Technology incubators: facilitating technology transfer or creating regional wealth?

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Abstract: Universities are increasingly under pressure to commercialise their technological innovation and generate revenues to justify ongoing public investment to support that innovation. Most universities respond to this pressure by focusing on licensing patentable technologies. However, as most licensees operate far from the universities, the local economic impact is reduced. Due to this factor, regional economic development agencies, when looking to extract commercial value from university research, see limited benefit from the licensing of technology patents generated by universities. Instead, they concentrate on promoting new business ventures as a mechanism for regional wealth creation. We propose an expanded model of knowledge transfer from university research that underscores the importance of creating new ventures and demonstrates how university-based incubators can catalyse knowledge extraction and, as a result, align the goals of regional economic development agencies and universities.

Keywords: innovation; technology incubator; technology transfer; knowledge transfer; venture creation; wealth creation; regional wealth; university commercialization; economic development; licensing.

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1 Introduction

Over the past three decades, universities have played an increasingly important role in regional economic development (e.g., Audretsch et al., 2006). In Canada, universities' cumulative impact on the economy (measured as wealth created by companies from the use of knowledge generated in universities) was estimated at CDN $50 billion in 2004 (Association of Universities and Colleges of Canada or AUCC, 2005). In today's global economy, the creation, dissemination and utilisation of knowledge are required to enhance a region's economic well-being. As suggested by Waugaman and Tornatzky (1999), this well-being can be measured by the gross income, number of jobs, and exports generated from these activities. When knowledge creation, use and dissemination lead to technology commercialisation, these activities can provide direct financial income to universities and enhance their reputations, which in turn attract future generations of high-quality students and faculty.

However, traditional benefits to a university from technology commercialisation do not automatically translate into benefits to the regional economy. Technology license agreements create short-term revenue streams that university administrators often view as a measure of successful commercialisation of research (Agrawal, 2001; Colyvas et al., 2002). But the revenues flowing from the licenses are generally generated by a few large industrial partners operating far from the university, often in other provinces, states and countries (Waugaman and Tornatzky, 1999). While these licenses create a small royalty income for the university, they often have a limited effect on the local economy. Instead, the region in which the licensee operates accrues most of the economic benefit. Regional economic development agencies (REDAs) are frustrated with this licensing practice because, as Litan et al. (2007) note, it both understates the overall regional economic benefits derived from university research and encourages actions that are not beneficial to the local economy.

The creation of business ventures involving the use of patents from universities has been shown to generate greater regional economic benefits, but it requires significantly more resources for success than licensing (e.g., Rogers et al., 2000). New regional ventures create local jobs, facilitate regional infrastructure development, and have a multiplier effect on the local economy (e.g., by increasing demand for local services). However, university administrators see the economic impact on the region as providing limited direct benefits to the university. Siegel et al. (2003) argue that this university

perspective creates a conflict in commercialisation goals between universities and REDAs. This view on commercialisation by universities causes behaviours that can limit the overall benefits both parties derive from the commercialisation of university research.

This article investigates *how universities and REDAs can work together for mutual benefit to increase commercialisation activities.* We underscore the importance of new venture creation and describe the catalytic role played by a technology incubator to facilitate these activities. In Section 2, we examine current models of technology commercialisation that universities use and their economic impact. In Section 3, we present a more comprehensive model that incorporates additional channels of knowledge and money transfers between the university and industry to enhance the benefits of technology commercialisation for a region's economy. In Section 4, we explain how the creation of new ventures can intensify the resulting flows of knowledge and money. We offer two Canadian case studies to demonstrate that incubators can indeed multiply the benefits accrued by a university and the surrounding region from these flows. In Section 5, we conclude by proposing that examining additional commercialisation channels (and the resulting flows of knowledge and money) provide a broader perspective for each party that can, in turn, better align the goals of universities and REDAs.

2 Traditional university technology commercialisation models

Traditional models of university commercialisation reflect a one-way flow of knowledge from the university's research laboratories to commercial firms via the university technology transfer office (TTO) (Rogers et al., 2000; Siegel et al., 2003). Under this commercialisation mechanism, the university TTO grants a license to a firm (which becomes a licensee). This license gives the firm the right to use specific knowledge embodied in one or more university-produced patents in return for a fee. When the licensee signs such an agreement with the TTO, this confirms the commercial value of the innovation. This traditional model assumes that the creation of jobs and profits by licensees are the main engine of wealth creation (for the university, licensee and its region). While recognising that industry's recruitment of graduates for highly skilled jobs (facilitated by the university's placement office) enhances industry competitiveness, traditional commercialisation models emphasise the financial benefits to the university as flowing from license revenues from their intellectual property (IP).

2.1 Weaknesses of the traditional commercialisation approach

Historically established as educational institutions, most universities embrace research as a mechanism for expanding their mission. Consequently, universities across the world endeavour to attract well educated, highly credentialed faculty and researchers who can advance their educational mission and enhance their global or regional reputations (Etzkowitz, 2003). In addition, scholars have suggested that commercialisable academic research can be a viable source of revenues for academic institutions that rely on government funding (e.g., Mansfield, 1995; Salter and Martin, 2001). Feller (1990) and Poyago-Theotoky et al. (2002) bring our attention to how these competing agendas can create potential conflicts in universities, noting that the culture of open discovery and knowledge sharing has become increasingly challenged as opportunities for

commercialisation of research have grown over the past three decades. As noted by Markman et al. (2005a), potential conflicts are also created when the university's traditional reward system based on research, publication and tenure requirements come into conflict with the technology commercialisation process. In some cases, prior to tenure, academics are discouraged from commercialising their technology as it will distract them from publishing.

In addition to this internal tension, an external conflict also exists between universities and REDAs due to the ambiguity in which stakeholders – innovators, universities and public funders (governments) – derive the most economic benefit (Waugaman and Tornatzky, 1999). Although the university's role in community economic development has expanded from producing highly qualified personnel to using the knowledge it creates to stimulate local and national economies, it is difficult to measure the economic benefits to the university and the adjoining region (Goddard and Chatterton, 1999). Aware that the global economy is increasingly dependent on the development and utilisation of knowledge, regional and national governments are encouraging REDAs to help create high-paying jobs, increase innovation activities, and stimulate knowledge exchange between universities and industry (Goddard and Chatterton, 1999). REDAs therefore, look to universities to facilitate their economic development mandates. However as universities and REDAs measure commercialisation success in different ways, many of the actions taken by each organisation are not aligned. For instance, REDAs only see real benefits if licensing revenues to universities are generated from firms in the local economy, whereas universities often see greater licensing potential from licensing to firms outside their surroundings.

Nevertheless, in the past three decades firms have been increasing the extraction of commercial value from university research, which has been facilitated in part by the adoption of university and federal government policies. For instance, in the US, the main initiative has been the 1980 Bayh-Dole Act (the University and Small Business Patent Procedures Act), which mandates institutional ownership of IP that is produced (with the support of federal government research grants) in public universities, with a corresponding responsibility for its commercialisation (Mowery and Sampat, 2005). In Canada, the AUCC signed a memorandum of understanding with the Canadian Government in 2002 aimed to triple universities' commercialisation activity over ten years in return for an increase in annual government grants of CDN $245 million to cover the indirect costs of research (AUCC, 2002). A similar mix of mandated IP policies and financial incentives is offered in most developed countries, including the European community.

As a result, university TTOs have been not only encouraging their innovators (professors, researcher, graduate students, etc.) to patent and commercialise IP through expanded technology-transfer capabilities but they have also been attempting to control the process by deciding who can and who cannot license their technologies. However, positive are the intentions of these laws and policies, scholars have identified fundamental problems with this approach. Some have questioned the commercial expertise of university TTO staff in making investment decisions (e.g., Rothaermel et al., 2007). Litan et al. (2007) suggest that the control of technology transfer by a TTO restricts the commercialisation potential because it encourages universities to adopt a licensing commercialisation model, and they are encouraged to make decisions based on short-term benefits to the university as opposed to broader (regional) benefits.

2.2 Universities' focus on licensing may not pay off

Despite these weaknesses, many universities undertake traditional technology transfer activities like licensing without clearly understanding how this can generate financial returns. Blake (1993) has shown that even if a technology has commercial potential, only 10% of invention disclosures generate patents, and, excluding cases where inventors license their own technologies, only 1% of these disclosures provide a return that exceeds the cost of establishing the license. Furthermore, revenues from these successful licenses, even in the long term, do not, on average, provide sufficient returns to justify the original federal investment in R&D.

As shown in Table 1, federal government research funds generated a gross licensing return to universities of CDN $23.4 million in 1999, and CDN $51 million in 2003, and are expected to generate an estimated CDN $70.2 million in 2010. These amounts are lower when the costs of licensing activities are factored in, which diminish the total net income to CDN $1.4 million, CDN $14.6 million, and CDN $23 million, respectively, across all of Canada's 90 universities. The situation is similar in the US, where 40% of university TTOs earned less than US $600,000 each in 2004 after legal fees but before the salaries of TTO employees were factored in Thursby and Thursby (2007). In fact, more than 80% of US institutions of higher education are expected to make no money from their technology transfer activities (Bostrom, 2005; Shane, 2002) and, on average, licensing revenues represent less than 0.5% of universities' total income (AUCC, 2005).

Table 1 Canadian Government research funding of universities and net income from licensing

	1999	*2003*	*2010**
Research funding	$982	$1,626	$3,000
Gross income	$23.4	$51.0	$70.2
Expenditures	$22.0	$36.4	$47.2
Net income	$1.4	$14.6	$23.0
% of research funding	0.14	0.90	0.77

Notes: * Forecast

CDN $ million

Source: AUCC (2005)

We do not assert that licensing is an inconsequential technology commercialisation mechanism. Several well-known cases support technology licensing such as the Cohen-Boyer recombinant DNA patent developed at Stanford University and the University of California and licensed to numerous firms and research organisations (Odza, 1996). These well-documented successes have led to the assumption that universities enjoy large financial returns from licensing (Goldstein and Renault, 2005), and have encouraged TTOs to focus on licensing despite its limited success or the existence of other available options for commercialisation. Following the lead of Shane (2002), we also argue that focusing on the short-term financial benefits from licensing without understanding the potential benefits of other commercialisation mechanisms (such as research contracts, new venture creation, etc.) may lead universities to neglect other options for IP transfer that could not only bring in substantial benefits to the university but also to the region.

2.3 Commercialising through new venture creation

In most universities, a new business venture is created only when a potential licensee cannot be found for the IP developed at the university. The TTO then takes equity in the newly formed enterprise to catalyse a license revenue opportunity with the hope of benefiting from sale of that equity in the longer term. Markman et al. (2005a) found that universities' efforts to form joint ventures based on an IP or technology developed within their walls result in the creation of a new venture in only 17% of cases, compared to 72% in straight cash licenses (and the remaining 11% in research contracts). The lack of interest by universities in creating new ventures is primarily due to substantially higher requirements of the resulting enterprises, as well as the higher risk associated with starting up a new business compared to licensing a technology (Lockett and Wright, 2005).

Indeed, the investment funds and business expertise required to create a new business venture necessitates a local individual or organisation that possesses the complementary assets and expertise to build a viable commercial enterprise. These assets are necessary before the innovation is ready for market (Thursby et al., 2001). Even when a new technology is market-ready, identifying and attracting first customers and building the business requires significant expertise and resources that are rarely owned by the inventor or TTO. Most TTOs are constrained in developing such capabilities because the university places limits on the incentives (such as financial bonuses) it can offer to employees, whereby employees will typically leave for higher pay with venture capital firms or even for technology start-ups as they become more experienced. Bray and Lee (2000) contend that TTOs are reluctant to suggest starting a new venture if the inventor is not seen as someone who can actively participate in operating that venture.

A university's culture tends to focus TTO staff attention on easy-to-license technologies, encouraging a one-size-fits-all view of commercialisation (Rogers et al., 2000). Consequently, inventors are disappointed when their technologies fail to be commercialised, and some engage in expensive legal battles with their universities over ownership and rights (Berners-Lee, 1999). TTOs tend to concentrate on a one-way technology transfer process – from university to industry – which limits the potential for direct interactions between researchers and the marketplace, and reduces the chances of successful commercialisation (Etzkowitz, 2003).

This one-way approach reinforces the idea that the traditional licensing model (through TTOs) is unlikely to realise the full commercialisation potential. Next, we expand upon this model by adding new venture development as a means to facilitate wealth creation from university research.

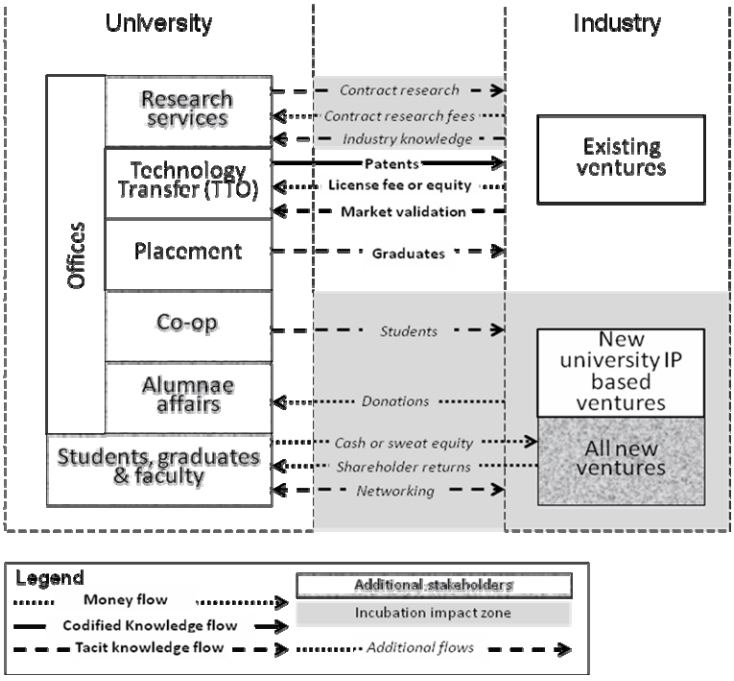
3 A model of knowledge extraction

Scholars (e.g., Rogers et al., 2000; Siegel et al., 2003) who study universities' economic impact on their surrounding regions have focused on licensing codified knowledge [i.e., compact and standardised information that can be easily transferred through information infrastructure, such as patents; David (1993)] to industry. A growing body of literature also links codified knowledge to economic growth, emphasising the accumulation and spill-over of technological knowledge into the community as essential for accelerating economic growth (e.g., Mueller, 2006). In addition to codified knowledge, tacit

knowledge [i.e., ill-defined or difficult to articulate insights acquired by individuals in the course of their work; Polanyi (1962)] transferred between university and industry can contribute to economic well-being. This knowledge is based on experience and thus resides inside the innovator (who understands how to use an innovation) and cannot be easily communicated to a third party.

Therefore, we argue that explicitly considering tacit knowledge, which can be extracted from graduate students and alumni (who go on to work in the community) or interactions between industry and academia, can better highlight the benefits of technology commercialisation on a region's economy. While some scholars have attempted to establish measurement systems to quantify the effects of knowledge flows (e.g., Goldstein et al., 1995), here we focus instead on identifying the mechanisms that facilitate these flows, such as employment of graduate students. Understanding the different mechanisms enables us to identify how goals can be better aligned between universities and REDAs through the creation of new ventures and their development in incubation programs. We build a framework based on flows of knowledge and money not currently accounted for in traditional commercialisation models, as summarised in Figure 1. By considering a wider range of knowledge transfer activities in universities, we can better understand the iterative nature of the commercialisation process (Bramwell and Wolfe, 2008).

Figure 1 University-industry commercialisation model



3.1 Tacit knowledge in wealth creation

We first expand the traditional flow of codified knowledge through a university's TTO by adding transfers of primarily tacit (as well as some codified) knowledge via the university's office of research services. This office negotiates fee-paying contracts with companies and/or governments to undertake research or obtain funding to participate in collaborative research projects. Collaborative research (i.e., research contact) is an excellent mechanism for transferring a university's technical expertise, knowledge and resources developed in the laboratory to an industry. Not only can those in the lab transfer tacit knowledge to an industry, but people in that industry can also provide insights to those in the lab (Meyer-Krahmer and Schmoch, 1998). Indeed, research findings can lead to commercialisable innovations that enhance firms' competitive positions and stimulate their growth. The university becomes a connectivity point in a global knowledge network and a conduit for sharing information with the local community (Bathelt et al., 2004).

The tacit knowledge embedded in faculty and students can also be transferred to industry through formal programs [e.g., cooperative education work terms coordinated by the university's coop office; Nelles et al. (2005)], informal activities such as local networking events and conferences (Markman et al., 2005a), or when that industry becomes an early technology adopter [as it creates a mechanism for identifying opportunities and facilitating implementation; Gertler (2003)]. Such transfers are enabled by the absorptive capacity of the industry – its ability to learn from external sources and to readily deploy resources to take advantage of the knowledge learned (Cohen and Levinthal, 1990).

While these knowledge transfer options are valuable, the most significant transfer of tacit knowledge occurs when students graduate from the university and either take jobs in an industry or start their own business (Goldstein and Drucker, 2006). These flows of tacit knowledge, facilitated by the university's placement office, can have a greater impact in determining the true economic value extracted from university research than the traditional flows of codified knowledge due to licensing (Bramwell and Wolfe, 2008). While attending the university, students participate in both basic and applied research and have access to sophisticated technology under the supervision of skilled and knowledgeable professors. These activities give students a profound understanding of both technology and problem solving, thus, creating highly qualified personnel (Wolfe, 2005). In a recent article, Xu and McNaughton (2006) identify that key role that this pool of talented individuals play in transferring tacit knowledge to new technology ventures and large research-based organisations. Mike Lazaridis, Chancellor of the University of Waterloo and founder of Research in Motion (RIM), also supports this view: "If you really want to understand commercialisation, all you have to do is to attend convocation (graduation ceremony) at your local university" [Lazaridis, (2004), p.8].

In noting how the policies of TTOs and the commercialisation model based on licensing can limit the conversion of knowledge into new products and processes, Acs and Varga (2005) suggest that new venture creation, rather than traditional industry linkages, is a knowledge transmission channel that can avoid these limitations. New business ventures based on licenses from a university's IP are already accounted for in the commercialisation activities of a university. However, a larger group of new ventures not based on university IP are in fact valid commercialisation activities and yet they materialise from the presence of the university because, among other things, these

ventures are often created by graduate students. These students develop an idea while at the university and decide to start a business (more often than not in close proximity to that university). While these ventures do not bring in licensing fees to the university, they can create significant long-term benefits to universities by providing employment and research contracts.

The flow of tacit and codified knowledge thus, reaches industry through licensing, research contracts undertaken at a university's labs, informal and formal networking, cooperative education work terms, and through graduate students and alumni who work in local industries or start their own ventures in the university's community. These knowledge channels are strengthened by new ventures that take advantage of both codified and tacit knowledge stemming from the university. They then develop a two-way knowledge street between local industries and the university.

3.2 Licensing may pay off with new ventures

With traditional technology licensing, Markman et al. (2005a) suggest that a TTO chooses the type of commercialisation activities based on its capacity to maximise cash flows while minimising financial and legal risks. Thus, a TTO will sell a license to the company best able to pay the license fee. Based on this motivation, Waugaman and Tornatsky (1999) argue that university licensees are often located outside a licensor's (university's) region, resulting in wealth creation outside the region. In addition to reducing the direct regional economic impact from this license motive, this commercialisation strategy reduces the opportunity for additional flows of tacit and codified knowledge in the university's region through graduate job placements and research contracts from the licensees.

Creating new ventures that use university licenses can provide economic benefits to a region because these ventures tend to locate in close proximity to the university (Hisrich and Smilor, 1988), create higher paying local jobs and employ the university's graduates (Feldman, 1994), and are better receptors for knowledge spill-over than large firms because they are quicker to react to new opportunities (Acs et al., 1993). Licensing through existing or new ventures in the region also increases the likelihood of successful technology implementation, which requires the exchange of further knowledge to enable proper utilisation (Senker, 1995). Further, spin-offs of new ventures have been shown to account for more long-term license and other revenues (Bray and Lee, 2000). When the university takes equity in lieu of license fees, it maintains the potential payoff from the technology, even if the ultimate commercialised technology is not based on the original IP produced at the university (in which case a traditional license agreement would be terminated).

Using case examples of two Ontario-based research universities, the University of Waterloo and University of Toronto, we demonstrate the payback for the university and the region when a university supports new ventures. We do so by examining the income obtained by these two universities. As shown in Table 2, technology entrepreneurs at the University of Waterloo have been a significant source (at least 50%) of gifts and donations through the university's office of alumnae affairs. This university's entrepreneurial success over the past five years has resulted in nearly 70 times more income for the university than from licensing IP. In the case of the University of Toronto, gifts and donations are also more significant than licensing income (a little over 30 times,

on average). The payback from supporting entrepreneurial activity and maintaining ongoing linkages with alumni is greater than from the licensing activities of the TTOs for both universities.

Table 2 Two Canadian universities' research, gift and license income

	University of Waterloo			
	Research income	*License income*	*Gifts and donations*	*% of gifts and donations from tech entrepreneurs*
2001	$68	$0.6	$23	60%
2002	$71	$0.7	$71	50%
2003	$73	$0.7	$55	60%
2004	$77	$0.8	$56	50%
2005	$80	$0.8	$37	70%
	University of Toronto			
	Research income	*License income*	*Gifts and donations*†	*% of gifts and donations from tech entrepreneurs*
2001	$350	$3.1	$98	20%
2002	$370	$3.3	$122	30%
2003	$400	$3.9	$76	30%
2004	$420	$2.9	$71	30%
2005	$428	$1.7	$83	20%

Notes: † These numbers only include the main institution and not the colleges that have their own donations.

2001–2005, CDN$ million

Sources: Donor Reports and Annual Reports from the University of Waterloo and the University of Toronto (http://www.connected.uwaterloo.ca/; http://www.finance.utoronto.ca/Page799.aspx); Association of University Technology Managers (AUTM) Annual Reports, 2002–2006.

3.3 Aligning the goals of university and REDA

The commercialisation model proposed above and summarised in Figure 1 provides insight into how and why universities should increase their range of commercialisation activities (including those non-IP-licensed-based) and thus, create more opportunities to provide regional benefits that will align with the goals of REDAs. In most universities, the TTO, research services office, placement office, coop office, and office of alumnae affairs are continuously involved in both transferring knowledge from the university to the community and attracting money (e.g., research grants, gifts and donations) to the university. These five offices are also involved in finding opportunities for collaboration to stimulate interactions between academia, industry and, to a lesser extent, government. Creating a culture that encourages these three organisations to collaborate and enable activities in one university office to benefit other offices across the university, and the region as a whole, can promote additional wealth creation and non-monetary benefits (such as goodwill and a sense of cooperation).

For instance, companies that lease licenses for IP from universities may also be motivated to enter into research contracts with the university or hire student interns or alumni. Similarly, alumni working in firms in the region may be favourably disposed to sponsoring university activities, including alumni activities and fundraising, or hiring student interns for their work term. Increasing the opportunities for knowledge extraction by enhancing interactions between local industry and academia through these activities promotes regional wealth creation. We recognise that augmenting the role of these offices to further facilitate the transfer of codified and tacit knowledge creates internal dilemmas for the university (Bercovitz and Feldman, 2005). Nevertheless, we hope to stimulate a discussion of how such dilemmas can be addressed as they can have a profound impact on a university's mission and how it develops relationships with the local community (DiGregorio and Shane, 2003).

The benefits of these interactions between university and industry are most easily seen when universities stimulate the creation of new ventures, either by licensing their IP locally and/or by fostering an entrepreneurial culture in its academic programs. This culture encourages alumni to form new enterprises in the university's surroundings. The creation of these ventures provides mutual benefits to the university and its surrounding region, thus, aligning its goals to those of REDAs. Understanding the value of new ventures to the university and the surrounding region should serve to motivate both organisations to support the development of incubation programs, which programs go beyond supporting ventures based on a university's IP. We propose that university-linked incubation programs can fulfil this role if they are designed to maximise the various flows of tacit and codified knowledge described in our model. In the next section, we identify the catalytic role that incubators can play in facilitating commercialisation.

4 Role of university-linked incubators

By broadening our understanding of how new ventures create regional wealth, while also considering ventures not based on university-licensed IP, we can better appreciate the role of incubators in growing a region's economy. In this section, we describe how technology ventures can create benefits to universities and REDAs if located in an incubator with strong links to a university. More specifically, we demonstrate how the additional flows of knowledge and money resulting from incubation activities provide benefits to various parties. We return to the University of Toronto and the University of Waterloo and examine two of their incubators to illustrate the importance of clearly articulated and aligned objectives and an entrepreneurial culture for a university to achieve successful commercialisation.

4.1 Expanding the traditional role of incubators

Technology incubators have been shown to enhance the success of early-stage technology companies (Mian, 1994) as well as their rate of growth (Wolcott and Ballou, 2003). We now expand the current view of the value of incubation programs to universities.

Mian (1996) notes that by facilitating the access of university-based technologies and well-trained graduate students to the start-ups they incubate, incubators make available

resources and advice, as well as tacit and explicit knowledge, they could not otherwise afford. According to Markman et al. (2005b), universities are increasingly recognising the value of incubation. Based on interviews with 128 TTOs, Markman et al. (2005b) found that 62% of universities and their surrounding communities establish business incubators and build research parks as a way to encourage technology-based new ventures. Smilor and Gill (1986) further demonstrate that incubators combine talent, technology and capital in order to accelerate the technology commercialisation process. Markman et al. (2005a) elaborate on the importance of this acceleration process in facilitating the transfer of knowledge and, as a result, incubators enhancing the likelihood of creating commercial value, especially in the long run.

Incubators also play an important role in creating an entrepreneurial innovation hub within a region, which enhances networking and linkages, and facilitates the sharing of tacit knowledge (Asheim and Gertler, 2004; Etzkowitz, 2002). In turn, new technology ventures stimulate local economies (e.g., Audretsch et al., 2006), create high paying jobs (Porter, 2003), derive a higher portion of their gross revenues from export sales (Bleaney and Wakelin, 2002), encourage local early technology adopters (Holbrook and Clayman, 2003), and create local wealth for shareholders (Feldman et al., 2002; Mason and Harrison, 1995). Further, the establishment of an incubator can catalyse interactions between members of the wider business community and with the university, providing direct and quantifiable benefits to the local economy.

Incubators play two key valuable roles: they have a direct and positive impact on incubatees and they facilitate the flow of knowledge and funds between university and industry (which creates wealth in the region). This dual role in extracting knowledge from the university and then stimulating a region's wealth creation is shown in Figure 1 as the 'incubation impact zone'. Given the iterative nature of the knowledge flow from the university to both new and existing ventures, and then back to university labs and faculty/students, incubators can speed up knowledge transfers by facilitating interactions between all players. These interactions can especially benefit new ventures because they increase the potential for research contracts and encourage market validation, thus, increasing the likelihood of successful exploitation of technological innovations. In essence, incubators act as social networks to connect players from academia, local industry and local government.

By nurturing successful technology ventures that generate full- and part-time jobs for students and alumni, an incubator offers a means for creating regional employment. In some cases, these job opportunities may lead to investment opportunities for students, alumni and faculty, either in the form of capital (cash) or sweat equity. The five university offices identified in our model play dual roles of satisfying the internal needs of the university and facilitating interactions with the broader community. By collaborating with each other and with their local incubators, these interactions are more frequent and accelerate the transfer of knowledge between university and industry. In essence, the incubator becomes a portal for businesses and academia interactions. In addition, as Clotfelter (2003) argues, increased interaction between industry/alumnae and universities increases the likelihood of donations and endowments.

4.2 Two Canadian incubators

We reviewed the activities of two technology incubators created in the past decade in Ontario, Canada to demonstrate how incubators can increase and accelerate the benefits

accrued by a university and its region from the transfer of knowledge and money. While each had tri-party support from government, university, and industry that provided resources and infrastructure, each incubator operated under substantially different mandates. One, the Exceler@tor, operated under the simple mandate of increasing the likelihood of success for technology ventures created by the university's TTO, whereas the other, the Accelerator Centre, had a broader mandate – to increase economic development – and thus, it welcomed all of technology ventures, university-related or not.

The University of Toronto in 2002 launched the Exceler@tor and owned and operated this incubation facility with limited private sector (CDN $1.2 million, mainly in-kind) and government support (CDN $200,000) until 2005, when it closed the Exceler@tor, despite the fact that it had assisted 32 companies that raised over $9 million combined. A group of stakeholders from the Region of Waterloo, who gained support from the University of Waterloo, launched the Accelerator Centre in 2006 in the university's Research and Technology Park. The Accelerator Centre celebrated its third anniversary in spring 2009, at which time it also opened a second building.

The Exceler@tor – As one of Canada's largest research institutions, the University of Toronto has a strong history of developing innovative technologies. It has an IP policy similar to most institution-owned enterprises, with the university taking a percentage of generated income. The University of Toronto also established an arms-length, full-service commercialisation organisation, the University of Toronto Innovations Foundation, which seeks to obtain the maximum financial return from its commercialisation activities. In early 2001, that foundation migrated from a traditional licensing approach to creating and funding three technology ventures, with only one based on the university's traditional IP-owned model. These companies were housed remotely from the university and the Innovations Foundation, reducing the potential for synergies. The initial impetus to open the Exceler@tor was thus logistical, to provide co-located offices that were not only more cost effective, but closer to the university and the Innovations Foundation to encourage interactions.

Limited government funding was obtained conditional on Exceler@tor agreeing to admit organisations/entities beyond the University of Toronto groups and its IP-based ventures. As a result, over 120 companies applied to participate in this incubator of which 32 were accepted (only three were directly linked to the university's IP). As the incubator was required to be self-funding, each member offered share options to Exceler@tor. But during the first three years, only two incubated businesses had liquidity events that converted these options into cash. The university did not value the unexercised options or other benefits such as employment of graduate students and alumni, and research contracts from the incubation program. When government funding ran out, the university, which owned Exceler@tor, was faced with covering operating costs for this incubator that supported 23 companies of which 20 had no direct link to the university. Consequently, the University of Toronto closed the Exceler@tor due to short-term negative cash flows. That decision was facilitated by the creation of MaRS, a new publicly funded incubator located only 500 meters away.

The Accelerator Centre – This incubator was created through the combined efforts and funding from regional and provincial REDAs and the University of Waterloo. The Accelerator Centre is located on land owned by the university, which it leased under a long-term contract to a private developer in return for 21,000 square feet of free

incubation space in the new building. According to the agreement, the developer earns guaranteed rent from the anchor tenants, while the incubatees' rent provides value-added services to the tenants, creating a viable long-term business model. The Accelerator Centre provides incubation facilities primarily (but not limited) to the University of Waterloo's alumni. The Accelerator Centre explicitly does not focus on the university's IP for two reasons: the university's basic IP policy is that inventions/patents are inventor-owned, and, due to its engagement with REDAs, the university understands that most new ventures located in the incubator are not directly related to IP-created ventures flowing from research labs. The Accelerator Centre does not consider university license revenues as an objective, nor does it receive equity or options in its incubatees.

The Accelerator Centre reflects the entrepreneurial philosophy of the University of Waterloo, and epitomises its belief that ongoing engagement with technology ventures provides long-term benefits to the university. This has been further strengthened by the recruitment of an incubator manager who also functions as the university's associate VP for commercialisation. The University of Waterloo's rationale in supporting such activities is reflected, in part, in President David Johnston's comment during an interview with one of the authors: "Strong local technology companies founded by and employing University of Waterloo's alumnae will find their own way to contribute financially to the ongoing success of the university." Such thinking is not based on the positive outcomes of a previous incubation program, but on the mindset and culture of the university that emanated from its creation over 50 years ago when it was established to support the needs of local industry.

Key differences in the timeframe of their objectives may explain these two incubators' different outcomes. The university's decision to close Exceler@tor due to long-term viability concerns may have been based on a limited understanding of the incubator's role in, and value to, both the university and the REDA. Such a mistake, however, appears to have been avoided with the Accelerator Centre. As we show in Table 3, the long-term success of each appears to be a function of the differing mandates under which they operated, the different environments in which they existed, and possibly the performance of the incubator itself. As universities develop a broader understanding of the commercialisation process, the longer-term benefits of an incubator will become more apparent. If universities can work with REDAs to stimulate regional entrepreneurial activity, then goal miss-alignment can be reduced. As a result, conflicts regarding university commercialisation activities will be minimised (because these activities will now be in the best interests of the region) and governments will be encouraged to fund both universities and REDAs.

We have also learned from these two case studies that funding incubators can be challenging. While the presence of an incubator can accelerate the flow of knowledge in and out of the university, the greatest beneficiary from incubation activities is the region in which the incubator operates. As a result, it would seem natural for REDAs to fund incubation activities. As articulated by Litan et al. (2007), the risks faced and resources necessary for extending the mandates of TTOs to support new ventures oppose their short-term revenue objective. On the other hand, REDAs' mission is to invest in and support activities that stimulate longer-term regional wealth.

Table 3 Factors differentiating the two incubators

Factor	*Exceler@tor (University of Toronto)*	*Accelerator (University of Waterloo)*
Cost model	Market rent paid for space	Space provided by private landlord in return for ability to use university owned land
Revenue model	Above market rate and share options charged for services	Space charged at market rates, no equity position
Ownership	100% owned by Innovations Foundation, which in turn was 100% owned by the University of Toronto	Owned by separate not-for-profit entities with multi-party stakeholders, including university, industry and government
Mandate	Incubator – break even, support TTO spin-offs	Incubator – break even, support all local new ventures, enhance university networking
	University – academic excellence and research	University – train people for local industry and stimulate innovation
University IP policy	University owned	Inventor owned
University-incubator linkages	Very limited	Master's in entrepreneurship program located in the University of Waterloo's science park

Furthermore, we have learned how various stakeholders can be recruited by examining the Accelerator Centre case. To detail this, we must travel back over 50 years to the founding of the University of Waterloo. Local businessman Gerry Hagey founded the university in 1957 to provide relevant training for local businesses and large corporations. In 1963, business leaders in the Kitchener-Waterloo area purchased 1 square mile of cornfield, which later became the University of Waterloo's North Campus, and provided 640 acres for future university expansion. In 1992, the university's Board of Governors commissioned a master plan for 'developing a detailed strategy for the long-term management of the North Campus' to address the 'changing context of the university in the dynamic city and region that surrounds it' [Berridge and Greenberg, (1992), p.5]. A key element of this master plan was that 'the university should encourage development which can initiate the potential for transfer of knowledge between university research activities and the private sector. Those links should be actively promoted and encouraged through the furthering of social and informal contact as well as through more formal connections to the university' [Berridge and Greenberg, (1992), p.42]. In July 2004, a board of directors for the Accelerator Centre (housed on that land) was put in place, and included 18 representatives from a cross-section of the business community including its founding partners: University of Waterloo, Wilfred Laurier University, University of Guelph, Conestoga College, Government of Canada, Ontario Government, Regional Municipality of Waterloo, and City of Waterloo. The Accelerator Centre opened its doors on 18 May 2006, with strong support from its founding partners and local industry.

5 Concluding remarks

We have identified several conflicts that restrain the commercialisation of university research: the university's academic versus economic objectives, its emphasis on TTO licensing (and hence, on the translation of codified knowledge), and its ambiguous perception of the benefits from investment in commercialisation activities. To address these conflicts, we propose that universities and REDAs join forces to better align their goals and adopt a broader, more far-sighted model of knowledge and money flow between the university and local industry. This will create a wider range of commercialisation activities that are valued by and will benefit all stakeholders. This model highlights the importance of creating new ventures and better understanding how they and their regional impact can be strengthened by the presence of an incubator.

Based on the University of Waterloo's and its REDAs' approach, we point out eight lessons learned in Table 4 that offer recommendations to other universities and REDAs trying to stimulate their region's commercialisation activities while also accruing benefits. These recommendations start at the most strategic level, with goals for the university that must be aligned with those of the REDAs, and include the development of appropriate commercialisation policies aimed at benefiting the various commercialisation channels identified. The recommendations then become more tactical, including establishing a combined performance measurement system, identifying additional funding opportunities, and creating new business and technology ventures via incubation programs. The recommendations also emphasise the importance of including graduate students, summer and coop employment opportunities, as well as the participation of the universities and REDAs in strategic planning and networking opportunities to facilitate the transfer of knowledge. Moreover, the ongoing engagement of alumni is recommended.

The development of a combined performance measurement system to accompany our model can help all parties understand how specific actions (such as IP and tenure policy, cooperative education and support for new venture creation) can increase knowledge flow and better align the goals of universities and REDAs. However, a measurement system designed simply to evaluate the performance of TTOs (e.g., Rogers et al., 2000) or incubators (e.g., Wiggins and Gibson, 2003) either overlooks the regional economic impact of commercialisation activities or understates the importance of industry linkages with universities and the development of human capital. Mian (1997) also recommends an expanded role for incubators that highlights both short- and long-term benefits to the range of stakeholders.

We, thus, propose a measurement system that is based on each of the knowledge and money channels developed in our expanded commercialisation model in Figure 1. Our suggested measurement system shown in Table 5 allows universities and REDAs to estimate the relative importance of each channel, both generally and specifically in relation to a region's economy. As the physical manifestation of all stakeholders' desire to increase the benefits from commercialising university research, the incubator can work with the REDA and the university to introduce this tri-party measurement system. Collecting this data over time will allow all parties to determine the success, or failure, of activities designed to strengthen the flows of knowledge and money.

Our measurement system addresses some of the concerns raised by Mowery and Sampat (2005) in that it:

1 is based on an understanding of the overall role played by the university in a knowledge-based economy

2 can assess the regional economic impact of knowledge flows

3 provides a framework that enables the assessment of the strength of linkages and it can show how these links may change over time.

While our proposed measurement framework identifies income sources for universities, REDAs and incubators, it also gathers information on the characteristics of these incomes, which helps to identify opportunities for increasing them. We augment the measurement of traditional knowledge and money channels with additional channels that may be more significant in the long term. For instance, we include the number of regional jobs created from these incubators in measuring the output of universities, not just in terms of the number of new graduate students employed but also their average starting salaries (an important factor in examining how they contribute to wealth creation).

Table 4 Factors fostering industry/REDA/university linkages

Factor	*Particulars*
Goal alignment	Universities and REDAs must understand and support the goals of each other, and understand the impact on their culture.
Policy development	Universities must adopt a comprehensive series of policies that support their goals and foster interactions with the region. Specific attention should be paid to: hiring, tenure and IP policies and the development of long-term programs that build on the local strengths of industry and academic institutions.
Performance measurement	Universities and REDAs must embed performance measurement systems that support the aligned goals and track/enhance knowledge flows between industry and academia.
Funding	Universities and REDAs should work together to obtain government and industry support for commercialisation activities, irrespective of which organisation gets to spend it.
Importance of new ventures	Universities and REDAs should develop joint working groups to enhance new venture creation opportunities, acknowledging their mutual importance and benefits.
Incubation programs	The importance of incubation programs should be recognised in achieving the goals of universities and REDAs. Multi-stakeholder group that includes several academic institutions, REDAs and industry players should lead these programs.
Employment	Greater industry-academic linkages should be stimulated to maximise the opportunities for knowledge extraction exchange and through coop student placement and graduate employment.
Enhanced networking	Universities and REDAs should recognise the importance of formal and informal interactions in increasing knowledge flows and identifying commercialisation opportunities. They should take specific steps to encourage such interactions, especially with the broader alumnae community.

Table 5 Proposed measurements for flows of knowledge and money

Activities	*University*	*REDA*	*Incubator*
Traditional income	Contract research and license revenue ($ by source/type)	Gross exports from region ($ by source/type)	Gross revenues from incubatee operations ($ by source/type)
Traditional grants	Government funding for commercialisation ($ by source/type)	Government funding for specific programs ($ by source/type)	Government funding to incubator & incubates ($ by source/type)
Venture creation	Number of start-ups from university-based IP (revenues/employees)	Number of start-ups (revenues/employees)	Number of start-ups (in incubator and recent incubatee graduates)
Venture outcomes	University equity ($ by source/type)	Market capitalisation for new venture ($ by source/type)	New financing raised ($ by source/type)
Employment full-time	Employment of full-time graduates (no. by salary/region)	Regional employment of graduate and non graduate employees (no. by salary/type)	Incubatee full-time employees (no. by salary/source
Employment part-time	Coop and part-time employment (no. by salary/type)	Spill-over employment (no. by salary/type)	Spill-over employment (no. by salary / type)
Tacit knowledge transfers	Networking activities (no. of participants)	Networking activities (no. of participants)	Networking activities (no. of participants)
Additional revenues	Alumnae donations ($ by source/type)	Tax base in region ($ by source/type)	Other income sources ($ by source/type)

Our proposed measurement system also takes into account the number of new ventures created both inside and outside the incubator and their success rates (e.g., through a liquidity event), and thus helps measure the role of the incubator. We expand the definition of 'new ventures' to include ventures not created from university-based IP (but via the incubator), highlighting the importance of tacit knowledge embedded in the people creating these ventures. Moreover, we extend the traditional measurement systems by accounting for more of the tacit knowledge flows associated with activities such as networking and work-term (internship) experience.

We further contribute to existing literature by proposing that incubators play a role in addressing several of the conflicts, such as funding and the challenges of cultural change that may discourage universities and REDAs from working together for mutual benefit to increase commercialisation activities. An incubator can be the nexus of industry and academia. In other words, an incubator can facilitate a two-way knowledge flow between university and industry (and thus help alleviate conflicts). Incubators can also help universities and their TTOs regard new venture creation as a viable commercialisation option. An incubator can stimulate research contacts and develop additional local employment opportunities through links with the five identified university offices (the TTO, research services office, placement office, coop office, and office of alumnae affairs). As incubatees build local partnerships and eventually emerge from the incubator, REDAs can measure the direct benefits of funding incubation activities (e.g., through the number of jobs created). In addition, monitoring the early-stage activities of incubatees allows an incubator manager to evaluate the spill-over effect into the local economy,

including the creation of secondary jobs and the attraction of other technology firms to the region. This, in turn, allows REDAs to quantify the increase in local taxes and justify their investments.

Finally, we underscore the recommendations of Clarysse et al. (2005), who suggest that an active incubation program can stimulate and enhance a university's entrepreneurial culture. Varying cultures exist across universities (and regions), which lead to different commercialisation views and mechanisms. The university's culture and mindset definitely influenced the way that our two case study incubators were structured, managed and overseen. Acknowledging the importance of new venture creation for the commercialisation of university research should motivate REDAs and universities to consider initiating incubation programs and to align their goals to increase their effectiveness.

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