology Managers (AUTM) Website
University Affairs
SSHRC/NSERC/CIHR Websites
CAUT and CATA Alliance Websites

B. Appendix B – List of Acronyms

AAAS – American Association for the Advancement of Science

AUCC – Association of Universities and Colleges of Canada

AUTM – Association of University Technology Managers

CAS – IBM Centres for Advanced Studies

CIHR – Canadian Institutes of Health Research

GDP – Gross domestic product

HQP – Highly Qualified Personnel

ILO – Industry-Liaison Office

IP – Intellectual Property

NCE – Networks of Centres of Excellence of Canada

NSERC –Natural Sciences and Engineering Research Council of Canada

NSExm – First generation non-medical natural sciences and engineering

OECD – Organisation for Economic Cooperation and Development

R&D – Research and Development

SSHRC – Social Sciences and Humanities Research Council

STIC – Science, Technology and Innovation Council

TLO – Technology Licensing Office

TTO – Technology Transfer Office

UBC – University of British Columbia

UW — University of Waterloo

C. Appendix C – Innovation Indicators

Indicator	**Statistics from the 2010 AUTM *Canadian Licensing Activity Survey***
Research Expenditures	Research expenditures from survey respondents totaled $6.1 billion. This represented a 4.4% increase from 2009. Of this, industry funding increased by 19.2%, federal government funding increased by 3.7%, and "other" forms of funding increased by 2.1% (AUTM, 2010, p. 23).
Staffing in TTOs	From 2009-2010, the total number of employees in TTOs of respondent institutions remained constant at 353 people, though the nature of TTO personnel work changed. The number of full-time licensing employees decreased 2.5%, while the TTO employees in other areas increased by 5.9% (AUTM, 2010, p.19).
Disclosures	From 2009-2010, the number of disclosures from survey respondents decreased by 9.8% despite the increased number of survey respondents (AUTM, 2010, p. 8).
Patents Filed	In 2010, survey respondents filed 986 patent applications, a 6.5% increase from 2009, but still down 4.3% from 2008. 143 new patents were granted in 2010, an increase of 37.9% from 2009 (AUTM, 2010, p. 29).
Licensing and Options	In 2010, Canadian survey respondents reported 539 licenses, a decrease of 27.7% from 2009. Options increased 30.4%, from 69 to 90 (AUTM, 2010, p. 37).
License Income	In 2010, Canadian survey respondents reported $58.7 million in licensing income. This represents a 1.7% decrease from 2009 (AUTM, 2010, p. 41).
Startup Activity	In 2010, Canadian survey respondents created 50 startup companies, a 4.2% increase from 2009, but over the past 10 years the number of startups being formed has decreased by 29.4 % (AUTM, 2010, p. 44)
Products available for Commercial Use	33 products became available, an increase of 46.8% from 2009 (AUTM, 2010, p. 10).

Indicator	**Statistics from Statistics Canada's *Survey of Intellectual Property Commercialization in the Higher Education Sector* (2010)**
IP Management	81% of respondents were involved in IP management (88% of universities and 69% of hospitals) (Statistics Canada, 2010, p. 7).
Income from IP	Total reported income from respondents was $53.2 million in 2008, an increase of 9% from 2007 (Statistics Canada, 2010, p. 7).
Research Contracts	In 2008, income was just under $2 billion, a 55% increase from 2007 (Statistics Canada, 2010, p. 7).
Staffing	In 2008, there were 321 full-time employees involved in technology transfer, a 13% increase from 2007. $51.1 million were spent in IP management (Statistics Canada, 2010, p. 7).
Disclosures	In 2008, there were 1613 new invention disclosures, an increase of 20% from 2007. In 2008, respondent institutions granted 524 licenses and options (Statistics Canada, 2010, p. 8).
Patent Applications	In 2008, 1791 patent applications were filed, a total increase of 10%, but on average there was a 2% decrease per institution. On average, each institution has 15 patent applications at varying stages of development (Statistics Canada, 2010, p. 8).
Patents Issued	In 2008 there were 346 patents issued to universities and teaching hospitals, a decrease of 33% from 2008. In total, 5908 patents were held by these institutions by the end of 2008 (Statistics Canada, 2010, p. 8).
Licensing	39% of patents from these institutions are licensed, assigned, or commercialized in some manner (Statistics Canada, 2010, p. 8).
Spin-offs	19 spin-offs were created in 2008, bringing the total of spin-offs since 1999 to 1242 (Statistics Canada, 2010, p. 8).

D. Appendix D — Research Team Member Profiles

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