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UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER IN CANADA: AN ANALYSIS OF STAKEHOLDERS' PERFORMANCE USING SYSTEM DYNAMICS

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To her who always knew how to be by my side

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"Entrepreneurship is an action that successfully direct
the flow of resources towards the fulfillment of consumers needs"

(Robert Jacobson, 1992)

"My theorizing about firms reflects my belief that
one cannot understand technical advance in a particular field
unless one has a good theory of the firm
so that one can understand what they do and don't do.
But, on the other hand, one cannot characterize
what one wants to understand about the players (firms)
until one has characterized the game (technical advance) in some detail"

(Richard Nelson, 1992)

The challenge isn't to find occult links between Debussy and the Templars.
Everybody does that.
The problem is to find occult links between, for example, cabbala and the spark of a car.
Any fact becomes important when it's connected to another.
The connection changes the perspective.

(Umberto Eco, Foucault's Pendulum)

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Terms

ACOA	Atlantic Canada Opportunities Agency
ACST	Advisory Council of Science and Technology
AIAA	American Institute of Aeronautics and Astronautics
AUCC	Association of Universities and Colleges of Canada
AUTM	Association of University Technology Managers
BDC	Business Development Bank of Canada
CC	Commercializing Company
CFI	Canadian Foundation for Innovation
CIHR	Canadian Institutes of Health Research
DEC	Canada Economic Development for Quebec Regions
FedNor	Northern Ontario
GDP	Gross Domestic Product
GERD	Gross Expenditure in Research and Development
ILO	Industrial Liaison Office
IP	Intellectual Property
IRAP	Industrial Research Assistance Program
IRDI	Independent R&D Institution
NSERC	Natural Science and Engineering Research of Canada
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
SD	System Dynamics
SSHRC	Social Science and Humanities Research Council of Canada
TRIPS	Trade Related Aspects of Intellectual Property Protection
TTO	Technology Transfer Office
UITT	University-Industry Technology Transfer
VRQ	Valorisation Recherche Québec
WTO	World Trade Organization

Abstract

This research project concerns university-industry technology transfer (UITT) and entrepreneurial practices in Canada. The objective is to gain insight into the process of technology transfer and university spin-off creation. An important proposition in this research is that UITT and spin-off creation are complex phenomena fueled by structural feedbacks and time delays.

It is argued that UITT and university spin-off creation develop within a non-commercial environment. In this sense, uncertainty, informational gaps, and lack of receptor capabilities influence the success of spinning off companies, and thus the need to develop a dynamic approach to investigate these phenomena. To construct a theoretical framework for analyzing UITT and spin-off creation, five models are evaluated: the evolutionary model, the entrepreneurial opportunity and entrepreneurial capacity model, the stage model of academic spin-off creation, the technology transfer office (TTO) model, and the critical junctures model. However, system dynamics (SD) methods give the possibility to evaluate UITT and university spin-off creation from a dynamic perspective. In fact, SD simulation allows for evaluating change and its consequences for the evolution of a system over time. The SD model developed in this research analyzes stakeholders' decisions in terms of two different kinds of relationships that are linked trough material and monetary flows.

In Canada, the process of UITT and spin-off creation can be analyzed within a general framework that includes a TTOs, commercializing companies and university spin-off. A theoretical model is developed establishing a dynamic hypothesis as a preliminary explanation on these phenomena. Then, a baseline scenario and two other alternative scenarios are established for policy evaluation purposes. However, using data released by the Association of University Technology Managers (AUTM) and Industry Canada, the model is calibrated and evaluated for validation.

The results confirm some principles already discussed in the literature. The results achieved in this research are evaluated from the perspective of an alternative environmental and government policy, as well as an alternative university policy and organizational structure. Nevertheless, the conclusions in this research suggest the importance of initial subsidy, external financing sources and university income distribution rules as important features characterizing stakeholders' performance, and thus the technology transfer pathway at Canadian universities. However, the main contribution of this research is the development of a SD model to evaluate UITT and spin-off creation as complex phenomena.

Keywords: technology transfer, university spin-offs, system dynamics, Canada.

Résumé

Ce projet de recherche concerne le transfert technologique universitaire vers l'industrie (TTUI) et les pratiques entrepreneuriales au Canada. L'objectif est d'obtenir un aperçu sur le processus du transfert de technologie et de la création d'entreprises dérivées. Une proposition importante dans cette recherche est que le TTUI et la création d'entreprises dérivées sont des phénomènes complexes, alimentés par des boucles de rétroaction et des délais.

Cette thèse fait valoir que le TTUI et la création d'entreprises dérivées se développent dans un environnement non commercial. En ce cas, l'incertitude, les lacunes d'information, et le manque de capacités de récepteurs influencent la réussite de lancement des entreprises universitaires, d'où la nécessité de développer une approche dynamique pour investiguer ces phénomènes. D'ailleurs, pour construire un cadre théorique pour l'analyse le TTUI et la création d'entreprises dérivées, cinq modèles sont évalués: le modèle évolutionniste, le modèle de possibilités et des capacités entrepreneuriales, le modèle par étapes de la création d'entreprises dérivées, le modèle de bureau du transfert de technologique (BTT), et le modèle aux moments critiques. Toutefois, les méthodes de la dynamique des systèmes (DS) offrent la possibilité d'évaluer le TTUI et la création d'entreprises dérivées à partir d'une perspective dynamique. En fait, la simulation par la DS permet d'évaluer le changement et ses conséquences pour l'évolution d'un système dans le temps. En fait, le modèle DS développé dans cette recherche analyse les décisions des acteurs en termes de deux différents types de relations qui sont liés par des flux matériaux et monétaires.

Au Canada, le processus de TTUI et la création d'entreprises dérivées universitaires peuvent être analysés dans un cadre général qui comprend les BTTs, les entreprises à commercialiser et les entreprises dérivées universitaires. Un modèle théorique est développé instituant une hypothèse dynamique comme explication préliminaire sur ces phénomènes. Ensuite, un scénario de référence et deux autres scénarios alternatifs sont établis à des fins d'évaluation de politiques alternatives. Toutefois, le modèle est calibré et évalué pour la validation en utilisant les données publié par l'*Association of University Technology Managers* (AUTM) et Industrie Canada.

Les résultats confirment certains principes déjà discutés dans la littérature. En fait, les résultats obtenus dans cette recherche sont évalués dans la perspective d'une structure alternative de l'environnement et de la politique gouvernementale, ainsi que d'une politique universitaire et de l'organisation. Néanmoins, les conclusions de cette étude suggèrent l'importance des subventions initiales, les sources de financement externes et règles de répartition des revenus dans les universités, ainsi que les caractéristiques qui déterminent la performance des acteurs et donc la voie du transfert de technologie par les universités canadiennes. Toutefois, la contribution principale de cette recherche est le développement d'un modèle dynamique pour évaluer le TTUI et la création d'entreprises dérivées comme un phénomène complexe.

Mots clés : transfert technologique, entreprises dérivées universitaires, dynamique des systèmes, Canada.

I. Introduction

Introduction

This research project concerns university-industry technology transfer (UITT) and the entrepreneurial aspect of these practices in Canadian universities. The objective is to develop a dynamic model to evaluate stakeholders' performance within the process of technology transfer using system dynamics (SD) principles. This research aims to inquire about the performance of stakeholders in the creation of spin-off companies and mechanisms such as licenses to exploit university technology developments.

UITT and spin-off creation have become a widespread practice. The current research agenda on the study UITT addresses many topics. Mowery and Shane (2002) comment that the very important issues attracting scholars' attention today include: (1) the relations established between university research outcomes and private sector innovation, (2) the mechanisms used when transferring new technologies, (3) the evolution of UITT activities, and (4) the creation of new firms to exploit university technologies, among others.

From an empirical perspective, scholars agree that due to the emergence of the knowledge-based economy, current intellectual property (IP) systems ought to face new challenges. The latest legal and administrative changes observed in many countries have affected IP protection regimes and practices, and thus, uncovering the need to adjust IP regimes in these countries. In the United States, for example, the passage of the Bayh-Dole Act in 1980 has increased the interest in formal technology transfer and licensing (Jaffe and Lerner 2001; Mowery and Shane 2002), and more recently university equity participation in spin-offs. By passing the Patent and Trademark Act of 1980, authorities in the United States attempted to institute a uniform patent policy to remove any restriction on licensing. However, the Patent and Trademark Act of 1980, as well as the Trademark Clarification Act of 1984, the Federal Technology Transfer Act of 1986, and the National Competitiveness

Technology Transfer Act of 1989, allowed universities to hold their own patents drawn from federal research grants, supporting at the same time the creation of technology transfer offices (TTOs) in many universities and public research centers (Jaffe and Lerner 2001; Siegel et al. 2004). In Canada, ownership of IP resides in the universities and in some cases the inventor does, both options coexist (Gault and McDaniel 2004). However, IP ownership in this country is specified in university policies or in collective agreements.

A direct consequence derived from this wave of changes was the emergence of TTOs and the creation of spin-off companies in many universities. In fact, spin-off companies have played a key role in the process of technology transfer, carrying out a more proactive participation in regional economic development, increasing important interrelations between science and technology in many disciplines, as well as supporting new sources of financing for universities (Pirnay et al. 2003). Recently, this phenomenon has received much more attention from scholars, given that it opened up further opportunities to commercialize new knowledge. The result is that spin-off companies may have contributed to transform the perception from the "traditional" university to an "entrepreneurial" university (Etzkowitz et al. 2000; Rappert et al. 1999).

The emergence of the entrepreneurial university can be explain as a response to the importance of knowledge in national and regional innovation systems and its contributions to enhance innovation environments (Etzkowitz et al. 2000). Examples in the established literature in the analysis of knowledge creation, technology transfer and entrepreneurial academy are: Brett et al. (1991), Carayannis et al. (1998), Etzkowitz (1989), Etzkowitz and Leydesdorff (1999), Etzkowitz et al. (2000), Klofsten and Jones-Evans (2000), Roberts and Malone (1996), Smilor et al. (1990), and Stankiewicz (1986, 1994).

From an empirical perspective, there are many studies on technology transfer. For example, Henderson et al. (1998) analyze patents, Shane (2004) study academic start-ups, Thursby et al. (2001) investigate TTOs activities, Mian (1996) revise incubators formation, and Shane (2002) analyze university-industry research collaborations. In Canada, on the other hand, scholars have recently realized the strategic role that public laboratories and research centers can play in fostering a region's capacity to innovate through the creation and diffusion of new knowledge (Chrisman et al. 1995; Doutriaux 1987, 1992; Niosi 2006a, 2006b; OECD 1998; Samson and Gurdon 1993).

Making use of the SD methods, this research aims to contribute on understanding how UITT processes are carried out in Canadian universities, stressing the nature of the relations established between stakeholders participating in the process of technology transfer. In so doing, the main objective of this research is to develop a UITT model from the perspective of the SD methods, as a useful mean to gain insight into the complexity of the relations established between TTOs, commercializing companies (CCs), and emerging university spin-off firms. However, the relations established by these actors during the process of technology transfer are essentially complex, with feedback structures and time delays that impact the outcomes of their decisions.

From a theoretical perspective, it is possible to identify three alternative approaches to analyze the process of UITT (Mustar et al. 2006): (1) the resource-based view of the firm, (2) the business model perspective, and (3) the institutional approach. However, these theoretical frameworks allow the possibility to identify five models to explain more specifically the process of UITT and spin-off creation. The evolutionary model proposed by Bercovitz and Feldmann (2006) stresses the role played by universities in systems of innovation, incorporating economic, social, and political influences that impact the ability of universities to both create new knowledge and deploy knowledge in economically useful ways. The entrepreneurial opportunity and entrepreneurial capacity model offered by Hindle and Yencken (2004) explores the interactions established between institutions, organizational culture, and the external business environment in research commercialization activities, stressing the fact that tacit knowledge is actually an effective mechanism in research commercialization performance. The stage model of academic spin-off creation proposed by Nlemvo et al. (2002) analyzes the "black box" to identify, understand and distinguish the major issues raised by the creation of academic spin-off companies from the standpoint of both public and academic authorities.

The technology transfer office model described in Siegel et al. (2004) argues that a crucial function of the university-industry technology management should be to identify key organizational issues for promoting successful knowledge transfer. This model emphasizes the role played by TTOs in the process of UITT as a mechanism that facilitate commercial knowledge transfers or technology diffusion through licensing patents or other forms of IP resulting from university research inventions. Finally, the critical junctures model proposed by Vohora et al. (2004) assumes that entrepreneurial new challenges derived from the nature of the process of technology transfer and that university-originated companies emerge from an initial idea in a non-commercial environment, aiming to become established competitive rent-generating firms. Another important assumption in this model is that there are conflicting objectives between key stakeholders, such as universities, academic entrepreneurs, the management team, and other suppliers of financial resources.

A preliminary conclusion achieved in this research is that the five models mentioned in previous paragraphs should be seen as complementary when explaining UITT and spin-off creation phenomena. However, the need is well recognized to develop a dynamic approach that takes into account the relationships established between stakeholders' decision of participating in the process of UITT and academic spin-offs creation to get insight on the overall performance resulting from this process. Such an approach can be achieved using SD principles as a research method.

The UITT model developed in this research is constructed within a three-subsector framework (TTOs, CCs and spin-offs), differentiating between a real stock-and-flow variables side and a financial stock-and-flow variables side in each subsector. Using SD principles as a research method, this approach seeks to clarify the nature of the relations established between the actors participating in the process of technology transfer. The result is a detailed representation and comprehensive knowledge of this system. However, this approach suggests the existence of time delays, positive (reinforcing) and negative (balancing) feedback interactions, and thus side effects and non-linear developments in the process of UITT and academic spin-offs creation (Eisenhardt 1989).

This study is organized into six chapters. Chapter 1 presents a general introduction to this research. Chapter 2 offers an outline of the process of technology transfer in Canada. This chapter is organized into six sections. Section 2.1 offers an overview of the research project to be developed in this dissertation. Section 2.2 deals with the research context of UITT and spin-off creation in Canada. Section 2.3 discusses the research problem. Section 2.4 contains the research questions underlying this study. Section 2.5 presents the research objectives of this research. Section 2.6 concludes the chapter.

Chapter 3 reviews fundamental ideas and concepts in the literature on UITT and academic spin-off creation. This chapter is organized into four sections. Section 3.1 deals with IP and technology transfer. Section 3.2 contains the concepts for defining a theoretical framework for studying the process of UITT in Canada. Particularly, this chapter contains the taxonomy to address this phenomenon. It also discusses the theoretical approaches existing in the literature for studying the process of UITT: the resource-based view of the firm, the business model perspective, and the institutional perspective. In turn, these approaches suggest five models that explain the process of UITT in relation to spin-off creation: an evolutionary schema, the entrepreneurial opportunity and capacity model, a stage model of academic spin-off creation, the technology transfer office model, and the critical junctures model. Section 3.3 presents key issues about the SD principles as a research method. Finally, Section 3.4 concludes the chapter.

Chapter 4 is organized into five sections focusing on some procedural problems. Section 4.1 presents the steps to be followed in this research. Section 4.2 discusses the influence diagram or dynamic hypothesis underlying this research project. Section 4.3 considers the information and data requirements needed to develop this study. Section 4.4 discusses the validation of the model developed in this dissertation. Finally, Section 4.5 presents a conclusion.

Chapter 5 discusses the UITT and spin-off creation model developed in this dissertation. This chapter is organized into four sections. Section 5.1 contains the description of the model in terms of the three stakeholders participating in the process of UITT and spin-off creation: (1) university-TTO subsector; (2) commercializing company subsector; and (3) spin-off-entrepreneur subsector. However, each sub-sector is analyzed in terms of its technical stock-and-flow variables and financial stock-and-flow variables. Section 5.2 discusses the calibration of the general model. The process of calibration of the model aims for estimating the parameters (structure) to obtain a match between observed and simulated structure and model behavior. The objective is to examine differences between simulated output and data to identify possible reasons for those differences, adjusting model parameters in an effort to correct the discrepancy and re-simulate the model. The calibration process explicitly attempts to link the model structure to behavior for testing the dynamic hypothesis. Section 5.3 presents the general indicators of the model developed in this research to analyze the process of UITT and spin-off creation. Finally, Section 5.4 concludes with the main ideas discussed in this chapter.

Chapter 6 presents the results achieved in this research. The chapter is organized into three sections. Section 6.1 discusses a baseline scenario that allows for analyzing other scenarios. Section 6.2 contains a number of sensitivity analyses allowing for testing other scenarios: (1) the environmental and government policy scenario, and (2) the organizational structure and university policy scenario. Finally, Section 6.3 contains the main conclusions achieved in this chapter. The research contains an additional final section for general conclusions.

II. Research Context and Problem Definition

This chapter introduces the research context and problem definition of this research. The chapter is organized into six sections. Section 2.1 offers an overview about technology transfer and university spin-off creation practices in Canada. Section 2.2 deals with three topics for defining the context of this research: global trends, science and technology policy in Canada, and university spin-off creation. Section 2.3 analyzes the research problem explored this study. Section 2.4 discuses the research questions conducting this research. Section 2.5 defines the research objectives. Finally, Section 2.6 presents the conclusions on the research context and problem definition of this research.

2.1. Overview

From a historical perspective, the emergence of the patent institution goes back to 13th century in Europe, but it was just few decades ago when modern economics and management analysis of intellectual property (IP) started off (Drahos and Maher 2004; Scotchmer 2004).[1] It was K. J. Arrow (1962) and W. D. Nordhaus (1969) who first opened up the discussion on patent granting to determine the conditions for achieving a balance between incentives to innovate and incentives to disseminate new knowledge (Baldwin and Hanel 2003; Langinier and Moschini 2002). Thumm (2004) suggests that an optimal IP regime must be capable to attain an appropriate balance between innovation up-rising effects, competition inhibiting effects, and positive and negative effects on technology distribution.

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[1] The first patent law was promulgated in Venice in 1474. In 1623, the English Parliament passed the Structure of Monopolies, and it approved the first copyright law known as the Statute of Anne in 1710 (Scotchmer 2004).

Nevertheless, the emergence of the knowledge-based economy forced the world economy to address a new economic and legal realm, and thus to renew the interest on the analysis of IP protection. In the United States, for example, the Patent and Trademark Act of 1980 lead to the establishment of a new university-industry technology transfer (UITT) commercialization agenda, raising new challenges to researchers. The new challenges, however, lead IP regimes in many countries to adjust institutionally and legally, and hence to transform the possibilities of *who*, *what* and *when* inventions could be patented (Gallini 2002; Hanel 2004; Jaffe 2000). In this context, the new IP framework allowed public laboratories and research centers to patent and commercialize technologies developed with public funds, as well as it facilitated the rise of new technologies (for example, biotechnology and information technology) (Arundel 2001; Kortum and Lerner 1999).

The ultimate consequence attained from these trends was that national rules in almost all countries have been affected through the Trade Related Aspects of Intellectual Property Protection (TRIPS) negotiated into the Uruguay Round. Nowadays, current IP rights structures among countries are built up on the TRIPS agreement and they are mandatory to all members of the World Trade Organization (WTO).

However, many empirical and theoretical explanations have been offered to explain the link between IP and the UITT phenomena. Within this context, it is possible to find three different levels of analysis in the study of the UITT. At a more general level, the macroeconomic perspective, three alternative paradigms have developed (Bozeman 2000): (1) the market failure paradigm, (2) the mission technology paradigm, and (3) the cooperative technology policy paradigm. At a second level of analysis, there are three different strands of literature in the study of UITT and spin-off firm formation (O'Shea et al. 2005): (1) the literature referred to the characteristics of academic researchers, (2) the literature related to the influence of universities' policies, procedures and technology commercialization practices, and (3) the literature referred to environmental factors impacting academic innovations.

Finally, at a more specific level of analysis the literature refers to specific mechanisms to transfer technology from universities to industry. This section summarizes some important concepts found in the literature in relation to alternative theoretical frameworks that explain the process of technology transfer from a general perspective. It synthesizes some important references at a more specific level of analysis in relation to the process UITT and the mechanisms to transfer technology. Subsection 3.2.2 discusses in a more detail the theoretical approaches on UITT and Subsection 3.2.3 analyzes the models on the process UITT and spin-off creation.

From the macroeconomic perspective, Bozeman (2000) found that there are three competing paradigms that explain science and technology policy: (1) the market failure paradigm, (2) the mission paradigm, and (3) the cooperative technology paradigm. This author points out that the market failure paradigm is rooted into the neoclassical economic theory, and thus it assumes that market mechanisms will lead to optimal rates of science production, technical change and economic growth. Actually, three other assumptions underlie this assumption: (1) markets are most of the time an efficient allocator of information and technology, (2) public research developed by government laboratories should be limited just to market failures (for example, extensive externalities, high transaction costs and information distortions), and thus university research must be limited to basic research, and (3) most of the time innovation flows adequately from and to private sector. The basic technology and science policy derived from this paradigm is that governments may intervene in the economy just in case of clear externalities. Deregulation of science and technology activities, contraction of government role in science and technology activities, and R&D tax credits are good examples of this type of policies.

The mission technology paradigm assumes that government may play an important role in the programmatic mission of agencies. Under this paradigm, the government role should be closely tied to authorize programmatic missions of agencies. In this case, university R&D supports only traditional roles, such as agricultural and engineering extension, manufacturing assistance, and contract research for defense. Furthermore, under this paradigm, government should not compete with private sector in innovation and technology, but government and university R&D roles should be complementary.

Finally, the cooperative technology policy paradigm assumes that markets are not always the most efficient route to innovation, and thus there is room for government actors and universities to play an active role in the process of technology transfer and development. Typically, government's role can be as a research performer, including supplying applied research and technology to industry, or developing policies affecting industrial technology development and innovation. In fact, the cooperative technology paradigm emphasizes cooperation among sectors, or even among rival firms when developing pre-competitive technologies.

Bozeman (2000) concludes that universities and public research laboratories are particularly important players into the mission technology paradigm and the cooperative technology policy paradigm. However, under the cooperative technology policy paradigm, science and technology policy of government may play a highly important role in supporting innovation and technology transfer through public laboratories and universities. Indeed, this author continues, it is within the conceptual framework yielded by the cooperative technology policy paradigm that UITT and spin-off firm formation can be considered as extended phenomena.

At a different level of analysis, O'Shea et al. (2005) suggest that there are three main categories of literature on technology transfer that explain UITT and spin-off firm formation. The first category of literature considers the characteristics of academic researchers that appear to impact entrepreneurship. In this category, Shane (2004) identifies three major reasons as motivational characteristics when supporting technology transfer and spin-off firm formation: (1) a desire to bring technology into practice, (2) a desire for wealth, and (3) a desire for independence.

A second bulk of literature on spin-off firm formation is related to the influence of universities' policies, procedures and technology commercialization practices. In this category, for example, Siegel et al. (2004) suggest that to foster a climate of entrepreneurship, academic institutions and university administrators should focus on five organizational and managerial factors: (1) the UITT reward systems, (2) staffing practices at TTOs, (3) flexibility of university polices to facilitate UITT, (4) devoting additional resources to UITT, and (5) elimination of cultural and informational barriers that impede the UITT process. Along with this approach, Debackere and Veugelers (2005) suggest that in the process of UITT, universities should employ some kind of mechanism such as an incentive structure to reward academic entrepreneurial endeavors, a decentralized operating structure to provide greater autonomy to research teams, and a centralized staff of experienced technology transfer personnel to manage the 'contract' and 'training' issues associated with the UITT process.

Finally, the third strand of spin-off literature explores mainly the environmental factors impacting academic innovations. In relation to this, variables such as venture capital, knowledge infrastructure in specific regions, and high technology clusters may play a central role in encouraging the formation of spin-off companies (Florida and Kenney 1988; Saxenian 1994).

At a more specific level of analysis, the literature analyzes the mechanisms for transferring university technology to industry. In fact, it is widely recognized that there are many mechanisms by which technology can be transferred from universities and other public research centers to industry (Lockett et al. 2005; Hindle and Yencken 2004): publications, education/training, collaborative research, contract research, industrial consultancy, patents and licenses, spin-off companies, and joint ventures. However, all these mechanisms can be classified into two main categories (Mowery and Shane 2002): commercial channels, such as licensing or the foundation of new firms based on university inventions, and non-commercial channels, such as publication of scientific articles, education/training and so forth. Nevertheless, one of the most promising forms for transferring research results and new university technology into the creation of economic value is through the foundation of academic spin-off companies (Nlemvo et al. 2002).

Table 1 **GERD by Financing and Performing Sectors, 2000**

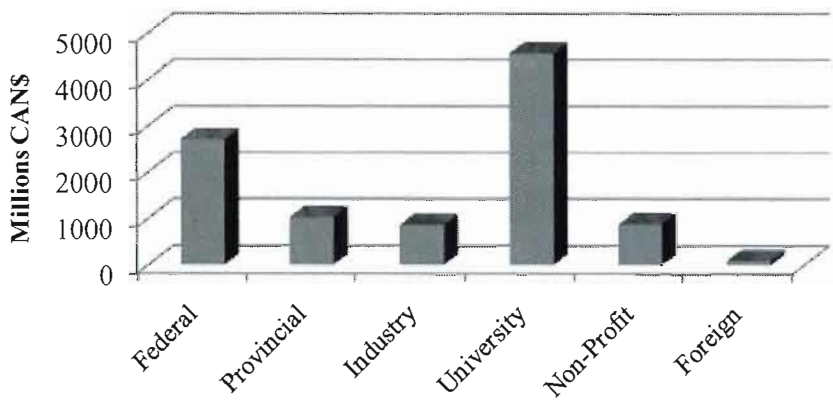
GERD	**By Performing Sector**			
	Germany	**Japan**	**USA**	**Canada**
By Financing Sectors				
Business Sector	65.5	77.9	68.4	42.5
Government Sector	32.0	21.7	27.1	22.7
Higher Education Sector	--	--	2.3	16.4
IRDIs	0.5	0.2	2.2	2.6
Foreign	2.0	0.2	--	15.8
Total	100.0	100.0	100.0	100.0
GERD/GDP	2.45	3.18	2.66	1.86
By Performing Sectors				
Business Sector	70.4	66.7	74.6	56.8
Government Sector	10.3	8.5	7.2	11.3
Higher Education Sector	16.1	19.7	13.6	30.9
IRDIs	3.2	5.1	4.6	1.0
Total	100.0	100.0	100.0	100.0

Source: Tesfayohannes (2007), p. 470.

From an empirical perspective, the study of technology transfer is highly complex since it is carried out through various players, takes on various kinds of modalities, and is done for various motivations (Reisman 2005). In Canada, university R&D spending and university-industry linkages have become an extremely important phenomenon. Accordingly, a Special Report developed by Gu and Whewell (1999) based on the survey *University Research and the Commercialization on Intellectual Property in Canada* states that Canadian universities account for one-fifth of all R&D spending and are second only after the private industry sector of R&D performance (university R&D totaled $2.9 billion in 1997, accounting for roughly 21% of all R&D). Table 1 shows GERD spending in Canada and in selected OECD countries by financing and performing sectors.

According to the same report, in Canada, university R&D financed by federal and provincial governments in 2007/2008 was $2,720.2 millions and $1,034.0 millions, respectively. Industry financed $870.1 millions and universities financed $4,574.1 millions of Canadian university R&D activities in the same period (figure 1). However, the contribution of Canadian industry to university R&D was the highest among the G-7 countries. The point to be stressed here is that this information suggests a strong presence of university-industry linkages in Canada.

Figure 1. **Source of Funds for University R&D Expenditure, 2007-2008**



Source: Statistics Canada. Science Statistics: Estimates of Research and Development Expenditures in the Higher Education Sector, 2006/2007, August 2008.

Accordingly, today many Canadian universities are involved in the process of commercializing IP. Statistics Canada (1999) reports that almost two-third of Canadian universities participate in managing IP. The *1998 Survey of Intellectual Property Commercialization* found that through the period 1997/98 academic researchers reported 661 new inventions, 379 patent applications were filed by 30 Canadian universities (health and agricultural/biological sciences), and 143 patents were granted to Canadian institutions. Moreover, in the same period, 243 new licenses were executed and the total number of active licenses was 788 with royalties of $15.6 million. The trends observed in these indicators are expected to continue growing in the near future.

Niosi (2006b) reports similar results in relation to spin-offs creation and development in Canada. This author analyzes these companies in terms of industry, technologies, regions, universities and growth. He found that the majority of Canadian spin-off companies (60%) were specialized biotechnology firms, even if growing companies in recent years are most often not in biotechnology. Spin-off companies in Canada are characterized to have a strong IP base. Many of these new firms had been granted US patents (80%). According to this study, the bulk of spin-offs in Canada are mainly located in three provinces: Ontario, British Columbia and Quebec. The author concludes that spin-off creation and growth in Canada are function of three variables: age, patents, and Industrial Research Assistance Program (IRAP) support.

Table 2. **Commercialization Activities at Canadian Universities, 1997-1998**

Activity	Universities	Number
Universities with Central IP Office	50	67
Invention Disclosures	24	661
New Patent Applications	30	379
New Licenses	26	243
Active Licenses	26	788
Royalties from Licensing	26	$15.6 million

Source: Statistics Canada's Survey of Intellectual Property 1997/98.

In this sense, the *Association of University Technology Managers (AUTM) Survey* confirms that Canadian universities commercialization activities have increased over time. According to this survey, 31% of licenses and options executed by major Canadian universities in 1997 were with spin-off companies. In the same way, Statistics Canada's *Survey of Intellectual Property 1997/98* confirms that Canadian universities have created a total of 366 spin-off companies. Table 2 shows data from the survey on commercialization activities in Canadian universities (1997-1998).

Today, Canadian universities are continuously creating spin-off companies to bring new technologies to the market. An important point drawn from this data is that the creation of spin-off companies in Canada is more likely to happen when there is a lack of receptor capabilities to new university-created knowledge. However, successful commercialization of university research depends on the active participation of the researchers who were the original discoverers of the knowledge to be commercialized (Siegel et al. 2003b).

2.2. Research Context

This section summarizes the main features characterizing the process of UITT in relation to spin-off creation and development supported by the new trends observed in the world in relation to these phenomena, and the science and technology policy implemented in Canada. The purpose is to present the main features of these phenomena in the investigation of spin-off creation and development. Even if the theoretical analysis of the process of UITT and spin-off creation constitutes a complex phenomenon, it is well recognized to be an important source of wealth creation, job opportunities and industrial development (Djokovic and Souitaris 2008; Steffensen et al. 2000; Stevens 2004). The rationale in this research is to gain insight on how science and technology policies give universities incentives to support and build an adequate infrastructure for commercializing new knowledge and research results (Rasmussen 2008).

In Canada, these initiatives have produced important consequences to the UITT process and academic research activity in universities. As in many other countries, governments have altered their policies to create incentives for researchers to contribute to the commercialization of their research results (Lockett et al. 2003).

Policy makers at national, provincial and university levels have allocated substantial resources to promote the creation of university spin-offs (Lockett and Wright 2005). In Canada, it appears that the direct government initiatives have successfully increased the commercialization of research and new knowledge in the last decade (Walsh et al. 1995).

2.2.1. Global Trends

Lester (2005) points out the importance of recognizing the different elements that individual universities may stress when transferring technology to industry. These elements may reflect their own particular missions, the economic circumstances of the particular localities or regions within which some universities are located, as well as the role university researchers choose to play in relation to the process of technology transfer. However, it has already been analyzed in many studies the different roles commonly played by university researchers when transferring new knowledge (Branscomb et al. 1999; Etzkowitz 1990; Etzkowitz et al. 1998):

1. Training of qualified personnel;
2. Advancement of scientific knowledge;
3. Entrepreneurial university.

Branscomb et al. (1999), Etzkowitz (1990), and Etzkowitz et al. (1998) suggest different ways in which these activities may be developed and appropriated to different local economic development pathways:

1. The creation of new industries for promoting or assisting entrepreneurial business that may lead to disseminate particular technologies;

2. The role played by universities through technical assistance in the process of the regional development strategy focusing around the importation or transplantation of industries;
3. The role played by university making bridges between disconnected actors in the local system and filling structural holes in the networks of activity and the creation of new industrial;
4. The problem-solving dimension and the use of faculty for consulting and contract-research.

However, Hughes (2006) suggests that the variety of interrelationships available allows a rich set of possible patterns of interaction. In each industry, or specific regional case universities, there will be only one among many sources of knowledge inputs so that potential impacts must be seen in this wider systems context. This author shows the importance of various types of relations: informal contracts, recruitment at first degree or master level, publications, conferences, testing and standards, recruitment at post doctoral level, problem-solving/consulting by university staff, joint research and development projects, internships, exclusive licensing of university held patents, innovation-related expenditure spent on universities, and non-exclusive licensing of university held patents.

From this perspective, Hughes (2006) suggests that innovative activity is mainly carried out in the context of the wider system of innovation related business interactions and thus it becomes important to know about the overall sources of knowledge for innovation. Nevertheless, university business innovation related interactions are a small part of the overall innovation system and must be seen in that light. These findings, and the importance of focusing beyond spin-off development and licensing, confirm qualitative arguments to the same effect in the recent influential innovation policy (Lambert 2003).

However, Lambert (2003) and Hughes (2006) suggest the following characteristics featuring UITT:

1. University business innovation related interactions are a small part of overall innovation system;
2. Attention must be paid to quality of interactions rather than increasing their incidence;
3. Smaller businesses are less likely being innovative and place importance on university interactions.

On the other hand, Hughes (2006) identifies at least four potentially separable kinds of interactions which work at the university-industry interface:

1. The basic university role of educating people and providing suitably qualified human capital for industry;
2. The role of research activity that allows to increase the stock of codified knowledge for commercial purposes;
3. The role of problem-solving in relation to specifically articulated business needs;
4. The "public space" functions that may include a wide range of interaction mechanisms between university staff and the business community.

This function may include tacit knowledge and the establishment of relationships which may feed back into other roles. Public support of university research is commonly justified on the grounds that the private sector is likely systematically to underfund basic or fundamental research because the results are difficult to appropriate, and thus patents are seen to be ill-suited to capturing the returns (Agrawal and Henderson 2002).

Yet, there are many forms of technology transfer from universities to industry. Generally speaking, UITT channels can be classified as commercial and non-commercial (Mowery and Shane 2002). Commercial channels include: patents and licenses, and the foundation of new firms. Non-commercial channels include: publication of scientific articles, education/training, conference presentations, free publications in refereed scientific publications. In this sense, Branstetter (2000), Cockburn and Henderson (1998) and Zucker et al. (1998a, 1998b) demonstrate the importance of geographic proximity, research collaborations, personal relationships, coauthorships and citations to academic papers in the transfer of knowledge.

Table 3. **University-Industry Technology Transfer in Canada**

	% Total (Standard Deviation)	**% Total that Respond at Least "Moderately Important" (3 on 4 Point Likert Scale)**
Patents and Licenses	6.6 (5.6)	11.6
Publications	18.5 (17.3)	17.4
Consulting	25.1 (18.4)	13.7
Conversations	6.3 (6.8)	17.5
Cosupervising	9.4 (10.2)	7.7
Recruiting/Hiring	16.8 (12.5)	8.5
Conferences	5.2 (5.6)	14.6
Research Collaborations	12.1 (10.8)	9.1

Source: Henderson, R. A. et al. (1998)

UITT can also be studied from the perspective of the allocation of property rights. Link et al. (2007) classifies this process in formal and informal mechanisms. Formal technology transfer mechanisms are focused on allocation of property rights and obligations, including licensing agreements, research joint ventures and university-based new firms. Informal technology transfer mechanisms property rights do not play a role, and obligations are normative rather than legal, including transfer of commercial technology, joint publications with industry scientists, and industrial consulting.

In relation to publicly funded research, its impact on economic growth is well recognized. However, from this perspective, university patents and licensing have become the most studied form of technology transfer by scholars. For example, Jaffe (1989), Henderson et al. (1998) have widely investigated patents as a measure of university output, Gregorio and Shane (2000), Jensen and Thursby (1998), Thursby and Thursby (2000) have studied licensing and new firm creation, and Mowery et al. (1998) have analyzed patents and the licensing simultaneously. The patent and license data have become an important source of information in these studies for several rcasons (Agrawal and Henderson 2002):

1. The patenting process requires: inventor names, dates, assignee institutions, locations, and detailed descriptions of invention claims be recorded;
2. Innovations that are patented are expected to be commercially useful;
3. Patenting data has recently become widely available in machine-readable form.

Agrawal and Henderson (2002) conclude that researchers might have a tendency to overestimate the relative importance of channels such as consulting and informal conversations and to underestimate the importance of more indirect channels such as patents and publications, and thus that patenting and licensing constitute a relatively small channel for the transfer of knowledge from academia to the private sector. Table 3 summarizes the main results achieved in these studies.

2.2.2. Science and Technology Policy in Canada

There are few studies investigating the policy instruments available for governments aiming to improve technology transfer from publicly funded research (Rasmussen 2008). Since the passage of the Bayh-Dole Act (1980) in the United States, policy makcrs are introducing in many countries reforms to improve innovative activity through changes in the academic system, designing new instruments for research funding and by setting up structures to support these activities (Benner and Sandstrom 2000; Hellström and Jacob 2003).

Rasmussen (2008) suggests that the Canadian case might be particularly interesting in relation to UITT for several reasons:

1. Compared to other countries, Canada has a long tradition of state involvement to promote the economic utilization of scientific research;
2. Canada has an important number of federal and provincial programs that may be used to support the commercialization of research;
3. This country has 178 initiatives for supporting UITT that represented an expenditure of 3.2 billion Canadian dollars a year (Gault and McDaniel 2004);
4. Canada has a very decentralized higher education system;
5. This country is characterized to have a large public research sector and a small domestic market;

6. Canadian universities have proven to be quite successful in commercializing their research (Niosi 2006b).

At a different level of analysis, Landry et al. (2007) have developed an analysis of UITT in Canada, suggesting several variables that explain knowledge and technology transfer from universities to industry:

1. Financial support academic research from private firms and government agencies;
2. The focus of the research projects on the needs of users such as private firms and government agencies;
3. The research unit size;
4. The intensity of the linkages between researchers and users;
5. The number of years of experience on research;
6. The number of publications;
7. The degree of novelty of the research results;
8. The affiliation of researchers with a large research university;
9. Particular research fields such as engineering;
10. Gender of the researchers. These authors found a positive and significant relation between these variables and the process of technology and knowledge transfer.

However, these authors conclude that there is statistical evidence indicating that researchers are more active in non-commercial knowledge transfer activities than in commercial knowledge transfer activities that involve protected IP. Nevertheless, it would be expected that faculty members within a more entrepreneurial tradition are more likely to transfer knowledge and technology involving protected IP.

Landry et al. (2007) suggest that the knowledge and technology transfer activities do not jeopardize the scientific activities of university researchers. In fact, these authors find that knowledge transfer increases as the number of publications increase. Furthermore, there is statistical evidence indicating that researchers in certain fields are much more active in knowledge transfer than in others. However, in the analysis carried out by these authors, there are two determinants explaining knowledge transfer across the fields studied, mainly the linkages between researchers and research users, and the focus of the research projects on users' needs. Hanel and St-Pierre (2006) corroborate that collaboration between users and academic researchers is actually one of the main sources of ideas and technologies feeding the innovative process.

Canada is ranked first amongst G7 countries in terms of industry-university collaboration and university research funding supported by the private sector (Industry Canada 1999b). Yet, Canadian universities have been the second largest spender on R&D behind industry since the 1970s, even if the share of real university R&D in total R&D spending has decreased in during this period (Hanel and St-Pierre 2006). In fact, Canadian universities are increasingly collaborating with industry to support and contribute funding their research (Hanel and St-Pierre 2006). In Canada, both provincial and federal governments continue to be the major sources of funding for research activities at universities, but the contribution of the private sector has nearly doubled in the last years (Hanel and St-Pierre 2006; Rasmussen 2008). However, the Government of Canada aims to launch Canadian firms to become highly competitive in the world markets following an innovative strategy supported by the generation and development of new knowledge at universities.

The strategy to be followed by the Government of Canada to achieve this goal is summarized in *Achieving Excellence: Investing in People, Knowledge and Opportunity* (Government of Canada 2000) and *Momentum: The 2005 report on University Research and Knowledge Transfer* (AUCC 2005). The role that universities can play in supporting innovative performance is well recognized (AUCC 2002; Industry of Canada 2002). Public science and research base may provide the platform for successful innovation by business and public services. In 2002, the Government of Canada released an innovation policy report known as *Achieving Excellence* (Industry Canada 2002) that included a specific initiative with respect to universities and commercialization. Additionally, the Government of Canada also released *Momentum: The 2005 Report on University Research and Knowledge Transfer* (AUCC 2005). The objective is thus to establish conditions under which academic institutions would be expected to manage the public investment in research as a strategic national asset by developing innovation strategies and reporting on commercialization outcomes (Langford et al. 2006).

This goal shall be followed by making use of three mechanisms (Langford et al. 2006): (1) Canadian universities have committed to triple their commercialisation performance, (2) they are responsible for the strategic coordination of the research efforts that will deliver these benefits, and (3) AUCC agrees to produce a periodic public report that demonstrates the collective progress made by universities in knowledge transfer including commercialization and innovation. Canada's innovation strategy can be summarized as follows:

1. By 2010, Canada is to rank among the top five countries in the world in terms of R&D performance;
2. By 2010, Canada is to rank among world leaders in the share of private-sector sales attributable to new innovations;
3. By 2010, current federal investment in R&D should at least double;
4. By 2010, the per capita value of venture capital investments in Canada should rise to prevailing levels of the United Sates.

In this context, it is recognized to advance research, knowledge transfer, and commercialization and innovation activities as milestones for Canada's innovative performance. Following this, for example, Canada spent $2.3 billion on university-based research, representing 24.5% of the total direct and indirect research investments in that sector ($9.3 billion) in 1997-1998, and it is estimated that by 2006-2007 the annual federal support for research in the higher education sector will be almost $2 billion more than in 1997-1998 (Library of the Parliament 2006).

On the other hand, the Canadian Foundation for Innovation (CFI), an independent organization with a mandate to invest in Canada's research infrastructure, support mechanisms to facilitate the commercialization of research discoveries and other enabling technologies needed to conduct world-class research, as well as to attract and retain highly qualified researchers. As a result, in 2004-2005, CFI made commitments of $2.93 billion in more than 4,000 innovative projects undertaken at 127 universities, colleges, non-profit research institutes and research hospitals in 62 municipalities across Canada, and $3.9 billion in additional funding were leveraged from provincial governments, the private sector and other partners (Library of Parliament 2006). This new initiative would imply that universities in Canada perform about one-third out of the total R&D, and hence, are becoming key players in Canada's innovation system (Industry Canada 2000).

These facts mean that technology transfer activities may become extremely important within Canadian universities in the near future. Commercialization and technology research transfer mechanisms may take, however, many forms such as the protection of intellectual property (patents and copyrights), licenses and spin-off of new companies. In fact, the commercialization of IP is just one form for transferring knowledge to industry. However, the trends and changes observed recently among Canadian universities transferring new knowledge and technology to industry are actually the result of latest changes experienced by many intellectual property regimes in the world.

In this sense, Rasmussen (2008) points out that the innovative initiative launched by the Government of Canada in 2002 recognizes the importance of many different actors responsible for promoting the commercialization of academic research. Moreover, this author also suggests this would depend on the structure of the R&D system given that the university sector is the responsibility of each province and thus most federal grants are awarded to the individual researchers. However, some provinces have more reach to implement research and innovation policies, and programs to support the Canadian federal initiatives (Liljemark 2004). Furthermore, Canadian universities have different approaches to intellectual property ownership and strategies, and thus of the organization of their technology transfer activities. In Canada, the ownership of IP resides, in some cases, in the universities, and in others the inventor does.

IP ownership in Canada often is defined by university policies or by collective faculty agreements (Gault and McDaniel 2004). However, the *Framework of Agreed Principles on Federally Funded University Research* acknowledge the responsibility of the federal government to provide the necessary levels of investment in university research and the AUCC agreed to produce a periodic public report to demonstrate the collective progress made by universities in relation to research, knowledge transfer and innovation (AUCC 2002; Gault and McDaniel 2004). Nevertheless, it has been demonstrated that in the Canadian case, there is no deep difference at all in the practices followed in terms of number of licenses, patents, licenses income and spin-offs creation (Clayman 2004).

The federal level initiatives to support the commercialization of Canadian research can be divided into three agency areas (Rasmussen 2008):

1. The federal research institutes;
2. Targeted schemes from Canadian Institutes of Health Research (CIHR), Natural Science and Engineering Research of Canada (NSERC), and Social Science and Humanities Research Council of Canada (SSHRC) towards commercialization at universities;
3. General agencies such as the Industrial Research Assistance Program (IRAP) and the Business Development Bank of Canada (BDC).

In addition, Industry Canada has many offices in the provinces and four regional agents for stimulating entrepreneurship, innovation at universities, the creation of high-tech ventures, commercialization of academic research, and economic development (Rasmussen 2008):

1. Western Economic Diversification Canada;
2. FedNor (Northern Ontario);
3. Atlantic Canada Opportunities Agency (ACOA);
4. Canada Economic Development for Quebec Regions (DEC).

However, the main institutions supporting research activities in Canada are Canadian Institutes of Health Research (CIHR), Natural Science and Engineering Research of Canada (NSERC), and Social Science and Humanities Research Council of Canada (SSHRC) (Rasmussen 2008). And in relation to spin-off creation in this country, about half of Canadian university spin-offs have received IRAP funds.

The importance of spin-off creation and development to the process of UITT is highly important at the regional level in Canada. NSERC, for example, has conducted a study of 141 spin-off companies created by university researchers during the last 30 years. These companies generated total of 3.5 billion Canadian dollars in sales and have almost 13,000 employees in 2004 (Rasmussen 2008). The government of Canada launched its innovative strategy in 2002. As part of this strategy, the government of Canada agreed with the Association of Universities and Colleges of Canada (AUCC) to triple the value of commercialization of university-generated IP and to double the expenditure on the performance of R&D in return for federal contributions towards the overhead costs of R&D by 2010 (Gault and McDaniel 2004). The commercialization policy established searches to increase productivity and innovation in Canada (Table 4).

Table 4. **Technology Transfer and Spin-Off Creation in Canada, 2001-2003**

Indicator	**2001**	**2003**	**Preliminary Change**
Invention Disclosures	1105	1177	7%
Inventions Protected/Patented	682	597	-12%
Inventions Rejected	Na	248	Na
Patent Applications	932	1254	35%
Patents Issued	381	337	-12%
Patents Held	2133	3105	45%
Income from IP Commercialization	$47.6 million	$51 million	7%
IP Income Distributed to Inventors and Co-Inventors	Na	$17 million	Na
Spin-Off Companies Created to Date	680	880	Na
Equity Held by the Institutions in Publicly Traded Spin-Offs	$45.1 million (universities)	$52 million (hospitals and universities)	15%
Start-Ups that Were Provided Space at the Institution	Na	63	Na
Investment in Spin-Offs Raised With the Assistance of the Institution	Na	$50 million	Na

Source: Statistics Canada 2004, 2003 Survey of Intellectual Property Commercialization in the Higher Education Sector.

Statistics Canada, along with other academic institutions, has organized a series of meetings to address key problems that must be faced by Canadian universities when transferring technology to industry. Specifically, the *Meeting on Commercialization Measurement, Indicators, Gaps and Frameworks* and the *Joint Statistics Canada – University of Windsor Workshop on Intellectual Property Commercialization Indicators* raised the crucial question: *why is Canada not gaining in personnel wealth when public investments in R&D, highly qualified personnel and a science and technology educational infrastructure are strong?* (Earl et al. 2004, p. 13). This inquiry stressed the importance of acquiring adequate marketing and management personnel to succeed in transferring and commercializing new technologies when creating spin-off firms. The role played by TTOs should be to find the best private sector partner or partners within a context of alternative technology transfer mechanisms. The commercialization of innovations and the commercialization of research results form the basis of spin-offs creation require a set of multiple types of skilled personnel and highly trained commercialization officers to develop spin-off companies (Earl et al. 2004). In Canada, only one innovation out of about three thousand ideas makes it to market (Earl et al. 2004).

2.2.3. University Spin-Off Creation in Canada

At university level, Rasmussen (2008) found that in Canada all major research universities have a TTO or an industrial liaison office (ILO) with a number of technology transfer staff varying from one up to thirty persons in some cases. The national average in Canada is 3.8 (AUCC 2003). In 2003, Read (2005) found that Canadian universities spent $36.4 million on IP management with an average distribution of institutional base funding (29%), institutional one-time allocations

(10%), IP commercialization revenues (licensing and cashed-in equity) (36%), and external sources (25%).

In Canada, universities, hospitals and government labs tend to license out technologies they have patented, spin-off companies to further develop a technology or make their research findings freely available in the form of scientific publications. From approximately $22 billion of R&D performed in 2003, about 10% is performed by the federal government and 35% by universities (Bordt and Earl 2003). From the survey, *Public Sector Technology Transfer in Canada, 2003*, it was estimated that about 1,400 firms licensed technologies from universities over the past three years (about 1,670 licensed from hospitals and 1,400 licensed from federal government labs). Additionally, this survey also suggests that approximately 1,350 firms considered themselves as spin-offs from Canadian universities. Actually, there are many means of acquiring technologies. In addition, licensing new technologies was a technology acquisition method undertaken by just one-fifth of private sector firms (Earl 2004).

However, Statistics Canada regularly surveys UITT activities and spin-off creation in Canada. The surveys carried out by Statistics Canada require a firm to be considered as an spin-off to have an administrative link with the university in terms that it was created to license the institution's technology, to fund research at the institution in order to develop technology that will be licensed by the company, or to provide a service that was originally offered through an institution's department or unit.

The surveys carried out by Statistics Canada report similar results in relation to commercialization activity, UITT and spin-off creation activities among Canadian universities and hospitals as those reported in Table 5. About 700 companies noted that technology acquired from federal government laboratories was important to their inception or growth. Universities and research hospitals not only license and spin-off companies, they also publish vast numbers of scientific papers, consult, and engage in research contracts. It is worthy to mention that this survey also showed that while federal government labs also license technologies to the private sector, they are less likely to spin off companies (Bordt 2004) and engage in research contracts.

Table 5. **Commercialization Activity at Canadian Universities and Hospitals**

Activity	1999	2001	2003
Universities and Hospitals Managing IP	63	77	87
Inventions Disclosed	893	1105	1133
Inventions Protected	549	682	na
Patents Held	1915	2133	3047
Patents Issued	349	381	na
New Patent Applications	656	932	1252
Active Licenses	1165	1424	1756
New Licenses	232	354	422
Licenses Royalty Revenues (CAN Millions)	21	47	na
Dividend and Equity (CAN Millions)	54	45	na
Number of Spin-Offs (Accumulated)	471	680	876
Spin-Off Revenues (CAN Millions)	na	2580	na
Employment in Spin-Offs	na	19243	na

Source: Rasmussen (2008), p. 4.

The fact is that in Canada more firms licensed from Canadian hospitals (about 1,670) than universities or federal government labs (about 1,400 each). This observation contrasts with the results of the most recent Survey of Intellectual Property Commercialisation in the Higher Education Sector (2001) which indicates that university-affiliated hospitals executed a small number of licenses (86) compared to the universities (1,338). One possible explanation is that many of the technologies that the firms reported having licensed from hospitals were not developed at those hospitals.

According to the survey, *Public Sector Technology Transfer in Canada 2003*, university spin-offs are distributed proportionally through the sectors of the economy. Of the 19 industrial sectors in the private sector, just one-half (10 sectors) had any university spin-offs. This survey also shows that about one-quarter of the university spin-offs were health care and social assistance firms, followed by firms in other services (except public administration) combined with administrative and support, waste management and remediation services at one-fifth of university spin-offs. Firms in professional, scientific and technical services comprised 16% of the spin-offs. About a one-tenth were in both real estate and rental and leasing and in manufacturing. Finally, wholesale and retail trade, transportation and warehousing, and information and cultural industries comprised the remaining 14%.

Within the health care and social assistance sector, university spin-offs were mainly concentrated in ambulatory health care services (44%) which include offices of physicians, dentists, out-patient care centers, and medical and diagnostics laboratories; and social assistance (36%) which includes such activities as child day-care services, family services and vocational rehabilitation services. This health orientation of university spin-offs is also seen in manufacturing where one-quarter of university spin-offs did work in pharmaceutical and medicine manufacturing. Another one-quarter of the university spin-off firms in manufacturing worked in computer and electronic product manufacturing, the vast majority of which specialized in semiconductor and other electronic component manufacturing. A further one-tenth was in basic chemical manufacturing. Finally, the largest proportion of the manufacturing spin-offs 37% comprised miscellaneous manufacturers.

The university spin-offs in professional services were evenly divided between management, scientific and technical consulting services and scientific research and development services. All of the university spin-off in wholesale trade was in building material and supplies wholesaler-distribution whereas the retail trade spin-offs were in sporting goods, hobby and musical instruments stores. It appears that university spin-offs reporting in *Survey of Electronic Commerce and Technology 2003* follow the industrial distribution implied by the definition that they are either associated with operations of the higher educational institutions such as offering employment services of looking for grant-making opportunities of fuelled by the research undertaken within the academic setting or offering the skills and expertise of created within the university environment to the market place. The spin-offs appear to be natural and complementary activities to the work done within academic settings.

Despite the fact that technology transfer from public sources is a rare event, the number of transfers reported on the business side is much higher than those previously reported by public institutions. This may be because businesses have a broader interpretation of licensing and spinning-off than do universities and federal labs. From this perspective, Djokovic and Souitaris (2008) suggest that the first problem to be addressed when studying academic spin-off creation is about definition and taxonomy. A discussion on the taxonomies commonly used when analyzing the relationship established between UITT and the academic spin-off creation phenomenon is presented in this research.

Clarysse et al. (2005), Mustar et al. (2006), and Pirnay et al. (2003). Djokovic and Souitaris (2008) suggest that any definition on UITT and academic spin-off creation must include the outcome and parties involved in the process of technology transfer, as well as core elements that are transferred. In this sense, the outcome is firm formation, and the parties involved in the process of technology transfer are: (1) the parent organization, (2) the technology originator, (3) the entrepreneur, and (4) the venture investor. Finally, the core elements transferred are technology (patent and licenses) and/or people (knowledge). The whole elements mentioned in this section are however contained in the definition proposed in this research: an academic spin-off can be defined as a new firm created to exploit commercially some knowledge, technology or research results developed within a university (Pirnay et al. 2003) and which have formal intellectual property licensing or similar relationships to the university (Hindle and Yencken 2004).

Three theoretical approaches aim to explain the process of technology transfer at different theoretical levels of analysis. In Section 3.2.2, the UITT theoretical approaches will be discussed: (1) the resource-based view of the firm, (2) the business model perspective, and (3) the institutional approach. In turn, the theoretical models for analyzing the process of spin-off creation will be discussed in Section 3.2.3: (1) the evolutionary schema (Bercovitz and Feldmann 2006), (2) the entrepreneurial opportunity and entrepreneurial capacity model (Hindle and Yencken 2004), (3) the stage model of academic spin-off creation (Nlemvo et al. 2002), (4) the technology transfer office model (Siegel et al. 2003, 2004), and (5) the critical junctures model (Vohora, Wright and Lockett 2004).

However, the UITT and spin-off creation models analyzed in this research should be seen as complementary since they identify four main phases in the process of spin-off creation (Ndonzuau et al. 2002):

1. Business ideas generation;
2. Finalization of new venture projects out of ideas;
3. Launching new spin-off firms from projects;
4. Strengthening the creation of economic value by spin-offs.

The framework that emerges from these approaches stresses the emphasis of the university commercialization of new knowledge in terms of economic value and job creation. In fact, the creation of spin-off has led to the recognition of the value of university commercialization activities for national wealth creation, shifting government technology policy from a "market failure paradigm" to a "cooperative technology paradigm" (Djokovic and Souitaris 2008). The models presented in Section 3.2.2 and Section 3.2.3 constitutes essentially a theoretical framework to analyze the process of UITT and spin-off creation for this research.

Table 6. **Canadian Spin-Off Companies**

Technology Field	Agriculture Biology	Health Science	Engineering	Information	Math Physical Science	Business Management	Other	Total
All Spin-Offs	90 13%	226 33%	122 18%	131 19%	78 12%	8 1%	25 4%	680 100%
Incorporated in 2000/2001	5 8%	25 40%	8 13%	12 19%	8 13%	-- --	4 7%	62 100%
R&D Spin-Offs	33 18%	105 58%	21 11%	7 4%	16 9%	-- --	-- --	182 100%

Source: De Koven (2004), p. 3.

On the other hand, form an empirical perspective, the evidence suggests that there are more Canadian universities involved in technology transfer and commercialization activities. De Koven (2004) found that the annual number of total spin-offs in Canada increased to 680 in 2001, and 62 of them were just incorporated in the period 2000 to 2001. According to this author, the major quantity of spin-offs in Canada are found in the agricultural/biology technology field (33%), followed by information technology (19%), and engineering (18%). Table 6 summarizes some data on spin-offs related technology field in Canada.

Canada does not have a uniform university IP policy, and thus the ownership of IP may reside either in inventor or in university (Afshari 2007). However, the inventor-owned model and the institution-owned model both have positive and negative attributes (Young 2007). Consequently, the federal granting councils do not require full disclosure by researchers of any IP generated from federally funded research grants, and they do not claim ownership of any resulting IP (Afshari 2007). Moreover, the transfer of technology to industry would be blocked by the inability of either actor to maintain exclusivity, resulting in a wide variety of practices in terms of ownership and disclosure. The results are critical to the success of technology transfer programs at universities, such as royalty policy, disclosure process, assignment of responsibility for seeking patent protection, research and institutional conflict of interest, dispute resolution, management of licensees' contractual performance, management of equity interests in spin-off companies, and many more requirements (Young 2007).

Since most university discoveries involve multiple researchers, this approach has resulted in much co-ownership of IP in Canada. The co-ownership of IP has made very difficult the negotiation of licensing agreements with established firms. Or, it has equally made difficult to entice risk capital providers and skilled managers to support the establishment of spin-off companies (Afshari 2007). In Canada, co-owners of patents cannot grant the exploitation of licensing rights without the agreement of the co-owners, resulting in the event of a licensing paralyzed conflict. In turn, co-ownership introduces an element of uncertainty and risk that is sufficient to dissuade many in the private sector from participating in technology transfers from Canadian universities.

The *Fortier Report Public Investment in University Research: Reaping the Benefits* realised by the Advisory Council of Science and Technology in 1999 suggests the following of some actions to correct shortcomings in relation to UITT activity in

Canada (ACST 1999). This goal should be achieved through following and implementing some strategies:

1. Developing a homogenous university IP framework;
2. Strengthening universities' commercialization capacity;
3. Developing a commercialization skills base;
4. Establishing an adequate competitive business environment;
5. Fuelling the innovation pipeline.

Additionally, some provinces in Canada, such as British Columbia, Alberta, Manitoba and Quebec provide additional assistance and funds for supporting UITT activity and spin-off creation. Since the 1980s, economic policy in these provinces has placed a great emphasis on supporting R&D. This economic policy has supported: (1) the development of a favorable venture capital climate, (2) the development of some sectors of excellence (aerospace, multimedia, biotechnology, nanotechnology, etc.), (3) acquiring a large pool of highly skilled workers, and (4) developing a competitive operating costs scheme. The objective of these initiatives is to develop a highly competitive R&D support system in the world.

Along with these initiatives, two primary models have emerged to support UITT activity and spin-off creation. The adoption of a specific functioning financial scheme for developing UITT activities at universities would define how the model within these activities is carried out (Young 2007):

1. The establishment of an internal institutional department or office (TTOs);
2. The formation of an external company (Commercializing Companies).

Generally speaking, the establishment of an internal office (TTO) for transferring technology to industry concerns some specific goals: to provide services to researchers (inventors), to promote regional economic development, and to generate incomes to stakeholders participating in this process. More specifically, the establishment of a TTO at any university implies four key reasons to advance academic technology transfer (AUTM 2004a):

1. To facilitate the commercialization of research results for the public good;
2. To reward, retain, and recruit high-quality researchers;
3. To build closer ties with industry;
4. To generate income for further research and education, and thus to promote economic growth.

When centralized TTOs are incapable to meet their goals, there are four alternative options for supporting and facilitating technology transfer to industry (Young 2007): (1) an external organization, (2) an individual and small internal TTO, (3) one TTO able to serve a consortium of several public research organizations in a region, and (4) an office funded by the national government or a philanthropic institution that could serve as TTO for several public research institutions. However, if the establishment of an internal office for technology transfer does not fulfill its objectives, the commercializing company model emerges as an alternative scheme to facilitate UITT activities (Afshari 2007). The main objective in the commercializing company model is to generate cash flow through a variety of related business activities, such as consulting, conference management, and professional development courses. In this sense, commercializing companies and TTOs activities can be seen as complementary in the process of technology transfer at universities. The commercializing company model has been adapted to the process of UITT in many countries such as Australia, India, Japan, South Africa, Russian Federation, as well as in some provinces in Canada (Afshari 2007).

Table 7. **Stakeholders in the UITT Process and Spin-Off Creation in Canada**

Stakeholder	Actions	Primary Motive(s)	Secondary Motive(s)	Perspective
University/ Scientists	Discovery of new knowledge	Recognition within the scientific community- publications, grants	Financial gain and a desire to secure additional research funding	Scientific
Technology Transfer Office	Works with faculty members and firms	Evaluate research results in terms of opportunity/Protect and market the university's IP	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Commercializing Company	Entrepreneurs to structure deals/Works with firms/entrepreneurs and TTOs as link to commercialize new technologies	Protect and market the university's IP/Financial gain	Facilitate technological diffusion and secure additional research funding/Maintain control of property technologies	Bureaucratic/ Entrepreneurial
Firm/ Entrepreneur	Commercialize new technologies	Financial gain	Maintain control of property technologies	Organic/ Entrepreneurial

Source: Adapted from Siegel et al. (2003), p. 115.

Effectively, some provinces in Canada have established a supporting program for developing UITT activities and spin-off creation at universities through the establishment of commercializing companies (Afshari 2007). From the perspective of the commercializing company model, there are four main participating actors involved in the process of UITT:

1. University scientists who discover new technologies;
2. University technology managers and administrative personal who serve as a link between academic scientists and industry;
3. Commercializing firms that manage university's IP;
4. Entrepreneur firms who commercialize university-based technologies.

Table 7 adapted from Siegel et al. (2003) syntheses this information within the commercializing company model. It includes the commercializing companies participating in the process of UITT and spin-off creation accordingly to the Canadian case. In this case, commercializing companies provide an adequate linkage between TTOs and spin-off companies. In Canada, IP is owned by universities in some cases and by researchers in others. Generally, TTOs evaluate for the opportunities of the research results, meanwhile commercializing companies act as coordinator of funding research sources and promoting the commercialization of research.

In the Canadian case, Rasmussen (2008) points out that universities provide the basic funding for TTOs, although it seems like government programs provide important support for maintaining their infrastructure. TTOs also play an important role mediating between academics and commercializing companies.

For example, in the case of Quebec, Afshari (2007) points out that four commercializing companies were funded by the injection of $50 million from the first phase of VRQ (*Valorisation-Recherche Québec*) financing. Each commercializing company was in charge of a number of member institutions:

1. SOVAR ($10 million): Université Laval and the Centre hospitalier universitaire du Québec;

2. UNIVALOR ($15 million): Université de Montréal and its affiliated schools and institutes;
3. VALEO ($10 million): Concordia University, École de technologie supérieure, Institut national de la recherche scientifique, and the network of the Université du Québec;
4. MBSI ($15 million): McGill University, Université de Sherbrooke, and Bishop's University and its affiliated health institutions.

It is important to stress that comparing to TTOs, commercializing companies are for-profit corporations owned by universities and driven by business objectives. Their mission is to generate added value from research results obtained by university researchers. The main functions of the commercializing companies are (Afshari 2007): (1) identification of the most promising technologies, (2) evaluation of commercial potential, (3) IP protection, (4) design of a plan to create added value, (5) early investments toward commercialization, (6) search for investors, (7) create spin-offs, (8) negotiate licenses, and (9) manage the patent portfolio.

However, there must be a link between TTOs and the commercializing companies. In fact, collaboration between the TTOs and the commercializing companies is a key issue to successfully transfer technology from universities to industry. Table 8 summarizes the main TTOs' and commercializing companies' tasks within this framework.

In short, there are many federal and provincial government programs to support UITT developments and spin-off creation in Canada. Rasmussen (2008) suggests that the support for entrepreneurship is generally handled at the provincial level. This author also points out that when a spin-off is established, there are a number of programs to support UITT and entrepreneurship in Canada. However, the most important program is the Industrial Research Assistance Program (IRAP) together with tax deduction schemes.

An important feature in this analysis is the possibility to identify the nature and repercussions of the links established between stakeholders participating in the process of UITT. The stakeholders' performance participating in the process of UITT depends on their own decisions and those concurrently taken by the others. The SD method allows the analysis from a total and global perspective of the decisions taken by actors of this process simultaneously influencing their outcomes.

Table 8. **TTO's and Commercializing Company's Task in the Process of UITT and University Spin-Off Creation**

Task/Roles	Commercializing Company	TTO	Joint Task
Early identification of the most promising technologies	X		
Raising the awareness of the researchers with respect to commercialization issues			X
Evaluation of disclosures and technological competitiveness analysis	X		
IP protection			X
IP consolidation and related legal questions			X
Commercialization plan drafting	X		
Financial plan elaboration	X		
Researcher coaching during commercialization	X		
Analysis of the technology positioning	X		
Collaboration and organization of data of the elaboration of the business plan	X		
Organization of spin-off companies	X		
Search for financial partners	Depending on the nature of the project	Depending on the nature of the	

		project	
Company coaching during the development stage	X		
Transfer negotiation	For commercialization projects	For academic partnership projects	
Follow-up after transfer	For commercialization projects	For academic partnership projects	X
Management of research contracts and joint academic partnerships		X	
Preparatory work for chairs, research institutes and industrial partnerships		X	
Management of confidentiality agreements, material transfer agreements, etc.		X	
Technical forums, training and sensitization	Depending on objective	Depending on objective	
Technology watch for fundamental research		X	
Technology watch for applied research	X		

Source: Afshari (2007), p. 31.

These outcomes are in fact influenced by the structure of the organizations wherein the process of technology transfer and spin-off creation takes place. This approach allows for the possibility to analyze the sources of amplification, time delays, as well as information feedbacks (self-reinforcing and self-correcting) in the process of UITT (Sterman 2000). However, the point to stress here is how it can be expected that this approach may determine the general indicators (outcomes) of the process of UITT and spin-off creation. Nevertheless, the difficulty arising at this point is the model evaluation process.

2.3. Research Problem

One of the most important research agendas on academic research, technology transfer and industrial innovation was established by Edwin Mansfield in the 1960s (Lerner 2005).[2] Since then, the analyses that examine commercializing knowledge and UITT have developed considerably. In these analyses, scholars agree about the importance of *uncertainty* and *informational gaps* as two key dimensions when creating spin-off companies. The process of spin-off firm creation and development is however largely affected by these variables as they determine some kind of conflicts emerging from the relations established between managers and investors when universities and public laboratories are transferring technology and new knowledge to firms (Lerner 2005). Along with uncertainty and informational gaps, the *lack of receptor capabilities* to new university-created knowledge is the principal reason why the creation of spin-off companies is more likely to happen in an academic environment (Siegel et al. 2003b). The process of technology transfer can take however many forms such as licensing agreements, research joint ventures, spin-offs and start-ups, among others (Siegel et al. 2003c).

From a different perspective, *technology commercialization*, *entrepreneurship* and *technological innovation* are recognized in the literature on technology transfer as three underlying and closely linked and intertwined components. However, there is still a lot of controversy (or conflicting evidence) on the precise nature of the relationships established between the underlying variables of these dimensions, as well as the stakeholders' participation into the process of UITT and commercialization (Hindle and Yencken 2004). In this sense, there are at least three promising areas of study in relation to UITT and commercialization: (1) the organizational practices in the management of university IP; (2) the role played by universities and TTOs in

[2] See for example, Mansfield (1968, 1991) and Mansfield and Lee (1996).

terms of management of resources and capabilities; and (3) the extent to which the capabilities of TTOs are important on the generation of university spin-off companies within a context of university's resources and environment (Lockett and Wright 2005; Siegel et al. 2004).

In addition to the problems introduced previously, many scholars point out that there is still an important gap remaining in the literature on UITT related to the research methods used in some analyses (Clarysse et al. 2005; Göktepe 2008; Lerner 2005; Lockett and Wright 2005; Vohora et al. 2004). These authors suggest that for the most part of the studies conducted until now are largely cross sectional, and thus it would be useful to adopt a *dynamic approach* to investigate specific problems types related to spin-offs emergence and growth. In effect, an important problem found in this literature relates to the typologies used in current analyses in that they have been designed as static categories to analyze spin-offs at a given point in time. Very importantly, current analyses overlook the dynamic process underlying spin-offs foundation and development, and thus it is not possible to figure out a complete knowledge of the nature of spin-off companies such as heterogeneity or how spin-off firms develop iteratively over time in terms of resources endowment, strategy, and links with their parent organization (Clarysse et al. 2005). Alternative analyses ought to be focused however on the *conflicts-of-interest* and resulting *trade-offs* perceived in the process of technology transfer to identify the conditions under which spin-off participating stakeholders can reconcile their concerns about conflict-of-interest with effective fomenting of spin-offs (Vohora et al. 2004).

In relation to spin-off participating stakeholders, Siegel et al. (2004) point out that there are three main sets of actors (or stakeholders) involved in the process of UITT: (1) university scientists who discover new technologies; (2) university technology managers and administrators who serve as a liaison between academic scientists and industry, as well as manage the university's IP; and (3) firms/entrepreneurs who commercialize university-based technologies. However, each stakeholder features its own actions, motives, and perspectives in the process of technology transfer (Table 9). The point to stress here is that stakeholders' actions, motives and perspectives are at times in contradiction or conflict between each other, raising thus some specific problems and tradeoffs related to the process of technology transfer.

Table 9. **Stakeholders in the Process of UITT**

Stakeholder	Actions	Primary Motive(s)	Secondary Motive(s)	Perspective
University Scientists	Discovery of new knowledge	Recognition within the scientific community-publications, grants (especially if untenured)	Financial gain and a desire to secure additional research funding (mainly for graduate students and lab equipment)	Scientific
Technology Transfer Office	Works with faculty members and firms/entrepreneurs to structure deals	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm/ Entrepreneur	Commercializes new technology	Financial gain	Maintain control of property technologies	Organic/ Entrepreneurial

Source: Adapted from Siegel et al. (2003).

A first attempt to resolve these problems may come from the analysis of the nature of the UITT mechanisms and thc nature of spin-off companies. The primarily objective should be to understand the structure of the system that drives the dynamic behavior and the nature of the conflicts-of-interest and tradeoffs perceived when transferring technology to industry, as well as to identify how this process can affect stakeholders' performance. In addition, the study of the dynamics of spin-offs emergence and development should take into account the resource endowment, the strategies, as well as the links established amongst stakeholders.

However, the creation of value from university knowledge underlies the need to identify, understand and distinguish key issues related to the support and creation of spin-off companies such as from the standpoints of public and academic stakeholders participating in the process of technology transfer (Nlemvo et al. 2002). In this sense, it would be necessary to study the multiple stages through which the UITT process is carried out (Subsection 3.2.3). Broadly speaking, Nlemvo et al. (2002) suggest the existence of four sequential stages in the spin-off development process: (1) generation of business ideas from research, (2) acquiring and finalizing new venture projects out of ideas, (3) launching spin-off firms from projects, and (4) strengthening the creation of economic value by spin-off firms.

From a different perspective, Vohora et al. (2004) offer a dynamic approach on UITT, suggesting the existence of five different stages when spinning off new firms: (1) research phase, (2) opportunity framing phase, (3) pre-organization phase, (4) re-orientation phase, and (5) sustainable returns phase. Each one of these phases is however characterized to have its own critical junctures (opportunity recognition, entrepreneurial commitment, threshold of credibility, and threshold of sustainability) that determine, in turn, the possibilities of success for spin-off firms. This approach is highly promising in developing further research on UITT and spin-offs creation.

Therefore, an important hypothesis in this proposal is that spin-off firm's sector-specific dynamics play a specific and significant role in shaping the pattern of UITT relations (Rappert et al. 1999). This notion opens up however new challenges in the analysis of technology transfer given that empirical studies have demonstrated that the emergence of spin-off companies faces two main challenges. First, spin-off companies emanate from a non-commercial environment, and thus it would be extremely important to analyze the conditions for which adequate resources and competences are guaranteed in the process of spinning-off new firms (Mustar et al. 2006; Vohora et al. 2004).[3] In this sense, much of the literature on academic-industry relations speaks on the need to break down cultural and organizational barriers between academic and industry given that universities have traditionally been perceived as lacking of business and marketing expertise (Rappert et al. 1999). Second, developing commercial abilities may be adversely impacted by conflicting objectives of key stakeholders such as the university, the academic entrepreneur, the venture's management team, and suppliers of finance (Clarysse et al. 2005). These two problems define the contextual basis within which this research is concerned.

These principles provide a rationale to establish a dynamic approach for analyzing UITT and spin-offs development. Under this approach, there is room to analyze the role of feedback loops and the potential for non-linear development in that some kind of resource differences, weaknesses, and inadequacies may constrain the spin-off development process and may be exacerbated by an un-entrepreneurial university environment (Eisenhardt 1989; Vohora et al. 2004). Kazanjian and Drain (1988, 1989) and Vohora et al. (2004) suggest that a resource-based approach is adequate to this analysis given that it allows studying spin-off performance taking into account the need to develop both resources and internal capabilities over time. The theoretical model drawn from this investigation is presented in Subsection 2.2.3 of this proposal.

On the other hand, Mustar et al. (2006) suggest that there are two main lines of research in the analysis of spin-off companies: spin-off creation and spin-off development. *Spin-off creation* is principally concerned with the types of inputs to be

[3] The Lambert Review of University-Business Collaboration of 2003, for example, recommended British universities to target resources to develop skills and capabilities to make new firms commercially viable (Lockett et al. 2005).

transferred and/or the strategies to be adopted by new firms. And *spin-off development* is concerned with the resource endowment and business plan. These authors conclude that today research on spin-offs appears to have moved from an exclusive focus on the process of firm creation to greater attention to firm development.

From this perspective, the formation of university spin-off companies can be seen as an output of university research-related activity and an outcome of the university's purposive technology transfer efforts (Link and Scott 2005). Specifically, there are two relevant sets of inputs to spin-off formations (Link and Scott 2005): (1) the research environment of the university, and (2) the characteristics of the research park to which the spin-off companies locate. These authors demonstrate the importance of the research environment of the university as significant for spin-off company developments. In relation to the research park characteristics, they make evident that age, distance and technology are the most important explanations into their model. Besides, these authors point out that they are not considering two main variables into their model: administrative incentives and specific characteristics of spin-off companies. In addition, a key constraint to the determinants and restrictions of spin-off creation is to have access to venture capital finances (Lockett and Wright 2005).

2.4. Research Questions

Research evidence emphasizes that UITT and commercialization of IP are phenomena characterized to be complex, highly risky, taking a long time, costing much, and that often fails (Jaffe and Lerner 2001; Powers and McDougall 2005a, 2005b; Rappert et al. 1999). The main objective of the process of technology transfer is to transform university-developed technologies into marketable products (Powers and McDougall 2005a). In this process, it is possible to find various participating stakeholders when transferring technology from universities to firms (Siegel et al. 2003c): university scientists, TTOs, and firms/entrepreneurs. The central research problem discussed in Section 2.2 is thus targeting this issue: *How do uncertainty, informational gaps, and lack of receptor capabilities influence the success in spin-off companies within a non-commercial environment and conflicting objectives of key stakeholders?* It is argued that answering this question, by inquiring about the structure by which these variables relate to one another, it would be possible to find specific outcomes for commercialization, entrepreneurial and technological innovation in spin-off companies. However, enquiring into this problem implies raising other specific questions to make tractable this research problem and to meet specific research objectives.

From an alternative perspective, the existence of empirical evidence experienced in many countries since the 1980s in relation to technology transfer and IP practices has already been cited. These changes have had significant implications on the nature of the phenomena related to IP commercialization, innovation, and spin-off creation. Certainly, the most important change observed in this environment has been the passage of the Bayh-Dole Act in 1980 in the United Sates that has also affected IP regimes and practices in other countries. In Canada, for example, the ownership of IP resides in the universities in some cases, and in the inventor in others. In fact, IP ownership practices in Canada are specified in university policies or in collective faculty agreements (Gault and McDaniel 2004). However, the *Framework of Agreed Principles on Federally Funded University Research* acknowledges the responsibility of the federal government to provide the necessary levels of investment in university research, and the *Association of Universities and Colleges of Canada* agreed to produce a periodic public report to demonstrate the collective progress made by universities in relation to research, knowledge transfer and innovation (AUCC 2002; Gault and McDaniel 2004). These attempts originated in a more general framework, the *Achieving Excellence, Investing in People, Knowledge, and Opportunity* report, establishes the importance of the Canadian government in supporting academic institutions to identify IP with commercial potential and forge partnerships with the private sector to commercialize research results (Cooper et al. 2006; Industry Canada 2002).

Perhaps, the most important lesson from the studies carried out in the last years is that in the process of UITT, actors' performance and external environmental factors interact amongst each other. From a system dynamics approach, this means that there are *feedback interactions* and potential *side effects* characterizing the complexity of these phenomena. Furthermore, throughout the development process of the various stages in spin-offs creation, it would be possible to recognize the role of *reinforcing and balancing feedbacks* and the potential for *non-linear developments* (Eisenhardt 1989). In this sense, the first group of questions arising in this proposal is *how environment variables affect the technology transfer process* or *how the environment affects the movements of know-how, technical knowledge, or technology transfer from one organization to another?* The process of technology transfer could be understood as "the movement of know-how, technical knowledge, or technology from one organizational setting to another". However, in the academic literature, it is possible to find many definitions on technology transfer depending on the discipline and purpose of the research (Roessner 2000): (1) economists such as Arrow (1969), Johnson (1970) and Dosi (1988) emphasize the properties of generic knowledge and focus particularly on variables related to production and design; (2) sociologists such as Rogers (1962) and Rogers and Shoemaker (1971) tend to link technology transfer to innovation, as well as to analyze the instrumental actions that reduce uncertainty in this process; (3) anthropologists such as Foster (1962), Service (1971) and Merrill (1972) interpret technology transfer within the context of cultural change and the ways in which technology affects this change; and (4) scholars from business disciplines such as Lake (1979), Teece (1976), in general, focus on intrasector transfer (Chiesa and Manzini 1996), the relation of technology transfer to strategy (Laamanen and

Autio 1996), and alliances among firms and how alliances pertain to the development and transfer of technology (Hagedoorn 1990; Kingsley and Klein 1998; Mowery and Langlois 1996; Niosi 1993; Niosi and Bergeron 1992).

This group of research questions implies that the process by which ideas, proofs-of-concept, and prototypes move from research-related to production-related phases of product development can be affected by important environmental variables (Bozeman 2000). Furthermore, some authors such as Jaffe and Lerner (2001), Lockett and Wright (2005) and Roberts and Malone (1996) have suggested that it would be interesting to analyze how patenting, the utilization of patents by spin-off companies, as well as other technology-transfer activities have shifted in response to environmental (legislative) changes observed around universities and/or strength the external environment for entrepreneurship. Hence, the second group of research questions concerns *how environmental variables affect the technology transfer process, or how the environment affects the movements of know-how, technical knowledge or technology transfer from one organization to another?* and *how different university environments and specific organizational structures affect the technology-transfer process, and what are the most significant resources and capabilities for creating successful university spin-off companies?*

Finally, in line with these two groups of questions, it is worthy to enquire about *how the heterogeneous features of spin-offs affect their success in commercialization?* Even if this question goes beyond the scope of this research, the greatest commercial activity has derived from universities that have remained focused (Jaffe and Lerner 2001). Moreover, facilities with turnover of contractors, when pressures from parties resistant to exclusive licensing are likely to have been lowest, have had greater success in accelerating their rate of commercialization (Jaffe and Lerner 2001).

2.5. Research Objectives

UITT and spin-off creation have become highly complex activities, and hence, they follow a non-linear development, as well as experience many reinforcing and balancing feedbacks interactions. The research objective proposed in this research is twofold: (1) to provide an understanding of the relations established between stakeholders participating in the process of UITT through the creation of spin-off companies, namely university/scientists, TTOs, commercializing companies (CCs) and firms/entrepreneurs, and (2) to provide a system dynamics (SD) model that illustrates UITT structural composition to analyze and understand the nature established amongst stakeholders participating in the process of UITT. Both objectives will be achieved simultaneously within this research given the nature of SD methods.

By making use of the principles of SD (feedback loops, stock and flow structures, time delays and nonlinearities), it is possible to determine the nature of the relationships established between stakeholders participating in the process of UITT and university spin-off creation. Furthermore, the nature of these relationships determines the outcomes resulting from stakeholders' actions and motives when transferring technology from universities to industry, as well as the behavioral patterns linked to the structure that characterize the underlying dynamics. In short, the analysis of UITT and spin-off creation from the perspective of the SD approach reveals the complexity of this system as they are subject to accelerated changes and uncertainty.

On the other hand, the literature review suggests the existence of many theoretical and empirical approaches on UITT and spin-off creation. This research contains a synthesis of this literature (theoretical approaches and models) in relation to a specific form of technology transfer, namely spin-off creation and development. These ideas contribute in fact to analyze and clarify the process of UITT and the creation of spin-offs in Canada. However, the process of technology transfer from universities to industry is specific for each country. In this sense, SD methods offer an adequate set of principles to analyze the Canadian case in relation to UITT and spin-off creation and development, allowing insight on the precise nature of these phenomena in this country.

2.6. Conclusion

This chapter introduced the research context and problem definition underlying this research. The research questions and objectives were also defined. The chapter presented an overview of the models on UITT and spin-off creation to be discussed in this research. Nevertheless, a primary conclusion in this chapter is that the models reviewed in this research should be understood as complementary given that. they identify the same phases of process of UITT and spin-off creation.

The difference between commercial and non-commercial UITT channels was established. In this sense, the importance of IP as a formal UIIT channel was emphasized. In addition, the university spin-off companies as a formal allocation of property rights, and patents and licensing as the most commonly using forms when transferring technology from university to industry for commercial purpose was discussed.

From an empirical perspective, the UITT was shown is as a highly complex phenomenon. In Canada, university-industry linkages and university R&D spending have become highly important to support wealth creation, job opportunities and industrial development. In this case, R&D spending financed by federal and provincial governments was established as the main external source of funding to Canadian universities. Furthermore, federal and provincial governments in Canada have altered their policies to encourage the commercialization of academic research results through the creation of university spin-offs. These policies have been implemented through changes in the academic system by designing new instruments for research funding and setting up adequate structures to support UITT activities.

It was also discussed in this chapter that Canada was as an interesting case to examine relation to UITT. From the literature review, financial support, experience on research, number of publications, affiliation with a large research university, and particular fields of research were found to be the main variables explaining the process of technology transfer in Canada. On the other hand, age, patents, and IRAP support were recognized as the main variables to support spin-off creation. However, in Canada, the importance of collaboration between users and academic researchers as the main sources of new ideas for creating new technologies and innovations was recognized.

Nevertheless, it was stated that the objective followed by the science and technology policy in Canada was to encourage Canadian firms to become highly competitive in the market through the generation and transfer of new knowledge from universities. This policy recognized the importance of university spin-off creation as a mechanism to support economic development in regions. In this sense, it was established that the federal initiatives to support the commercialization of research were conducted by many agencies and programs, such as the federal research institutes, CIHR, NSERC, SSHRC, IRAP, and BDC. The importance of the Western Economic Diversification Canada, FedNor, ACOA, and DEC was highlighted as key agencies that support the commercialization of academic research.

The importance of SD as a set of principles was introduced as an appropriate approach to address issues in uncertainty and nonlinearities when transferring technology from universities to industry. The analysis of UITT and spin-off creation from the perspective of SD methods allows to address the main questions raised in this research: the ones inquiring on the environmental conditions when transferring technology from university to industry, and the ones inquiring on good practices at the time technology is transferred and academic spin-offs are created.

Finally, some government initiatives aimed at supporting technology transfer and spin-off creation in Canada were presented. It was concluded that these initiatives might generate problems when technology was transferred, mainly uncertainty and non-linearity processes. The identification of this kind of problems justifies the use of a SD model to examine UITT and spin-off creation at Canadian universities. In this sense, a preliminary analysis of key variables affected by these processes when developing a university spin-offs model was made in this chapter, mainly research results, patenting files, patents and spin-off patents, spin-off incomes, and so on. However, a deeper study of the relationships established between these variables will be presented in Chapter 3, and their usefulness and relationships established within a SD framework will be discussed in Chapter 4.

The next chapter is concerned with the literature review. The literature review forms the basis for the discussion of the process of UITT and spin-off creation in Canada. In this sense, it establishes the relationships linking stakeholders' actions resulting in specific outcomes that will be evaluated in terms of their performance. As a result, three main topics will be studied in the next chapter: the theoretical approaches to analyze the process of technology transfer, the theoretical models that explain the process of university spin-offs creation, and the SD principles that will be employed to again a systemic understanding on these phenomena.

III. Literature Review

This chapter reviews some literature on university-industry technology transfer (UITT) and system dynamics (SD) principles. Section 3.1 summarizes key theoretical principles on intellectual property (IP) and technology transfer. Section 3.2 includes a discussion of some specific issues on UITT. Subsection 3.2.1 discusses the taxonomies used in the study of technology transfer. Subsection 3.2.2 deals with main theoretical approaches in the process of UITT: (1) the resource based view of the firm, (2) the business model perspective, and (3) the institutional perspective. Lastly, Subsection 3.2.3 analyses some empirical models aiming to explain how UITT is carried out: (1) the evolutionary schema (Bercovitz and Feldmann 2006), (2) the entrepreneurial opportunity and entrepreneurial capacity model (Hindle and Yencken 2004), (3) the stage model of academic spin-off creation (Nlemvo et al. 2002), (4) the technology transfer office model (Siegel et al. 2003; Siegel et al. 2004), and (5) the critical junctures model. Section 3.3 contains a review of the literature on SD principles. Finally, Section 3.4 contains summarizing conclusions.

3.1. Intellectual Property and Technology Transfer

The Bayh-Dole Act of 1980 focused on two main issues (Link and Scott 2005; Siegel et al. 2004): patenting activities as a general trend in universities and public research centers, and the establishment and operation of technology transfer offices (TTOs). Since then, many universities have established TTOs to manage and protect their IP to exploit and transfer science-based and technological knowledge to the private sector (Lockett and Wright 2005). There are many channels for transferring technology from universities and public research centers to industry (Locket et al. 2003): publications, education/training, collaborative research, contract research, industrial consultancy, patents and licenses, spin-off companies and joint ventures. However, these mechanisms can be classified into two main categories (Mowery and Shane 2002): commercial channels and non-commercial channels.

One of the most promising ways to transfer research results into the creation of economic value is however through the foundation of university spin-off companies (Nlemvo et al. 2002). From a theoretical perspective, even if there have been numerous studies of university patenting, licensing, and research joint ventures, there are not many systematic studies on university spin-offs development, managerial and policy implications since they are focused on very particular universities (Alistair 1991; Lockett et al. 2005; Lowe 1985; Main 1996; Olofsson 1993). By the time, three different theoretical approaches in the analysis of UITT have been developed (Mustar et al. 2006): (1) the resource-based view of the firm, (2) the business model perspective, and (3) the institutional perspective.

On the other hand, O'Shea et al. (2005) point out that there are three main categories of literature on UITT. The first bulk of literature assesses the personal characteristics of academics that appear to impact entrepreneurship. Shane (2004) suggests that there are three reasons as motivational characteristics: (1) a desire to bring technology into practice, (2) a desire for wealth, and (3) a desire for independence. The second block of literature on UITT stands on universities' policies, procedures and practices for spin-off developments and commercialization. Finally, the third bulk of literature explores environmental factors impacting academic innovations.

From this discussion, Debackere and Veugelers (2005) suggest that for acquiring successful technology transfer practices universities should employ:

1. An incentive structure to reward academic entrepreneurial endeavours;

2. Decentralized operating structures to provide greater autonomy to research teams;
3. A centralized staff of experienced technology transfer personnel to manage the 'contract' and 'training' issues associated with the technology transfer process.

3.2. University-Industry Technology Transfer

This Section addresses three main topics included into many explanations on UITT: typology used in those analyzes, alternative theoretical approaches, and some empirical models commonly used to explain the process of technology transfer. Subsection 3.2.1 reviews different typologies used in some studies on UITT research: Clarysse et al. (2005), Mustar et al. (2006), and Pirnay et al. (2003). Subsection 3.2.2 examines three alternative theoretical approaches for explaining technology transfer: the resource-based view of the firm, the business model perspective, and the institutional perspective. Subsection 3.2.3 presents some empirical models used to explain this process: Bercovitz and Feldman (2006), Hindle and Yencken (2004), Nlemvo et al. (2002), and Siegel et al. (2003c, 2004).

3.2.1. Taxonomy

"Silicon Valley" and "Route 128" are the greatest examples on how novel innovative firms develop around prestigious universities when introducing successful innovations into the knowledge-based economy (Pirnay et al. 2003). The university spin-off is definitely the prototype organization in the process of UITT. This section summarizes some literature in relation to the typologies formally used to classify UITT activities. Three particular papers dealing with this problem were identified: Clarysse et al. (2005), Mustar et al. (2006), and Pirnay et al. (2003).

The need for a suitable typology in guiding and in establishing adequate boundaries to a research like this is crucial. As it has already been pointed out, spin-off companies are heterogeneous in nature and thus the stepping process of development may be quite specific for each spin-off and the status of individuals involved in each spin-off company (Mustar et al. 2006). Additionally, the nature of the knowledge transfer process from universities to industry must be considered when studying the nature of spin-off companies in terms of goals, objectives and strategies in order to create successful spin-off companies (Clarysse et al. 2005; Pirnay et al. 2003).

Many definitions of spin-off have been proposed in the literature on UITT (Table 10). Pirnay et al. (2003) define spin-off firm as a novel organization that fulfils simultaneously three conditions: (1) it takes place within an existing organization, generally known as the "parent organization", (2) it involves one or several individuals, whatever their status and function within the "parent organization", and (3) these individuals leave the "parent organization" to create a new firm. The definition proposed by these authors contains four basic elements: new firms, created from universities, to exploit knowledge produced by academic activities, and in a profit-making perspective. Nevertheless, a simple working definition of university spin-off firm is the following: *new firms created to exploit commercially some knowledge, technology or research results developed within a university* (Pirnay et al. 2003). However, the four elements contained in this definition provide an adequate boundary to identify the research object in this thesis research.

Table 10. **Definitions of University Spin-Offs**

Authors	Year	Definitions
McQueen, D. H. Wallmark, J. T.	1982	" ... in order to be classified as university spin-off, three criteria has to be met: (1) the company founder or founders have to come from a university (faculty, staff or student); (2) the activity of the company has to be based on technical ideas generated in the university environment; and (3) the transfer from the university to the company has to be direct and not via an intermediate employment somewhere" (p. 307)
Smilor, R. W. Gibson, D. V. Dietrich, G. B.	1990	"a company that is founded (1) by a faculty member, staff member, or student who left the university to start a company or who started the company while still affiliated with the university; and (2) around a technology or technology-based idea developed within the university" (p. 63)
Weatherston, J.	1995	" ... an academic spin-off can be described as a business venture which is initiated, or become commercially active, with the academic entrepreneur playing a key role in any or all of the planning, initial establishment, or subsequent management phases" (p.1)
Carayannis, E. Rogers, E. Kurihara, K. Allbritton, M.	1998	"a new company formed by individuals who were former employees of a parent organization (the university), around a core technology that originated at a parent organization and that was transferred to the new company" (p. 1)
Bellini, E. Capaldo, G. Edström, A. Kaulio, M. Raffa, M. Riccardia, M. Zollo, G.	1999	" ... academic spin-offs are companies founded by university teachers, researchers, or students and graduates in order to commercially exploit the results of the research in which they might have been involved at the university ... the commercial exploitation of scientific and technological knowledge is realized by university scientists (teachers or researchers), students and graduates" (p. 2)
O'Gorman, C. Jones-Evans, D.	1999	" ... the formation of a new firm or organization to exploit the results of the university research"
Rappert, B. Webster, A. Charles, D.	1999	"University spin-offs are firms whose products or services develop out of technology-based ideas or scientific/technical know-how generated in a university setting by a member of faculty, staff or student who founded (or co-founded with others) the firm" (p. 874)
Clarysse, B. Heirman, A. Degroof, J. J.	2000	" ... research-based spin-offs are defined as new companies set up by a host institute (university, technical school, public/private R&D department) to transfer and commercialize inventions resulting from the R&D efforts of the departments" (p. 546)

Klofsten, M. Jones-Evans, D.	2000	" ... formation of new firm or organization to exploit the results of the university research" (p. 300).
Steffensen, M. Rogers, E. Speakman, K.	2000	"A spin-off is a new company that is formed (1) by individuals who were former employees of a parent organization, and (2) a core technology that is transferred from the parent organization" (p. 97)

Source: Pirnay et al. (2003) p. 357.

Pirnay et al. (2003) also found that even if this definition is simple and functional, it remains ambiguous about the *status of individuals* involved in the new business venturing process (researchers, faculty members, staff members or students), and the *nature of knowledge* transferred from university to the new venture (technology based spin-off or know-how services). As a result, these authors point out that there are two different possibilities in relation to the status of individuals involved in the process of UITT: *academic spin-offs* (individuals coming either from the scientific community, such as professors, assistants, researchers or doctoral students), and *student spin-offs* (individuals coming from the student community with little in-depth research background).

In relation to the nature of knowledge transferred from university to industry, this could be *codified knowledge* or *tacit knowledge*. Tacit knowledge is determined by the capabilities, expertise and experience of individuals involved in the technology transfer process (pieces of personal knowledge accumulated by individuals), meanwhile codified knowledge can be easily transferred, distributed and used but copied and imitated by others, and thus this characteristic introduces the problem of the protection of knowledge (Rappert et al. 1999). However, the protection of knowledge can be natural (degree of innovation and barriers to imitation) or artificial (patents and copyrights). Typically, tacit knowledge is service-oriented and codified knowledge is product-oriented. However, codified and tacit knowledge are closely related, and thus the economic exploitation of codified knowledge by spinning-off new firms can be problematic when the project is carried out by a surrogate entrepreneur with little technical expertise (tacit knowledge), given that it is really important to understand and fully exploit the technology (codified knowledge) (Pirnay et al. 2003).

These ideas allow these authors to establish a two-by-two matrix in relation to the status of individuals and the nature of knowledge. The two-by-two matrix is presented in figure 2. Within this approach and the ideas suggested by Hindle and Yencken (2004), it is possible to differentiate between direct *research spin-offs*, *technology transfer companies*, and *start-ups or indirect spin-off companies*. Spin-off companies are distinguished from technology transfer start-up companies in that the former is characterized to be formally protected by some form of intellectual property and/or some kind of exclusive licensing is involved.

Figure 2. **UITT Individual Status**

Knowledge Transfer	Researcher (academic spin-off)	Student (student spin-off)
Codified (product-oriented spin-off)	Type I	Type III
Tacit (service-oriented spin-off)	Type II	Type IV

Source: Pirnay et al. (2003) p. 361.

On the other hand, Mustar et al. (2006) take into account three dimensions to analyze spin-off developments: (1) the institutional strategies involved in the development process of spin-offs, (2) the business model used to develop the new organization, and (3) the resource endowment when spinning off new firms (human, financial/technological, and sources of the resources). Besides, these authors identify two main rationales behind the works analyzed in their paper. First, spin-off creation is considered as part of the process of technology transfer generated in a research organization. This process of technology transfer places particular emphasis on the relationship established with the parent research organization, and thus those analyses are conducted from the standpoint of the parent organization. Second, the papers analyzed from this perspective are focused on the process of spin-off development, addressing the opportunity to identify the activities performed, or the resources needed, as well as the sources of these resources, or a combination of both.

The first group of literature, spin-off creation, is concerned with the creation of spin-off firms in terms of the type of inputs transferred to the new organization and/or the strategies adopted by the research organization. The typologies devised by these authors place greater emphasis on institutional links. The following features characterizes this literature: (1) the institutional links are always an underlying dimension, (2) some of these typologies are actually unidimensional in that they consider only the institutional link as a means to transfer people or technology, (3) the parent's strategic choices are a separate aspect of the institutional link, (4) the inputs may have a lasting effect on the business model of the spin-off created in terms of the nature of the opportunities exploited or the type of activities performed. Examples of this literature are: Carayannis et al. (1998), Fontes (2001, 2005), Franklin et al. (2001), Hindle and Yencken (2004), Mustar (2002), Pirnay et al. (2003), Radosevich (1995), Steffensen et al. (2000), and Upstill and Symington (2002).

The second group of literature, spin-off development, focuses more directly on the process of development of spin-offs and the factors that influence it. The typologies devised by these authors place greater emphasis on the resource endowment and the business model. The following features characterize this literature: (1) the focus is on the resource endowment dimension, (2) the focus is also on the nature of opportunities identified and the activities performed to exploit (business model dimension), and (3) more complex typologies combine both dimensions. Examples of this literature are: Druilhe and Garnsey (2004), Heirman and Clarysse (2004), Mustar (1997), Shane and Stuart (2002), Stankiewicz (1994), and Wright et al. (2004).

From a different perspective, Clarysse et al. (2005) analyze the case of European research institutions and spin-off companies. In this study, these authors used a typology to analyze the goals and objectives of leading European research institutions, and the strategies employed to achieve these goals in terms of resources utilized and activities undertaken. In this study, however, the authors define three distinct incubation models: Low Selective, Supportive, and Incubator.

The Low Selective Model has a mission oriented towards maximizing the number of entrepreneurial ventures in line with the entrepreneurial mission of the research institute to which the unit is attached (these ventures tend to be self-employment oriented start-ups which only rarely grow beyond a critical size of employees). The Supportive Model is oriented towards generating spin-outs as an alternative to licensing out its intellectual property (this model tends to generate profit-oriented spin-outs with potential growth opportunity). The Incubator Model makes a trade-off between the uses of a body of research to generate contract research versus spinning-off this research in a separate company.

Table 11. **Resources Required by Different Models**

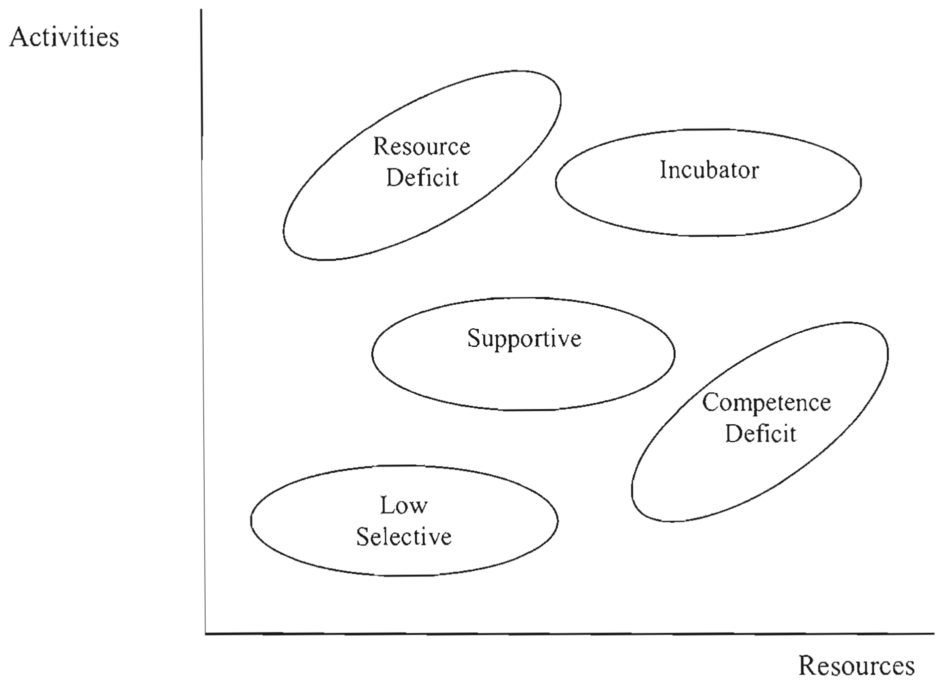
Resources	Low Selective Model Based upon Crealys and Twente	Supportive Model Based upon Leuven R&D and BioM	Incubator Model Based upon IMEC, TTP and Scientific Generics
Organizational resources Human resources	Public organizations, linked with universities Small team, familiar with public sector	Private organizations linked with universities Larger (5-7 persons) multidisciplinary team, with links to the financial world to be able to evaluate the business plans	Center of excellence, close link with industry Experience professional staff Able to draw upon 'in-house' specialists
Technological resources	No technological focus or specialisms	Focus on the best performing departments of the university, mainly applied research	Relatively narrowly focused on particular specialisms, in which it has a wealth of experience
Physical resources	Offer office space and infrastructure within the universities	Offer office space and infrastructure within an incubator center, at market prices	Internal research space and infrastructure is offered for free
Financial resources	Need a large amount of public money to offer at the spin-outs	Need to set up an associated fund with public/private partners	Invested money is private money, the TTO may have its own VC fund
Networking resources	Entrepreneurial climate within university or research center is very important	Entrepreneurial context is very important	Entrepreneurial context is scarcely important

Source: Taken from Clarysse et al. (2005), p. 200.

An important point to stress is that founding spin-offs can be seen as a process in which three different stages can be distinguished (Clarysse and Moray 2004): (1) the invention phase (technical uncertainty prevails), (2) the transition phase (technical uncertainty becomes more limited and the business idea is validated), and (3) the innovation phase (validation of growth expectation phase). Additionally, different activities of a proactive spin-off management process are identified (Degroof 2002): (1) technology opportunity search trying to identify technologies with a commercial potential, (2) IP filing (it includes examining choices between options of licensing and commercialization through spin-off venture), (3) selection of the spin-off projects based on their intrinsic potential and on the comparison with alternative projects, (4) business plan development, (5) potential sources of funding, and (6) spin-off venture incorporation and coaching. In the same way, six types of resources can be identified for spinning-off a new company (Brush et al. 2001): human, social, financial, physical, technological, and organizational resources (Table 11).

The three models described in that paper are not substitutes but complementary. Figure 3 presents the complexity of activities along the vertical axis and the heterogeneity of resources along the horizontal axis.

Figure 3. **Typology of Spinout Strategies and Outcomes**



Source: Clarysse et al. (2005), p. 204

Clarysse et al. (2005) explain that low selective interfaces are concerned with creating as many companies as possible. These projects are not attractive to private capital, so public money (small quantities) is an important resource in this model. The human resources needed also stay limited in quantity, but are very specific in nature. These projects are typically run by a few people with the skills to enhance the entrepreneurial climate at the university. However, the critical evaluation dimension is the number of companies that surrounds the university. In this sense, as these companies are so numerous, the total job creation in the regions is considerable. These features characterize the Low Selective model: (1) low levels of capitalization, (2) locally or nationally focused market, (3) life-style rather than significant wealth creation, and (4) less developed management structures and processes.

The supportive model, Clarysse et al. (2005) point out, originates from the idea of commercializing university technology through means other than licensing. Thus, this model requires substantial resources for IP assistance, and hence the support is provided in terms of patent and license negotiations with industry. In this model, TTOs happen to be very important. Once a specific technology is intended to be commercialized, the team of researchers is intensively coached to start-up the company. In this sense, the TTOs need very different resources than in the Low Selective model. These resources may include: (1) a larger multidisciplinary team with commercial experience and links to the financial community, (2) close public/private contacts willing to invest small to medium-sized amounts of resources, (3) an organization organized as a separate entity with control over triggers to motivate professors to work with them, and (4) to have sufficient contacts to support the research team during the process of spinning off.

Finally, Clarysse et al. (2005) argue that the incubator model takes into account different interests among many organizations that had developed proprietary technology analyzing the specific circumstances under which these firms could become more financially attractive than licensing or contract research within established industry. Opportunity seeking is proactive and oriented towards the early detection of promising technology platforms. The research remains inside the parent research institute until all resources are in place, and the venture is deemed ready to look for private venture capital and to hire a proven management team. When these companies leave the research institute, they are likely to be highly product/market-focused, to have a balanced and experienced team, and to be more adequately funded.

3.2.2. UITT: Three Theoretical Approaches

It is possible to find in the literature on technology transfer three alternative theoretical approaches to analyze the process of UITT (Mustar et al. 2006): (1) the resource-based view of the firm, (2) the business model perspective, and (3) the institutional approach. A brief description of these approaches is presented in this section.

3.2.2.1. The Resource-Based View of the Firm

The central idea in this approach is that resources differentiation is the main explanation of firm's competitive advantages. However, since this approach gives superior importance to organizational resources and capabilities when explaining firm's performance, it has emerged as one of the most influential frameworks in strategic management research (Barney et al. 2001; Mustar et al. 2006).

This approach stresses on four resource categories in relation to spin-offs creation (Barney 1991; Brush et al. 2001): (1) technological resources (firm-specific products and technology, degree of innovativeness, etc.), (2) social resources (firm's industry and financial contacts), (3) human resources (attributes of the founding team, the management team and the personnel of the company), and (4) financial resources (amount and type of financing of the firm). Each category has been explored when explaining spin-off companies' performance within this approach. However, a more dynamic approach would reflect firm's ability to achieve new and innovative forms of competitive advantages (Teece et al. 1997).

From this perspective, the resource-based approach provides a valuable perspective to understand the process and pace of UITT. In this sense, at the level of the individual entrepreneur, this approach focuses on the founder's unique awareness of opportunities and ability to acquire the resources needed to commercially exploit the opportunity of new technology. West and Bamford (2005) suggest that there are at least three facets of the resource-based theory that are appropriate for the application to this phenomenon: (1) its focus on generating competitive advantage, (2) the growing view that effective strategic positions involve bundles or collection or resources, and (3) the recent attention to the dynamic process of creating resources in entrepreneurial situations.

3.2.2.2. The Business Model Perspective

The business model perspective finds its roots in the management literature (Mustar et al. 2006). This approach can be summarized in terms of four concepts: (1) the articulation of the value proposition, (2) the identification of the market segment, (3) the position which is taken in the value chain, and (4) the estimated cost structure and profit margin (Chesbrough and Rosenbloom 2002).

However, the analysis of spin-off companies within the business model perspective can be divided into three categories (Mustar et al. 2006). The first category focuses on the activities taken by the firm: (1) consultants, (2) product oriented, and (3) technology asset oriented. The second category analyzes how technologies or knowledge can be transformed into commercial value: (1) infrastructure or platform companies, (2) product companies, (3) companies that move from product to platform, and (4) prospector companies. It is important to mention at this point that the analysis carried out by Druilhe and Garnsey (2004) adopts a dynamic perspective in that how the interplay between the entrepreneur's prior knowledge and experience and the intensity of resource requirements yield a business model. In this sense, these authors suggest that business models are altered as entrepreneurs improve their knowledge or resources and opportunities. Finally, the third category makes a distinction between new technology-based firms and resource-based spin-offs. Some important contributions to the analysis of spin-off companies and start-ups from the perspective of the business model analysis are: Bower (2003), Chiesa and Piccaluga (2000), Degroof (2002), Druilhe and Garnsey (2004), Heirman and Clarysse (2004), Mustar (2002), Pirnay et al. (2003), Stankiewicz (1994).

3.2.2.3. The Institutional Perspective

The institutional perspective is based on the recognition that spin-off companies are founded to exploit IP (Mustar et al. 2006). Within this approach, technology is transferred directly as it emerges from scientific activities and is typically embedded in a parent organization. The process of technology transfer is carried out by means of a license agreement or patent transfer. The institutional perspective is actually a more pragmatic approach in that it labels companies which have received a formal transfer of technology as spin-offs.

Some important contributions to the analysis of spin-off companies from the perspective of the institutional model are: Boeker (1989), Clarysse et al. (2005), Dacin (1997), Debackere (2000), Ferguson and Olofsson (2004), Franklin et al. (2001), Lindelof and Lofsten (2004), Link and Scott (2005), Meyer (2003), Moray and Clarysse (2005), Mustar (2002), Radosevich (1995), Steffensen et al. (2000), and Westhead and Storey (1995).

3.2.3. UITT and Spin-Off Creation

In relation to the literature on UITT, it is possible to find five alternative theoretical models to explain this process: (1) the evolutionary schema (Bercovitz and Feldman 2006), (2) the entrepreneurial opportunity and entrepreneurial capacity model (Hindle and Yencken 2004), (3) the stage model of academic spin-off creation (Nlemvo et al. 2002), (4) the technology transfer office model (Siegel et al. 2003, 2004), and (5) the critical junctures model (Vohora et al. 2004). This section presents a brief description of these models.

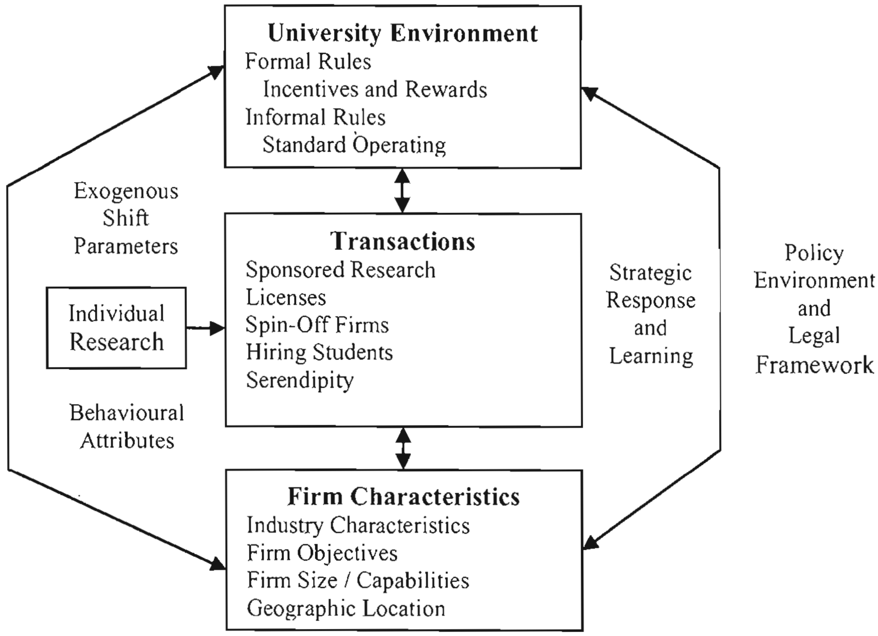
3.2.3.1. An Evolutionary Schema (Bercovitz and Feldmann 2006)

The main attempt of this model is to offer a framework to illuminate the role played by universities in systems of innovation. It incorporates economic, social, and political influences that affect the ability of universities to both create new knowledge and deploy that knowledge in economically useful ways. The objective is thus to build a more general understanding of university-industry relationships and their role in knowledge-based innovation systems.

In this model, universities are at the center of the analysis, given that they are the main source of production, diffusion, and deployment of new knowledge and innovation. In this sense, Bercovitz and Feldmann (2006) argue that university-industry collaboration has intensified in recent years due to four interrelated factors: (1) the development of new high-opportunity technology platforms, (2) the more general growing scientific and technical content of all types of industrial production, (3) the need for new sources of academic research funding created by budgetary stringency, and (4) the prominence of government policies aimed at raising the economic returns of publicly funded research by stimulating UITT. However, the big challenge is to take into account these factors to explain entrepreneurial and university's behavior (Etzkowitz 1983). The framework proposed by these authors is to examine the black box of university technology-transfer about motivations and incentives underlying these actors, and how economic, social and political influences shape the creation and deployment of knowledge in ways that are economically useful to firms (Bercovitz and Feldman 2006).

It is assumed that the commercialization of university research is a dyad involving transactions between the university and the commercial firm. This transactions can be multiple and of many different types. It also assumes that universities and firms are different in nature and thus both have their own rules, rewards and incentives structures. Universities are complex bureaucracies that involve a variety of educational and societal objectives, interests of faculty members, etc., in contrast to commercial firms that are managed with a relatively simple profit motive.

Figure 4. **University-Industry Relationship Evolutionary Model**



Source: Bercovitz and Feldmann (2006) p. 176.

In the university-industry evolutionary model, universities' relationships with industry are formed through a series of sequential transactions: sponsored research, licenses, spin-off companies, and students hiring (figure 4). It is important to notice that in this model both formal and informal mechanisms are equally important to explain UITT. The point is that to understand university-industry transactions, it is important to take into account firm's strategy and industry characteristics, university policies, the structure of the technology transfer operations, as well as the parameters defined by government policy.

A key feature characterizing university-industry relationships within the university-industry evolutionary perspective is that transactions occur through the mechanisms of sponsored research support, agreements to license university intellectual property, as well as hiring research students. In this context, the majority of sponsored research, awarded in the form of grants or contracts, is funded by government agencies, but it may also include company participation in industry-funded research centers. In this context, universities provide companies the right to use IP (licenses) granted in codified form (patents or trademarks). Negotiations of licenses are based on estimates of the subjective expected value of that portion of the knowledge that the firm may appropriate. In this case, royalties, rates, terms, and license fees are the first transaction negotiated by both parties. Universities are more likely to negotiate licenses that are calibrated to certain use or specific geographic markets and reflect industry practices.

Spin-off companies and students hiring differ as technology transfer mechanisms. In fact, university spin-offs have become a favored mechanism by which universities transfer technology to the commercial realm. These new companies are seen as a means to transform local economies, as well as a mechanism which provides a way to capture the benefits of proximity to research universities. In this sense, this phenomenon has transformed entrepreneurship into a decidedly local phenomenon.

In relation to the individual researcher factor, these authors found three reasons to explain why individual faculty members do not choose to participate into technology transfer activities: (1) inventions disclosing and applied R&D take time, (2) the patenting process may imply delays in publication, and (3) many faculty members believe that commercial activity is not appropriate for an academic scientist. In the same way, the decision of the individual faculty members to participate in technology transfer may be influenced by three factors (Bercovitz and Feldman 2004): (1) training effects, (2) leadership effects, and (3) cohort effects. From a different perspective, a firm's R&D strategy should be linked to other external entities as they contribute to search, discover and develop new knowledge. Indeed, it is the integration of new knowledge to the firm that leads to path-breaking innovations.

In a few words, these factors, along with the national and local policy environment and legal framework, influence the efficiency and evolution of university-industry relationships. The reason is that universities are involved in a two-phase process that influences the production of knowledge and its application and diffusion.

3.2.3.2. The Entrepreneurial Opportunity and Capacity Model (Hindle and Yencken 2004)

This model explores the interactions established between institutions (set of rules), organizational culture, and the external business environment in research commercialization activities. These authors found that tacit knowledge is actually an effective mechanism in research commercialization performance. They explore the nature of the knowledge inputs and the entrepreneurship capacity inputs involved in the process of technology innovation to explain the emergence and development spin-off companies. In this sense, spin-off companies should be understood as a commercialization channel for university research outcomes. This analysis is developed under the resource-based theory applied to entrepreneurship (Alvarez and Busenitz 2001).

A key idea in this model is that technological innovation results from the commercial exploitation of new knowledge, given that the ultimate objective of firms should be wealth creation. In fact, the exploitation of new knowledge leads to discover commercial opportunities that essentially change the production function. This study also analyzes some basic concepts related to the technology transfer process, such as innovation, entrepreneurship and so on. In relation to R&D, these authors discuss four generations of R&D: (1) R&D for searching scientific breakthroughs, (2) R&D focused to applicability in the market place using project management, (3) R&D using surveys to establish existing customers' needs to create products and services to fulfill those needs (continues innovation), and (4) R&D characterized by cooperative R&D and systematic links between independent research agents (Niosi 1999). The point is that public research spin-offs may operate quite successfully and survive in any one of these disparate modes. However, the literature suggests that spin-offs operating in these second and third generation modes may survive, but are unlikely to show significant growth (Stankiewicz 1994).

In relation to commercialization channels, these authors identify a variety of channels by which innovation from the commercialization of university and other public research can take place: publication, education/training, collaborative research, contract research, industrial consultancy, licensing, spin-off companies and joint ventures.

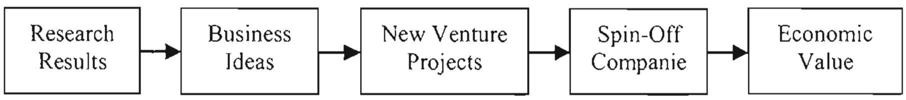
3.2.3.3. A Stage Model of Academic Spin-Off Creation (Nlemvo et al. 2002)

The objective of this model is to open the black box in order to identify, understand and distinguish the major issues raised by the creation of academic spin-off companies from the standpoint of both public and academic authorities.

Four stages are identified as relevant to explain the transformation of academic research results into economic value: (1) the generation of business ideas from research with regard to possible commercialization, (2) the realization of new venture projects out of ideas that translate the most promising of them into genuine entrepreneurial projects, (3) launching spin-off firms from promising projects, and (4) the consolidation and strengthening of spin-off firms to create economic value.

The big problem in this approach is that not all research results generate business ideas. Not all ideas amount to opportunities for new venture projects, attractive opportunities do not necessarily lead to the creation of spin-off firms, and such firms do not necessarily all generate economic value. Figure 5 summarizes this model

Figure 5. **Stage Model of Academic Spin-Off Creation**



Source: Nlemvo et al. (2002).

In terms of the model, the first stage concerns the generation of business ideas. In this stage the main problem is to reconcile two traditional and opposite conceptions of science in order to exploit it commercially: the scientific conception and the economic conception. Dasgupta and David (1993) suggest that actually the attempts to encourage commercialization alter the institutional rules and conventions under which academic research takes place. Thus, two additional difficulties must be overcome by universities to generate successfully spin-off companies: the academic culture and the internal identification.

These difficulties, in turn, imply the need to consider how to resolve the tension created by two traditional and opposite conceptions of science in order to exploit academic knowledge by not jeopardizing the basic role of the university (Lee 1996;

Nlemvo et al. 2002; Rappert et al. 1999). In theory, university spin-offs offer a means of resolving some of the tensions of commercializing knowledge while providing a mechanism for capturing economic benefits at the local, regional or national levels (Rappert et al. 1999).

According to this model, the purpose of the second stage is to transform an unstructured new idea into a coherent and structured venture creation project, addressing three specific issues: protection, development, and financing. The protection of a potentially commercial new idea underscores two additional problems: how to identify clearly the owners of results yielded by research efforts, and how to protect these results efficiently form counterfeiting, copying and imitations. In fact, the development of any new business idea requires the recognition of its economic potential and to be legally protected (selling, licensing or spinning-off). If spinning-off is chosen, the next step is to transform the idea into a genuine entrepreneurial project through technological developments (production of a prototype) and commercial developments (construction of a business plan and design a coherent strategy). Lastly, financing a new idea is undoubtedly the key problem to overcome to finalize genuine entrepreneurial projects.

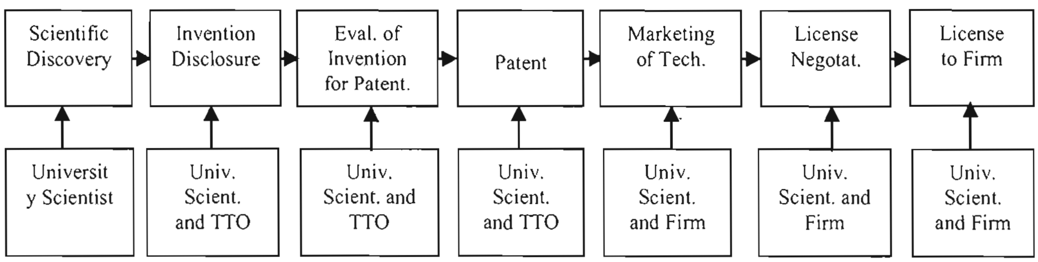
The third stage concerns launching the spin-off firm. This stage deals with the creation and exploitation of new opportunities. In this stage, the new spin-off company must be managed by a professional team and supported by available resources. The problems arising at this stage however is the availability of resources (intangible and tangible) and the relationships established between the spin-off firm and its parent university (relationships established either at an institutional level or at a personal level).

The final stage concerns the strengthening and the creation of economic value. At this point, two specific problems emerge: risk relocation and non-exploitation of full industrial potential of technological projects (change of trajectories).

3.2.3.4. The Technology Transfer Office Model (Siegel et al. 2003, 2004)

This model emphasizes the role played by TTOs in the process UITT. A crucial function of the university-industry technology management should be to identify key organizational issues that promote successful knowledge transfer. University management of IP through TTOs is however a relatively new phenomenon. These authors define the role played by TTOs as the activities that facilitate commercial knowledge transfers (or technology diffusion) through licensing patents or other forms of IP resulting from university research (inventions). The main objective is to get insight on cultural and informational barriers found when transferring knowledge, given that the stakeholders in this process have different motives and behaviors and they operate within different environments.

Figure 6a. **Technology Transfer from University to Firm or Entrepreneur I**



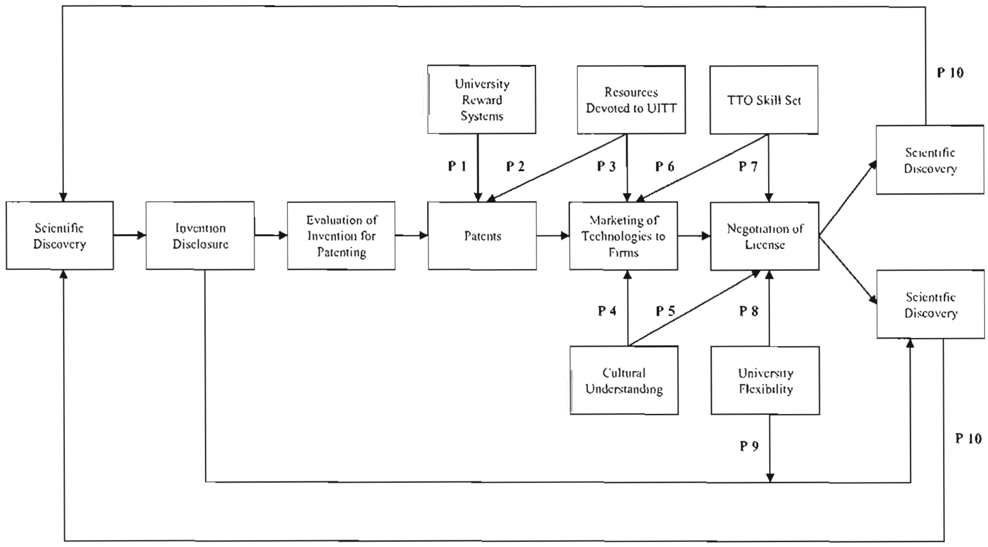
Source: Siegel et al. (2003) p. 114.

Accordingly, the main stakeholders in the process of UITT are: (1) university scientists who discover new technologies, (2) university technology managers and administrators who serve as a liaison between academic scientists and industry, and manage the university's intellectual property, and (3) firms/entrepreneurs who commercialize university-based technologies. Table 7 in section 2.2.3 summarizes actions, primary and secondary motives, as well as perspectives in relation to stakeholders participating in the UITT process.

This approach considers that the primary motive to technology transfer is to safeguard and to market the university IP to private firms. This process includes securing additional research funds for universities via royalties and licensing fees, sponsored research agreements, and to promote technological diffusion. Figure 6a shows the relationships established by actors in the process of technology transfer.

This model aims to gain insight on four key questions: (1) how stakeholders participating in UITT define the outputs of the process, (2) how the formation of relationships, networks, or boundary spanning behavior affect UITT, (3) what are the organizational/managerial barriers to UITT, and (4) how organizational factors and managerial behaviors can improve to help facilitate UITT.

Figure 6b. **Technology Transfer from University to Firm or Entrepreneur II**



Source: Siegel et al. (2004).

To gain insight on these questions, these authors reformulate their model and establish the following propositions: (1) universities that provide greater rewards for faculty involvement in technology transfer will generate more patents and licenses, (2) universities that allocate more resources to the TTO will generate more patents and licenses, (3) universities that allocate more resources to the TTO will devote more effort to marketing technologies to firms, (4) cultural misunderstanding reduces the effectiveness of the university's efforts to market university-based technologies to firms, (5) cultural misunderstanding impedes the negotiation of licensing agreements, (6) TTOs managed by individuals with marketing experience and skills will expend greater effort in establishing partnerships with firms, (7) TTOs that are managed by individuals with negotiation experience and know-how will be more successful at consummating technology transfer deals with firms, (8) a high degree of university inflexibility will result in fewer technology transfer agreements with firms/entrepreneurs, (9) when university inflexibility is high, university scientists will circumvent formal UITT processes and rely on informal commercialization and knowledge transfer, and (10) universities that become involved in formal and informal UITT will experience an increase in basic research activity. Figure 6b shows the relationships established in these propositions.

In a few words, administrators that wish to foster commercialization need to be mindful of some kind of organizational and managerial factors: (1) reward systems, (2) staffing practices, (3) flexible university polices in relation to technology transfer, (4) devoting additional resources to UITT, and (5) elimination of some cultural and informational barriers that impede the process of UITT.

3.2.3.5. The Critical Junctures Model (Vohora, Wright and Lockett 2004)

The critical junctures model is dynamic in nature. It assumes that entrepreneurial new challenges derived from the nature of the process of technology transfer. It is assumed that university–originated companies emerge from an initial idea in a non-commercial environment, aiming to become established competitive rent-generating firms. It is also assumed that there is a kind of conflicting objectives between key stakeholders (universities, academic entrepreneurs, the management team, and other suppliers of finance).

This model is rooted in the resource-based view tradition. In this sense, university companies need to develop both resources and internal capabilities over time to progress through different phases of development. This approach recognizes the role played by some kind of feedbacks and potential non-linear developments in the process of spin-off creation (Eisenhardt 1998; Van de Ven et al. 1984; Vohora et al.

2004). Additionally, it considers the fact that a sort of resource deficiencies, weaknesses and inadequacies may constrain the development of any university–originated firm (Vohora et al. 2004; West and DeCastro 2001).

Accordingly, these authors analyzed empirical data that have supported three main features: (1) university-originated firms develop in a non-linear fashion over five distinct phases, (2) spinouts encounter some "critical junctures" that must be overcome in order to make the transition from one phase of development to the next, and (3) spinouts analyzed in that study are characterized to be highly heterogeneous in terms of their resources, capabilities and social capital. These characteristics will determine in fact the speed when developing a spinout company.

The phases of growth is characterized by research phase, opportunity framing phase, pre-organization phase, re-orientation phase, and sustainable returns phase. At the *research phase*, valuable know-how, technological assets and IP are created which generate the potential opportunity for commercialization. The *opportunity framing phase* is mainly focused on academic and TTO relationships. It is seen as the transition between already recognized opportunities and other formative steps to create a new company. At this point, it is important to evaluate and screen the applicability of the technology outside the laboratory. Additionally, in this phase, there is a lack of commercial skills to exploit scientific discoveries in relation to creating commercial value from them. Framing and re-framing the opportunity becomes thus an interactive exercise for entrepreneurs. The third phase, *pre-organization phase*, is the time for implementing strategic plans and it represents the steepest learning curve for academic entrepreneurs. The new company gains sufficient credibility to access and acquire requisite resources to start-up the business. The *re-orientation phase* concerns entrepreneurial teams facing the challenges to identify, acquire, integrate, and re-configure resources. Finally, in the *sustainable returns phase*, the precise business model is defined, requiring a management team with solid commercial experience.

Besides, in this model, there are four critical junctures characterizing the dynamics of the technology transfer process: (1) opportunity recognition, (2) entrepreneurial commitment, (3) venture credibility, and (4) venture sustainability. Critical junctures occur because of the conflict between a university-generated new firm venture's existing level and type or resources, capabilities and social capital, and those required to perform in the subsequent phase of development. In fact, resources, capabilities, and social capital must evolve by re-configuration, replacement or development to eliminate impeding weaknesses, deficiencies and inadequacies. Furthermore, critical junctures arise due to three key characteristics: (1) scarcity of a particular physical, financial, human or technological resources, (2) insufficient level of social capital, and (3) inadequacies in the internal capabilities required by the venture to employ resources and knowledge productively to enhance its performance and value may exist.

In the *opportunity recognition critical junctures*, the academic team realizes on the connection existing between specific knowledge and commercial opportunities. The main concern is the need for recognizing commercial opportunities, as well as the ability to synthesize scientific knowledge with an understanding of markets. At the *entrepreneurial critical junctures*, it must be certain to have access to successful entrepreneurial role models for the academic entrepreneur. In the *critical juncture*, the problem arising is related to the entrepreneur's ability to gain access to and acquire an initial stock of resources (financial, physical, technological, and human resources). Finally, in the *sustainable returns juncture*, it has to be assured that sustainable returns may take the form of revenues from customers for services and products sold milestone payments from collaborative agreements, or investment from existing or new investors. At this juncture, the ability to continuously re-configure existing resources, capabilities and social capital with new information, knowledge and resources is required.

This model can be considered as an extension of the evolutionary growth path of new technology-based firms approach developed by Kazanjian (1988) and Kazanjian and Drain (1989). Under this approach, the role played by social capital, resources, and internal capabilities is fundamental to support new university-originated firms. As these companies are by definition resource limited, the task of the entrepreneurial team is to identify, acquire and integrate resources to create strategic assets and internal capabilities, allowing these companies to generate sufficient revenues and compete effectively.

3.3. System Dynamics Principles

This section presents system dynamics principles through the review of key references on innovation activity in relation to system dynamics methods. This section contains some references on innovation activity from the perspective of system dynamics methods. Finally, it establishes some preliminary conclusions.

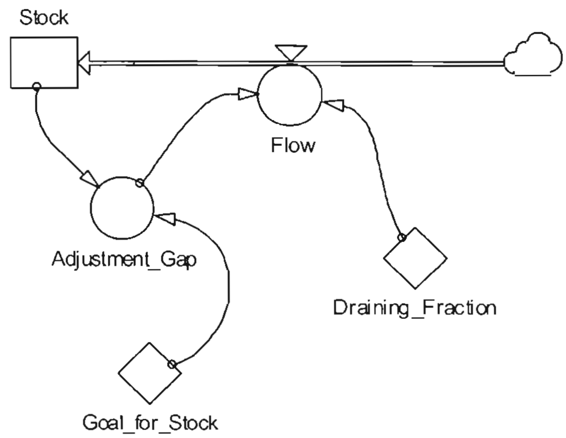
Statistical and inferential methods are at the core of analyses related to testing in social science. Modeling and simulation are important methods to acquire knowledge in economics and management. However, modeling techniques have evolved as they have had to address problems that relate to change over time (Cloutier and Rowley 2000).

Cloutier and Rowley (2000) point out that in management and economics, the process of development in modeling and simulation techniques in economics and managements span over three successive periods. In the first period, modeling business cycles was the main task of academic researchers. The modeling construction process in this period attempted to incorporate problems related to causal linkage determination between variables. In the second period, nonlinear models were widely used by academic researchers, as they started to be interested on the dynamic properties of economic systems. Finally, in the third period, there was an extensive use of computer hardware and software for simulation purposes. The initial developments by Forrester of SD principles correspond to this period.

Although there were great effort made to model and simulate in economics and management in the last years, Forrester (1975) has suggested that many empirical models have failed to answer fundamental questions about the behavior that arises from social, economic and environmental interactions. This perspective emphasizes the importance of complexity as a feature characteristic of modern organizations. Moreover, complexity means for the organization a set of feedback interactions and side effects, making traditional experimental methods in social science less flexible.

Through this approach, it is possible to know and characterize the underlying structure of an organization. Indeed, this approach allows for the use of both quantitative data and qualitative relationships between variables. In doing so, SD models take into account a broader range of information sources and mental models of decision-makers to achieve knowledge about changing systems (Forrester, 1975, 1994). Figure 7 taken from Albin and Choudhari (1996) shows the generic structure of a negative feedback loop.

Figure 7 Generic Structure of a Negative Feedback I



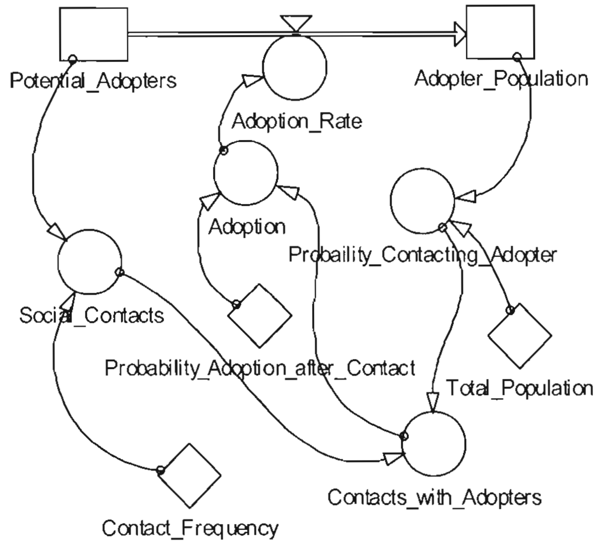
More formally, a feedback loop is a closed sequence of causes and effects, or a closed path of action and information (Richardson and Pugh 1981). However, there are two kinds of feedback loops: positive (reinforcing) feedback loop and negative (balancing) feedback loop. Following Kirkwood (1998), a positive (reinforcing) feedback loop can be explained as a reinforcing change with even more change. This can lead to rapid growth at an ever-increasing rate. Sometimes reinforcing feedback loops are called vicious or virtuous cycles, depending on the nature of the change that is occurring. Examples of reinforcing loops include pollution and population growth.

On the other hand, Kirkwood (1998) points out that a negative (balancing) feedback loop seeks a goal. This author suggests that if the current level of the variable of interest is above the goal, then the loop structure pushes its value down, while if the current level is below the goal, the loop structure pushes its value up. It is important to stress that a balancing feedback loop with a substantial time delay can lead to an oscillation behavior. However, when reinforcing and balancing loops are combined, a variety of patterns are possible. An example of this combination is the s-shaped pattern because the reinforcing feedback loop leads to initial exponential growth, and then when the balancing feedback loop takes over it leads to goal seeking behavior.

Complexity is a feature characteristic in business systems, and it has become an important challenge for researchers, requiring more adequate tools for both theoretical and empirical inquiry. In this context, SD is a response to the demands imposed by the complex nature of these phenomena. Forrester (1975), Ford (1999) and Sterman (2000) suggest that SD is a way to inquire about complexity and complex systems. These authors mention that one of the most important contributions is the analysis and explanation of behavioral patterns in the organization that must be firmly linked to its structure. Figure 8 from Sterman (2001) shows the complexity and the behavioral pattern characterizing a product innovation and diffusion process. This example shows how the product innovation and diffusion process is a complex process by non linear behavioral patterns.

In the same manner, Sterman (2000) suggests that systems and organizations have become increasingly subject to accelerated change and uncertainty. Structure, complexity and uncertainty are concepts strongly related in SD. Structural change and uncertainty are the most important sources of complexity in firm behavior. In the SD approach, systems are treated as dynamic and complex entities. Complexity means that systems are constantly evolving and in disequilibrium. Addition to these principles, Forrester (1975) and Sterman (2000) emphasize that complexity arises because systems are dynamic, tightly coupled, governed by feedback, nonlinear, history-dependent, self-organizing, adaptive, counterintuitive, policy resistant, and characterized by trade-offs.

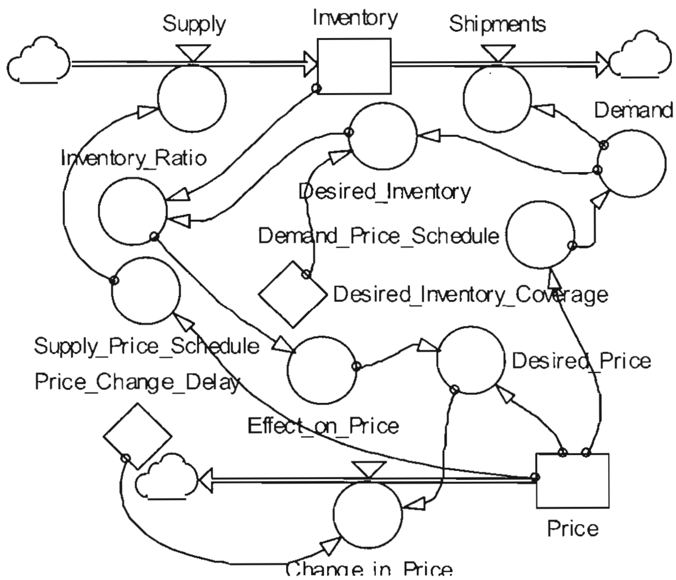
Figure 8 Product Innovation-Diffusion



Sterman (2000) defines these terms in the following manner. *Dynamics* refers to any process of change and it arises from feedbacks. *Tightly coupled* means that, in any system, there are actors interacting strongly with one another and with the natural world. *Feedback* is the process by which actors feedback on themselves. *Nonlinearity* means that effects are not proportional to cause and arise when multiple factors interact in a decision-making process. *History-dependent* is equivalent to the path-dependency concept, meaning that actions already taken are irreversible. *Self-organizing* means that the dynamics of a system arise spontaneously from their internal structure. *Adaptiveness* concerns the changing process of capabilities and decision rules of the agents in complex systems. *Counterintuitive* concerns to the process by which decision-makers commonly confuse symptoms and cause (as a result that cause and effect are distant in time and space). *Policy resistant* comes from the resistance displayed to understand complex systems. *Trade-offs* is strongly related to the concept of counterintuitive, meaning that there is a kind of time delay in feedback channels between long-term and short-term responses.

SD models comprise four elements: (1) feedback loops, (2) stock and flow structure, (3) time delays, and (4) nonlinearities (Forrester 1975; Sterman 2000; Wolstenholme et al. 1993). From this perspective, economic and managerial systems are complex multi-loops and interconnected systems, reinforced by feedbacks loops and reveal the actual organization of any structure (Forrester 1994). In strategy, this means that symptoms, actions and solutions are not isolated linear cause-to-effect stepping processes. Instead, SD considers management and economic systems as circular and interlocked structures (Forrester 1994). The demand and supply model developed by Whelan and Msefer (1996) is a representative example of how these principles operate within a system.

Figure 9 Whelan-Msefer's Demand-Supply Model



This model equates supply with demand through an adjustment mechanism, different from that proposed by traditional economic theory, although basic neoclassical principles of supply and demand are simultaneously incorporated. In this model, inventory is a core variable for achieving a solution. Whether inventory is less than the desired level, the firm indirectly raises the supply level and the price in order to increase the desired rate of production. This study demonstrates though that the availability of a product is the most important variable affecting and regulating market prices and demand. In the Whelan-Msefer demand and supply model, feedbacks, stocks and flows, time delays and nonlinearities model and analyze the market in terms of its demand and supply forces. Figure 9 shows these relationships.

Sterman (2000) stresses the importance of feedback loops in the SD modeling process. The main difference between SD and other modeling techniques does not concern the cause to effect relationships established between variables, this principle is actually "accepted" by all approaches. Instead, SD assumes that cause and effect relationships are generally distant in time and space, and thus policy resistance arises because economic agents are not sensitive to the full range of feedbacks operating in the whole system (bounded rationality).

Roberts (1978) emphasizes the philosophy underlying SD models and suggests that behavioral patterns in a organization are principally caused by the organization structure itself (physical aspects of the plant and production process, policies and traditions that dominate the decision-making process in the organization), and by the fact that an organization should be understood in terms of their common underlying flows instead of separate functions. Wolstenholme et al. (1993) and Sterman (2000) suggest that the structural framework of an organization is characterized to contain sources of amplification, time delays, information feedbacks, and flow diagrams and equations representing modeled relationships. Feedbacks loops can be reinforcing (self-reinforcing) or balancing (self-correcting), and the interaction of both kinds of feedbacks determine jointly the dynamics of the system. Any learning process is actually a feedback process that includes all forms of information, both quantitative and qualitative, to determine the dynamics of the system (Sterman 2000).

The behavior of the system is calculated using a set of first-order linear difference equations. Other important definitions in SD are levels and rates. Technically, the structure of a system in SD is an interconnected set of levels and rates variables (Sterman 2000). Indeed, SD emphasizes the fact that fundamental processes in managed systems convert resources between states using these kinds of relationships. Wolstenholme et al. (1993) define levels as measurable quantities of any resource in a system at any time. Rates represent the speed at which these resources are converted between states. Rates can only depend on levels since these measurable variables of the system, along with parameters. Rates are usually referred as policy, strategy or decision variables.

The innovation process shown in Figure 8 is a good example of how SD methodological principles operate in the analysis of a system. An innovation process is unpredictable and constantly reshapes the market structure. An innovation process depends on many variables, influencing each other at the same time. An innovation process is characterized to be highly complex and uncertain, and thus the key way organizations are able to manage complexity and uncertainty is through knowledge. From this perspective, SD is useful to analyze technological change and innovation.

The problem of traditional frameworks of technology transferring and innovation is the implicit assumption of a linear innovation model (Cooper et al. 2006). In fact, measurements of innovation activities within spin-off firms are inherently based on linear models of innovation and hence a quantitative and qualitative study of the patterns of university-industry interactions may be more recommendable. Cooper et al. (2006) provide an analysis on this kind of limitations suggesting that there are three key features characterizing statistical data indices on UITT activities:

1. They are constructed under a linear approach and do not measure several important paths of knowledge flow;
2. They are aggregated and do not reflect the idiosyncratic, context, path dependent nature and unique of the innovation process (firms are heterogeneous and the treatment and measurement of data is homogenous);
3. The goals and incentives are skewed or misinterpreted.

Even if the empirical analysis of technology transfer and spin-off creation must face the same limitations pointed out before, SD methods are adequate tools to deal with this sort of limitations. The use of quantitative and qualitative information and the possibility to model feedbacks and time delays are important features characterizing the modeling process. However, it is pertinent to raise the question about the implications of aggregated and homogenous proxies on activities that are inherently heterogeneous (Cooper et al. 2006). Moreover, there are factors influencing technology transfer processes that are not always easily modeled.

3.4. Conclusion

This chapter presented the main literature on the process of UITT and spin-off creation. A discussion on the taxonomy of university spin-offs was also presented. An important conclusion drawn from this discussion was that spin-offs were definitely the prototype organization in formal UITT. In this sense, university spin-off companies were defined in terms of the nature of the knowledge to transfer and the status of the individuals involved in this process. However, it was established that a university spin-off should be defined as a novel organization that simultaneously fulfills three conditions: (1) it takes place within a parent organization, (2) it involves individuals from the parent organization, and (3) individuals involved eventually leave the parent organization to create a new firm. The university spin-offs surveyed in the AUTM Canadian Licensing Survey precisely matches with this definition.

Three theoretical approaches on UITT were analyzed: (1) the resource-based view of the firm, (2) the business model perspective, and (3) the institutional perspective. However, each of these approaches gave superior importance to different features of this process. The resource-based view, for example, stressed the importance of organizational resources and capabilities (technological, social, human, and financial) in developing a firm's ability to achieve new and innovative forms of competitive advantage. It was stressed the importance of spin-off founders' unique awareness of opportunities and the ability to acquire resources needed to commercially exploit the opportunity of new technology. The business model perspective emphasized three concepts when analyzing the process of UITT: activities taken by the firm (the importance of distinguishing between consultants, product oriented, and technology asset oriented when analyzing university spin-off companies), how technologies or knowledge can be transformed into commercial value (infrastructure or platform, product companies, companies moving form product to platform, and prospector companies), and a distinction between new technology-based firms and resource-based spin-offs. Finally, the institutional perspective recognized the importance of exploiting IP (license agreements or patent transfer) as formal mechanisms for transferring technology from universities to industry.

In relation to spin-off creation, five models were analyzed: (1) the evolutionary model, (2) the entrepreneurial opportunity and capacity model, (3) the stage model of academic spin-off creation, (4) the technology transfer office model, and (5) the critical junctures model. An important conclusion in this chapter is that these models should be seen as complementary since they identify four main phases in the process of spin-off creation: business ideas generation, finalization of new venture projects out of ideas, launching new spin-off firms from projects, and strengthening the creation of economic value by spin-off firms. However, each model emphasizes one aspect of this process. The evolutionary model, for example, stressed the idea that economic, social, and political issues affect the ability of universities to both create and deploy new knowledge in economically useful ways, developing new high-opportunity platforms and raising the economic returns of publicly funded research by stimulating UITT. From this perspective, it was argued that universities' relationships with industry were formed through a series of sequential transactions (sponsored research, licenses, spin-off companies, and students hiring).

The entrepreneurial opportunity and capacity model and the stage model of academic spin-off creation analyzed the interactions established between institutions, organizational culture, and the external business environment in research commercialization activities, searching to open the black box of academic spin-off creation. However, the stage model of academic spin-off creation explained in detail the stages through which spin-off creation takes place. It is important to mention at this point that from the perspective of the stage model of academic spin-off creation it was difficult to determine how research results generate successful business ideas and thus successful spin-off companies. However, the technological transfer office model and the critical junctures model contributed to get insight on these issues.

The technological transfer office model emphasized the role played by TTOs in the process of UITT, identifying key organizational issues that promote successful knowledge transfer practices (IP management and licensing patents). However, the importance of some cultural and informational barriers when transferring knowledge given that stakeholders in this process have different motives and behaviors, and thus they operate within different environments was mentioned. In this sense, this model stresses the idea that the reward system, staffing practices, the university technology transfer policy, resources devoted to UITT would affect the process of spin-off creation. Finally, it was established that the critical junctures model was dynamic in nature. It assumed that university spin-off companies emerge from a non-commercial environment, needing to develop resources and internal capabilities over time to get progress through different phases of development. This approach recognized the role played by some kind of feedback and potential non-linear developments in the process of spin-off creation. The critical junctures model suggested five phases through which spin-offs develop: research phase, opportunity framing phase, pre-organization phase, re-organization phase, and sustainable returns phase. The critical junctures were: opportunity recognition, entrepreneurial commitment, venture credibility, and venture sustainability.

The SD approach allows for the integration of the main features of these models as a complex system. In this sense, complexity must be understood as a feedback process that allows for the possible identification of structural effects. Complexity implies an evolving and disequilibrium system characterized by accelerated changes and uncertainty. Furthermore, the UITT and spin-off creation models revised in this chapter offer adequate frameworks to address the problems raised in this thesis with respect to spin-offs creation and development: uncertainty, informational gaps, conflicts-of-interests, and lack of receptor capabilities. It is also important to count on a dynamic approach, such as that offered by SD methods, to analyze the features characterizing these processes (side effects, feedback interactions, reinforcing and balancing feedbacks, and non-linear developments). SD methods can assist in explaining the structure and rules of interaction of the system in the process of measuring the evolution of key indicators.

IV. Research Methods

This chapter elaborates on the research methods for conducting this research. The objective is to analyze the conditions for the creation of university spin-offs in Canada. This chapter focuses on the contextual features framing the process of technology transfer from university to industry and the analysis of spin-off creation in Canada using the system dynamics (SD) methods. The chapter is organized into four sections. Section 4.1 presents the steps to be followed to develop this study from the perspective of the SD methods. Section 4.2 presents the dynamic hypothesis on university-industry technology transfer (UITT) and spin-off creation phenomena analyzed in this research. Section 4.3 discusses the information and data requirements needed to feed the model, as well as to evaluate alternative scenarios and policies. Finally, Section 4.4 deals with model evaluation issues.

4.1. Research Steps

Once the qualitative feedbacks loops, structural stock and flow model, time delays, and nonlinearities are defined and specified, the simulation process becomes the most important task in the study of any hypothesis using SD principles. Indeed, the simulation process is at the core of the analysis in SD. The process for constructing a SD model is specific to this research method (Wolstenholme et al. 1993; Forrester 1994; Sterman 2000). It is important to keep in mind that the simulation process reveals the underlying relationships in the system. Formally speaking, Cloutier (2002) defines an influence diagram as a specific use of language, representing qualitatively the causes and effects of the structure of a system. The influence diagram provides the information concerning reinforcing and balancing feedback loops of the system under consideration to capture its structure.

Forrester (1994) and Sterman (2000) stress that the simulation of a model is the ultimate objective of the SD method. This principle is one way to conduct experimentation in SD. In fact, these authors have also suggested some reasons to believe that simulation and experimentation are key to SD. These reasons are: (1) dynamic complexity, (2) limited information, (3) ambiguity on variables, (4) limited rationality and unexpected consequences from actions taken, (5) unreliable inferences related to the dynamic of the systems, (6) judgment errors, (7) interpersonal obstacles to learning, and (8) failure taking adequate decisions.

Indeed, simulation gives the possibility to evaluate change and its consequences in the evolution of a system over time. Moreover, simulation improves the ability to understand the results derived from actions or a decision-making process. Forrester (1994) emphasizes that SD simulation is an adequate environment to prototype alternative possibilities in organizations. Lyneis (1999) expresses the same idea suggesting that SD models can play an important role to understand problems, to determine the consequences of alternative courses of action and to test alternative solutions under alternative scenarios.

A feature of the SD method is the relationship between mental models of decision-makers and the structure of a system. If the mental model changes, the structure of the system can be modified, and there exists the possibility to create different decision rules, and thus alternative strategies. New decisions rules and emerging strategies generate other changes in the mental model of decision-makers (Cloutier 2002). This discussion relates to the problem of bounded rationality in economics and management (Simon 1982). To learn in a world of dynamic complexity, and imperfect information, decision-makers must develop some kind of insight skills. This idea relates to the possibility to learn and acquire capabilities to improve organizational performance. In a few words, the features stated below suggest that SD modeling is an iterative or feedback process, not a linear sequence of research steps (Sterman 2000).

Sterman (2000) suggests to follow five steps in the SD modeling process: (1) the problem definition and articulation (including selection, problem definition, key variables and time horizon), (2) the formulation of dynamic hypotheses, generating initial hypotheses, endogenous focus and mapping, (3) formulation of a simulation model, containing specification, estimation and tests, (4) testing process, containing comparison to reference models, robustness under extreme conditions and sensitivity, and (5) policy design and evaluation, including scenario specification, policy design, sensitivity analysis and interaction of policies.

In this process, Sterman (2000) has suggested, modeling with the SD principles should be understood as an ongoing process of continual cycling between the virtual world of the model and the real world of action. The *problem definition and articulation* is, however, the most important step of the modeling process. The initial characterization of the problem should be developed mainly through data collection, interviews, and direct observation. In this step, it is important to keep in mind that the choice of the time horizon for the simulation results can dramatically influence the definition of the problem, as well as the evaluation of policies.

The second step suggested by Sterman (2000) in the SD modeling process is the formulation a *dynamic hypothesis*. This author points out that once the problem has been identified over an appropriate time horizon, a theory, called a "dynamic hypothesis", must be developed. The point to be stressed here is that the theory implies a "dynamic hypothesis" because it is a provisional explanation of the dynamics characterizing the problem in terms of the underlying feedback and stock and flow structure of the system. Moreover, the goal in this step is to develop an endogenous explanation for the problem dynamics. In fact, an endogenous explanation generates the dynamics of a system through the interaction of the variables and agents represented in the model (structure and decision rules in the system). However, SD accounts on a variety of methods to determine the boundary of a model and to represent its causal structure: model boundary diagrams, subsystem diagrams, causal loop diagrams, and stock and flow maps. Within the context of this research the dynamic hypothesis of the UITT system is presented and detailed in the next section.

The third step concerns the formulation of a *simulation model*. This step leads to model design once it is developed from an initial dynamic hypothesis, model boundary, and conceptual model. This step implies moving from the conceptual realm of influence diagrams to a fully specified formal model, complete with equations, parameters, and initial conditions. Within this research, this step consists in integrating data provided by the *AUTM Canadian Licensing Survey 2004* and *AUTM Canadian Salary Survey 2004*, as well as some other sources (section 4.3), into a formal stock-and-flow quantitative model. This step is carried out within the contextual framework of university new knowledge commercialization practices in Canada. However, at this point, it becomes the task to distinguish between stock-and-flow variables for the definition of adequate equations and parameters (Sterman 2000). Once these problems are overcome, the task is to execute the model to obtain a simulated behavior of the spin-off emergence and development practice.

Testing is the fourth step of the SD modeling process. According to Sterman (2000), one of the main objectives of testing is to compare the simulated behavior of the model to the actual behavior of the system. Testing implies the reasonable replication of historical behavior, to adequate variables to a meaningful concept in the real world, equations to be checked for dimensional consistency, and to assess adequately the sensitivity of model behavior and policy recommendations (parametric and structural) in light of the uncertainty in assumptions. In this sense, this step consists in comparing the results achieved from the simulation model to data obtained from the *AUTM Licensing Survey 2004* (section 5.2) or any other sources of information (section 4.3) to assess the robustness of the model. This means that the model should behave in a realistic fashion no matter how extreme the inputs (extreme values on the data set) or policies imposed (research questions) may be (Sterman 2000).

The final step in SD modeling is *policy design and evaluation*. Policy design and evaluation allow for the creation of entirely new strategies, structures, and decisions rules. Moreover, policy design and evaluation may involve changing the dominant feedback loops by redesigning the stock and flow structure, eliminating time delays, changing the flow and quality of information available at key decision points, and reinventing the decision processes of the actors in the system. At this step, policy design and evaluation must be tested in terms of robustness and sensitivity to uncertainties given the possibility of alternative scenarios or interactions of different policies. In this research, this step will consist in asking a series of questions that relate to spin-off creation and development to gain insight on the research questions established in this research.

4.2. Dynamic Hypothesis

The steps to establish a research plan using SD methods (Sterman 2000) are as follows: problem articulation, formulation of dynamic hypothesis, formulation of a simulation model, testing, and policy design and evaluation. This section contains the dynamic hypothesis to be studied in this research. This step is developed for establishing the initial hypothesis using an endogenous focus and developing the casual structure (key variables, reference modes, available data, causal loop diagrams, stock and flow model, policy structure diagrams, etc.), keeping in mind that the goal of this step is to develop an endogenous explanation for a specific problem dynamic.

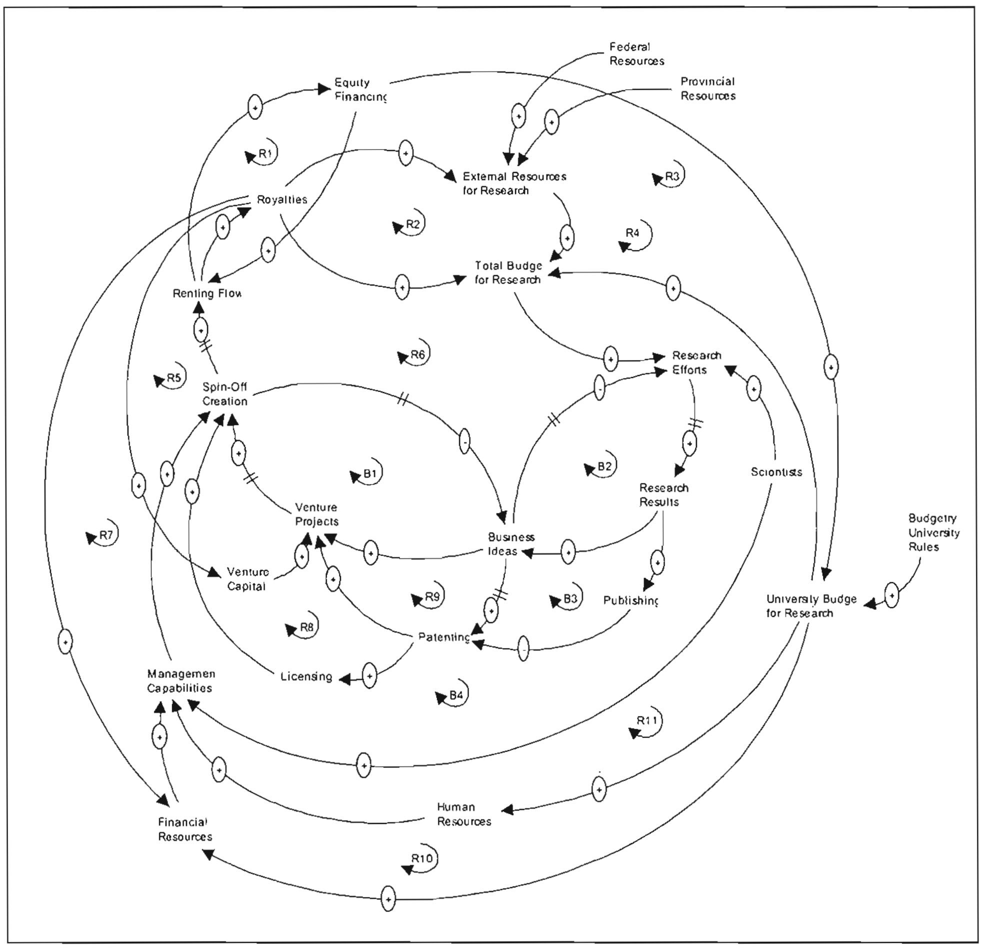
A *dynamic hypothesis* (working theory) provides a preliminary explanation of the dynamics characterizing a specific problem in terms of its underlying feedback structure. The point is to make clear the importance of exploring the patterns of behavior created by the structure and rules that characterize the proposed SD model, as well as to explore how the behavior might change when altering the structure and rules of the model (Sterman 2000). In so doing, it sets up the model boundary chart, subsystem diagrams, and the stock and flow, and influence diagram.

Table 12. **Spin-Off Variables**

Endogenous	Exogenous
- Number of patents - Number of spin-off - Number of licenses - Royalties - External resources for research - Total budget for research - Renting flow - Number of years TTO is involved in transferring technology - Faculty number in RD activities (scientists) - Joint venture capital availability - Rcscarch efforts - Research results - Business ideas - Financial resources - Human resources (technology management)	- Federal resources - Provincial resources - Budgetary university rules

Model Boundary Chart. The objective of the model boundary chart is to determine which variables in the model are endogenous, exogenous or excluded. However, feedback structures in SD models allow treating core variables as endogenous, giving them an actual dynamic attribute. In contrast, exogenous variables must be characterized to have small or negligible feedbacks but are considered to influence the behavior of the endogenous structure. Table 12 summarizes this information in relation to the endogenous structure characterizing the process of spin-off creation in Canada. The dynamic hypothesis in figure 10 is characterized by fifteen reinforcing/balancing feedback loops: eleven positive (reinforcing) and four negative (balancing) feedback loops. The loop R1 implies a positive relationship between equity financing and renting flow. This loop reflects the fact that when universities actively participate in spin-off creation by means of equity financing, renting flow will considerably increase.

Figure 10. **Spin-Off Development Process, Dynamic Hypothesis**



The loop R2 means that external stakeholder participants (federal government, provincial government and joint venture participants) are more willing to invest in spin-offs creation when there is an important flow of royalties. Hence, R2 implies a positive feedback loop into the total budget for research, affecting it directly (quantity of available resources) and indirectly (structure of available resources). The loop R3 implies a positive relationship between equity financing, university budget for research, financial resources, management capabilities, spin-off creation, and renting flow. R3 means that when universities actively participate in spin-off creation by means of equity financing, there will be more incentives to develop management capabilities through investing financial resources. Similarly, the loop R4 implies a positive relationship between equity financing, university budget for research, human resources, management capabilities, spin-off creation, and renting flow. As in R3, the loop R4 means that when universities actively participate in spin-off creation by means of equity financing, there will be more incentives to develop management capabilities through investing financial resources.

Similarly to the loop R2, the loop R5 implies a positive relationship between royalties, renting flow, venture capital, venture capital projects and spin-off creation. The reinforcing effect amongst these variables is quite evident, but it models one of the most important features characterizing risky investment decisions: uncertainty and time delays. When there is a positive and important renting flow (royalties), venture capital stakeholders are more willing to invest in new venture projects or to increase the quantity of resources to be invested in already successful spin-offs.

The point is that, after some time delays, the bigger the quantity of royalties drawn by established spin-offs, the bigger the availability of the quantity of venture capital, and thus the greater number of venture projects and potentially new spin-offs creation. This loop intends to model the financial side contained into the process of spin-off creation and development. The time delays observed in this loop means that it takes time to make decisions on investment, and thus investment decisions are taken only after the risks associated to this variable are evaluated.

However, in the process of spin-offs creation, the technological and knowledge transfer is essentially the ultimate goal of the process. Keeping in mind the features characterizing loops R2 and R5, it is possible to determine a new loop, R6. The link between R2 and R5 can be established through two variables also present into loop R6: royalties and total budget for research. This characteristic results from the fact that the process of UITT and spin-off creation has two aspects: the technical side and the financial side. R6 means that the bigger the total budget for research, the bigger research efforts, and hence a major quantity of research results, business ideas and venture projects. However, there is some time delay between a research effort and a research results due to the time it takes to complete a research. However, there is no guarantee that spin-offs creation will succeed commercially after obtaining research results. In fact, many projects must be re-evaluated to obtain a viable company. The re-evaluation of a project could be set up at two different levels, determining two additional negative (balancing) loops: (1) from spin-off creation to definition of the business ideas, B1, or (2) from definition of the business ideas to research efforts, B2. These two negative (balancing) loops involve time delays due to the process use to re-evaluate venture projects and research results, respectively.

In turn, research efforts are increased by the number of scientists that also determines management capabilities. Management capabilities are influenced by scientists, human resources, and financial resources. Thus, management capabilities, spin-off creation, renting flow, royalties and financial resources determine a positive (reinforcing) loop, R7, characterized to have a delay due to the time it takes to create a new firm and obtain rents from it.

There are two other positive (reinforcing) loops in this model related to patent activities in universities when technology is transferred to industry. When business ideas are patented, venture projects are likely to be successful, R9, and when patents are granted, licensing influence positively spin-off creation, R8. However, these loops are also characterized by two time delays to account for the time it takes from the time a patent application is filed to the time the patent is granted, and the time a venture project is initiated, and the spin-off is effectively created. In line with this, when research results are published, there is no incentive to patent and thus no incentive to generate business ideas nor to create spin-offs, determining a negative (balancing) loop, B3, and when research results are not patented (published), there is no possibility for licensing, B4.

Finally, management capabilities are influenced directly through the management of human resources and financial resources, that along with university budget research, determine a positive (reinforcing) loop, R10, and along with scientific human resources (scientists) determine a positive (reinforcing) loop, R11.

4.3. Information and Data Requirements

In this research, the main source of statistical data on university commercialization activities is the surveys conducted by the Association of University Technology Managers (AUTM). This organization has surveyed major Canadian universities and hospitals since 1991. The AUTM Canadian Licensing Survey has collected information from 18 universities and hospitals in 1991 and from around 39 institutions in 2006. There are two main surveys developed by the AUTM: the *AUTM Licensing Survey2004* and the *AUTM Salary Survey 2004*. Both sources of data from these surveys are used in this research.

The *AUTM Licensing Survey* is mainly focused on research expenditure (federal and industrial sources), licenses, license incomes, invention disclosures, patent applications filed, and patents issued. The *AUTM Salary Survey* is focused on the number of staff members managing technology transfer at TTOs at different levels (director, assistant/associate director, licensing associate, licensing assistant, marketing manager, business manager, patent manager, administrative assistant, director of startups/spin-offs, and in-house counsel) and salaries. However, Statistics Canada produces statistics on technology transfer activities and spin-off creation in Canada through the Survey of Intellectual Property Commercialization in the Higher Education Sector. In the same way, the Association of Universities and Colleges of Canada (AUCC) and several universities have also produced statistics and studies on the economic impact of technology transfer using extensive interviews with university faculty members and staff (Chrisman 1994; Livingstone 1997; Unrau and McDonald 1995).

Table 13. **Expenditures on Intellectual Property Management**

	Employees Dedicated to IP Management (FTEs)	**Salaries (FTEs)**	**Patent Application Expenditure**	**Legal Costs**	**Other Operational Expenditures**	**Total Operational Expenditures for IP Management (CAN$ 000)**
Hospitals	8.5	549	-.-	-.-	106	989
Universities	169.1	10,008	5,679	1,499	3,843	21,029
Total	177.6	10,557	-.-	-.-	3,949	22,018

Source: Survey of Intellectual Property Commercialization in the Higher Education Sector 1999, p. 6.

Tables 13 and 14 report statistical information from the AUTM Canadian Licensing Survey and the AUTM Canadian Salary Survey, respectively. The Association of Universities and Colleges of Canada (AUCC) has facilitated discussions with university representatives resulting in further recommendations for being discussed with intellectual property managers in major universities (Industry Canada 1999c).

Table 14. **AUTM Canadian Licensing Activity Survey: 1991-2002**

Year	Total Research Expenditure (CAN$ 000)	Invention Disclosure	New Patent Application	Licenses Executed	Licenses Option Executed	Active Licenses	Startups (Spin-Offs)
1991	580,826	250	59	49			
1992	590,526	284	80	54			
1993	886,291	393	65	177			
1994	934,419	445	98	141			241
1995	1,294,253	578	157	172	28	44	223
1996	1,166,175	509	137	206	25	727	248
1997	1,449,327	690	190	227	35	837	333
1998	1,568,989	797	203	246	43	950	364
1999	1,667,643	714	205	225	44	979	344
2000	2,065,077	951	237	313	48	1,344	454
2001	2,784,625	933	415	333	40	1,442	68
2002	3,169,890	1,173	421	362	32	1,712	49
2003	3,561,468	1,282	425	448			58
2004	4,067,957	1,307	572	544			45

Source: AUTM Canadian Licensing Survey (various).

The AUTM data is the main input for the model developed in this research. However, this model has been developed in terms of three stakeholders (TTOs, CCs and Sin-Offs), and two axes for each stakeholder (technical axis and financial axis) (Section 5.3). Table 15 shows statistical data on employees dedicated to IP management, salaries, patent application expenditure, legal costs, and other operational expenditures.

Table 15. **TTOs, CCs and Spin-Offs Salary by Position in Canada, 2006**

Position	Mean	Median	Standard Deviation	Number
Director	98100	95725	26616	18
Assistant/Associate Director	85974	82482	15363	12
Licensing Associate	65738	64389	13902	37
Licensing Assistant	45892	48885	7401	13
Marketing Manager	na	na	na	1
Business Manager	60100	64389	11846	7
Patent Manager	69820	62672	32012	8
Administrative Assistant	37694	34341	12106	19
Director of Startups (Spin-Offs)	91406	103022	31927	3
In-House Counsel	74478	67177	19370	5

Source: AUTM Canadian Salary Survey 2006.

To reach these goals, the Government of Canada recognized the strategic role to be played by universities (AUCC 2002; Industry Canada 2002). However, the type of partnership and interactions between industry and universities depends on the contribution and motivation of both parties, allowing the academic party to participate in research projects as a stakeholder, a co-proprietor of a new company or as a recipient of license royalties (Hanel and St-Pierre 2006; Jensen and Thursby 2001).

Statistics Canada recommends a set of 50 indicators to measure the components of the commercialization process of new technologies (Industry Canada 1999c). These indicators and the framework from which they are derived (Creating Intellectual Property, Identifying Intellectual Property, Protecting and Managing Intellectual Property, Exploiting Intellectual Property, Faculty Intellectual Property Transfer, Company Support, and Intellectual Property Transfer Impacts) provide a basis for supporting subsequent works at Statistics Canada and for consulting with academic institutions. However, the Association of Universities and Colleges of Canada (AUCC) recommends additional indicators on technology transfer activities at Canadian universities. Table 14 presents data from Statistics Canada on expenditures on IP management in Canada in terms of employees dedicated to IP management, salaries, patent application expenditure, legal costs, and operational expenditures. Indicators for the commercialization of IP by the higher education sector such as licenses, patents, spin-offs and sources funding are available from various sources: the *Survey of Intellectual Property Commercialization in the Higher Education Sector, 2001* (Statistics Canada 2001), the *AUTM Licensing Survey, 2002* (www.autm.net), and the document *Research Means Business: A Directory of Companies Built on NSERC-Supported University Research* (The Natural Sciences and Engineering Research Council of Canada 2005), among others.

In addition, there are documents explaining how the framework within the commercialization process in Canada is carried out. Examples of this literature are: *Federal Investment in Research and Development and Capacity Building in the Higher Education Sector* (Library of Parliament 2006), *Framework of Agreed Principles on Federally Funded University Research between the Government of Canada and the Association of Universities and Colleges of Canada* (AUCC 2002), *In the Service of Canadians: A Framework for Federal Science and Technology* (Industry of Canada), *Momentum: The 2005 Report on University Research and Knowledge Transfer* (AUCC 2005), *Achieving Excellence: Investing in People, Knowledge and Opportunity. Canada's Innovation Strategy* (Industry Canada 2001), *University Research and the Commercialization of Intellectual Property in Canada* (Industry Canada 1999), and *OECD Science, Technology and Industry Outlook 2004: Country Response to Policy Questionnaire, Canada* (OECD 2004).

Table 16. **Variables from AUTM Licensing Survey**

Worksheet Column	Field Name	Description
A	INSTITUTION	Name of the institution
B	STATE	Institution's state available only on disk, not in published report
C	COUNTRY	Country in which institution is located
D	INSTTYPE	Institutions grouped by: 5U, 4HRI, 3CN, and 2PMF
E	MEDSCHL	Response to medical school question (yes or no)
F	PROGYEAR	Year in which the institution devoted 0.5 professional FTE to technology transfer
G	LICFTE	Licensing FTEs in technology transfer office
H	OTHFTE	Other FTEs in technology transfer
J	CIDEXP	Research expenditure: industrial sources (Canadian institutions, CAN$)
L	CFEDEX	Research expenditure federal government sources (Canadian institutions, CAN$)
N	CTOTEX	Total research expenditure (Canadian institutions, CAN$)
O	LCEXEC	Licenses/options executed
P	LCEXEQ	Licenses executed with equity
Q	ACTLIC	Cumulative active licenses
R	LCEXCL	Licenses executed on exclusive basis
S	LCNEX	Licenses executed on non-exclusive basis
T	LCEXSU	Licenses executed to start-up companies
U	LCEXSM	Licenses executed to small companies (excludes start-ups)
V	LCEXLG	Licenses executed to large companies
W	SUEXCL	Licenses/options to start-up companies: exclusive
X	SUNEX	Licenses/options to start-up companies: non-exclusive
Y	SMEXCL	Licenses/options to small companies: exclusive
Z	SMNEX	Licenses/options to small companies: non-exclusive
AA	LGEXCL	Licenses/options to large companies: exclusive
AB	LGN-EX	Licenses/options to large companies: non-exclusive
AD	CRESFD	Research funding related to licenses/options (Canadian institutions, CAN$)
AF	CLIREC	Licenses income received (Canadian institutions, $CAN)

AG	LCGNLI	Licenses/options generating license income
AI	CLIPDI	License income received that was paid to other institutions (Canadian institutions, CAN$)
AK	CLIRUN	Licenses income received: running royalties (Canadian institutions, CAN$)
AL	LCGNRR	Licenses/options generating running royalties
AN	CCAIEQ	License income received: cashed-in equity (Canadian institutions, CAN$)
AP	CLIOTH	License income received: other income (Canadian institutions, CAN$)
AQ	LC1M	Licenses/options generating more than $1M in licenses income received
AS	CEXLGF	Legal fees expended (Canadian institutions, CAN$)
AU	CRMLGF	Legal fees reimbursed (Canadian institutions, CAN$)
AV	INDIS	Invention disclosures received
AW	TPTAPP	Total patent applications filed
AX	NPTAPP	New patent application filed
AY	USPITS	U.S. patents issued
AZ	STRUP	Start-ups initiated
BA	STRTHS	Start-ups initiated operating in home states
BB	STRNOP	Start-ups that became non-operational
BC	STOPCM	Cumulative operational start-ups as of the end of FY 2002
BD	STUPEQ	Start-ups formed in which the institution holds equity
BE	LTAV	Number of licensed technologies that became available for consumer or commercial use in FY 2002

Source: AUTM Licensing Survey Diskette (FY 2002).

The research is using all the information, documents and data resources presented in this section. However, the most import source of data information to this research will be the *AUTM Licensing Survey*. In this research, data from the AUTM Canadian Licensing Survey is the main source of information. Table 16 contains a short description of the variables drawn by this survey. Data on university technology transfer from universities to industry, as well as the description of the variables contain in this survey are detail in table 16.

There are several theoretical approaches and models that explain UITT and spin-offs creation and development. The review of literature in Chapter 3 offered a summary on the main features and ideas characterizing these approaches and models. All these explanations contribute to understand the process of UITT and spin-off creation. However, some theoretical approaches may be more adequate in some cases than in others.

In the context of this research, once the model is simulated, changes in some parameters or the rules characterizing this model (for example, federal resources, provincial resources, or budgetary university rules) can be evaluated in terms of its consequence for UITT activities. However, these activities may include the number of new spin-off firms created, royalties yielded by these new firms, resources originated on licenses, venture capital participation into spin-off creation, number of patents, management capabilities, marketable university research results, and so forth.

4.4. Model Evaluation for Validation

In SD methods, the model evaluation problem concerns the fact that the simulation model is an approximation of the actual system, and therefore, producing a close enough approximation to the actual system (Martis 2006). Moreover, the conclusions derived from a valid model should be alike to the actual data collected in the real system. In this sense, Sterman (2000) suggests that validation and verification are impossible, and thus the emphasis should be more on model testing or the process to build an appropriate confidence model for a specific purpose. In this sense, some models may be better than others, and some models while not completely valid, possess a greater degree of authenticity than others (Martis 2006). However, the power of a model or modeling technique is a function of validity, credibility, and generality (Solberg 1992). This statement suggests that model validation is not an option but a necessary condition in a dynamic modeling scenario (Martis 2006).

Following Carson (1989), Kleindorfer et al. (1998) and Martis (2006), two important features must be stressed at this point. First, validation cannot be carried out by the researcher alone, and thus communication with users plays a large role in building a valid model and establishing its credibility. Second, how much the model output could deviate from system output and still remain valid. Martis (2006) points out that since the model created is an approximation of the actual system, some errors are and approximations are unavoidable. In this sense, Goldberg et al. (1990) suggest that model validation resides in decisions between the researcher and users in that when the both are satisfied, the model is considered valid. However, a wide range of tests to build confidence in a model have been developed by authors: Barlas (1989 and 1996), Forrester and Senge (1980), Khazanchi (1996), and Saysel et al. (2004).

The importance of validation of the model developed in this research relates to the process of establishing confidence in the usefulness of a model (Coyle 1977). In this sense, Martis (2006) points out that validation deals with the assessment of the comparison between sufficiently accurate computational results from the simulation and the actual/hypothetical data from the system. This author continues saying that validation does not specifically address how the simulation model can be changed to improve the agreement between the conceptual results and the actual data. Furthermore, the fundamental strategy of validation involves identification and quantification of the error and uncertainty in the conceptual/simulation models, quantification of the numerical error in the conceptual solution, estimation of the simulation uncertainty, and finally, comparison between the computational results and the actual data. Consequently, the strategy only asserts the simulation results as the most faithful reflections of reality for the purpose of validation (AIAA 1998).

Some reasons to which a model may fail the validation tests are the following (Carson 2002; Law 2003; Martis 2006):

1. Model structure might be inadequate for capturing complex dynamics;
2. Numerical solution might differ dramatically from the ideal solution;
3. Input values might be known only approximately;
4. Observation errors might be inaccurate observations of real system;
5. System noise might fail to recognize random changes existent in the system;
6. Project management errors revolve around project management and related communication issues;
7. Inappropriate simulation software;
8. Misinterpretation of simulation results.

Particularly, Forrester and Senge (1980) propose a validation scheme when modeling a system:

1. Identifying the importance of the model objective;
2. Validating the model structure;
3. Validating the model behavior;
4. Validating the policy implications.

These features will be used in the following chapters to identify and determine the appropriateness of the model developed in this research.

4.5. Conclusion

This chapter presented the major research steps in applying SD methods for developing a research model. SD modeling requires the following steps: problem definition, formulation of a dynamic hypothesis, a simulation model, testing process, and policy design and evaluation. The chapter contains the following sections: dynamic hypothesis, determination of information and data requirements and model validation. The chapter has highlighted the importance of the simulation process under the approach of SD methods given that it allows the evaluation of alternative solutions under different scenarios. The influence diagram, as a language for representing qualitatively the causes and effects of the structure of the UITT and spin-off creation process was also discussed.

In this research, the simulation model consists in integrating publicly available data by the AUTM Canadian Licensing Survey and AUTM Canadian Salary Survey into a formal stock-and-flow quantitative model. Testing the model consisted in comparing the results achieved from the simulation model to actual data obtained from the AUTM surveys. Policy design was tested in terms of robustness and sensitivity. To develop these tasks, key variables and indicators were selected. The objective was to integrate into a SD model the models of spin-off creation discussed previously within a general framework of UITT. It was emphasized that the SD approach implied an endogenous perspective of these phenomena.

The working theory (dynamic hypothesis) presented in this chapter allowed for revealing the structure of the UITT phenomenon at Canadian universities. The SD perspective is more complex given that the models presented in previous chapters were developed from the perspective of the traditional methods corresponding to a linear analysis. The dynamic hypothesis established in this research is characterized by fifteen reinforcing/balancing feedback loops: eleven positive (reinforcing) feedback loops and four negative (balancing) feedback loops. Aiming to develop a SD model on UITT and spin-off creation in Canada, key indicators were defined: spin-off creation, renting flow, venture projects, venture capital, royalties, equity financing, licensing, patenting, management capabilities, financial resources, human resources, business ideas, publishing, total budget for research, external resources for research, federal resources, province resources, research efforts, research results, scientists, university budget for research, and budgetary university rules. As it was already stated, the relationships established between these variables were established from the literature review as an endogenous provisional explanation of the dynamics characterizing this process, and constituting the basis of the model developed in this research. These indicators were defined in accordance to the recommendations of Statistics Canada and the Association of Universities and Colleges of Canada.

The main sources of information were data released from AUTM Canadian Licensing Survey and AUTM Canadian Salary Survey. This information was used both as input to feed the model, as well as calibration and validation purposes. Once the model is simulated, changes in some parameters and rules will be evaluated in terms of alternative policies and scenarios.

V. Model Design

This chapter presents the main features characterizing the model developed in this research on university-industry technology transfer (UITT) and spin-off creation in Canada. It contains three subsectors aiming to describe stakeholders' performance in this process: (1) technology transfer offices (TTOs)-universities, (2) commercializing companies (CCs), and (3) spin-offs-entrepreneurs. The discussion in this chapter searches to model stakeholders' actions, motives and perspectives. The chapter is organized into three sections. Section 5.1 presents a description the model in terms of three subsectors characterizing the process of spin-off creation: the university-TTO subsector, the commercializing company subsector, and the spin-off-entrepreneur subsector. For each subsector, the material stock-and-flow variables side and financial stock-and-flow variables side are specified. Section 5.2 discusses the procedure to calibrate the model. Finally, Section 5.3 discusses specific model indicators in the case of UITT and spin-off creation.

5.1. Model Description

The model is developed featuring participating stakeholders' behavior in the process of UITT: (1) University-TTOs, (2) CCs, and (3) Spin-Off-Entrepreneurs. Each actor is characterized to maintain two different kinds of relationships that are linked through material and monetary flows. However, the system dynamics (SD) approach allows a global perspective on how UITT stakeholders participate in the process of technology transfer, as well as how their decisions affect the outcomes resulting from this process.

Figure 11.**University-Industry Technology Transfer and Spin-Off Creation Model**

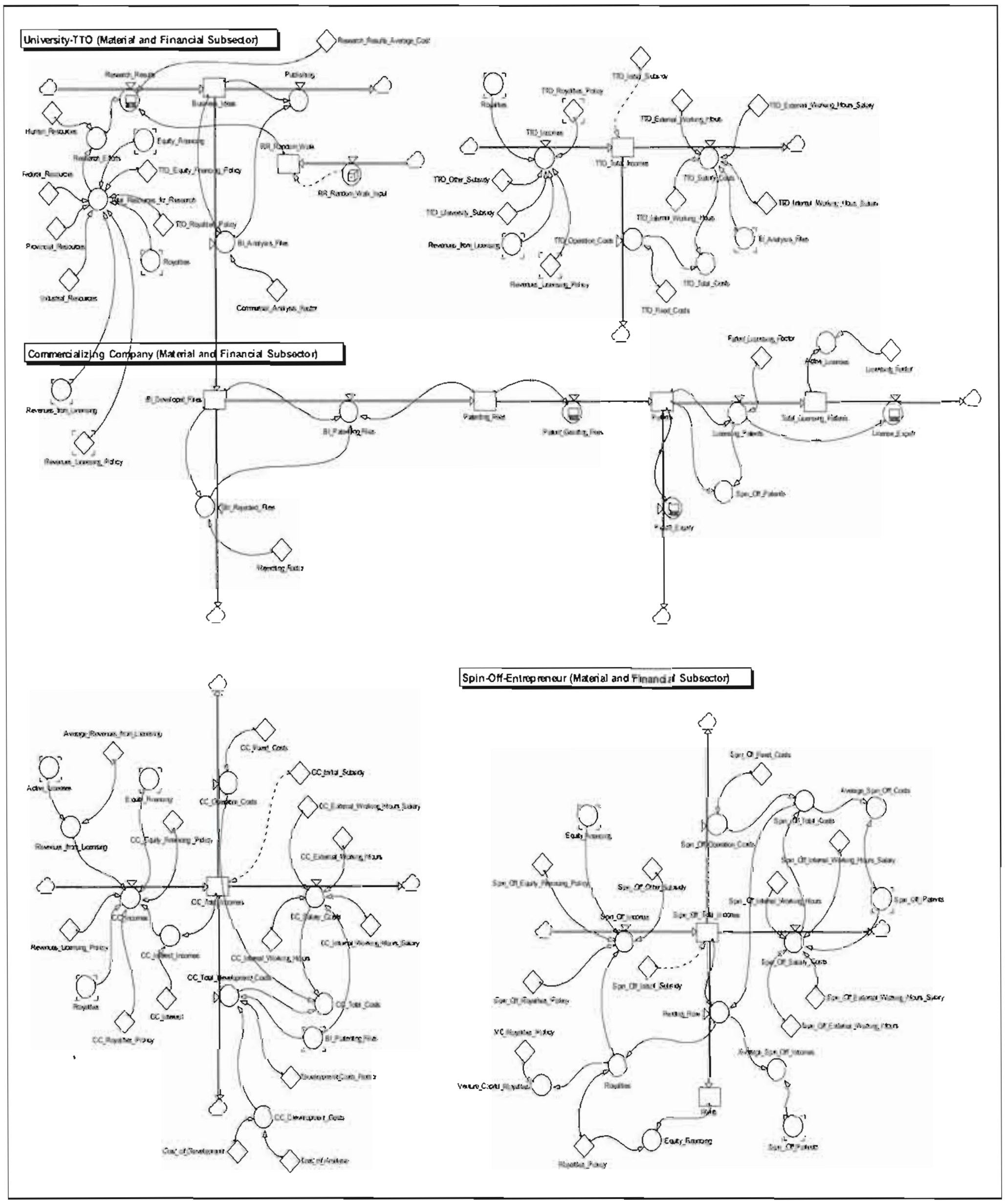


Figure 11 gives an overall view of the model developed in this research. As it was already stated above, it contains three subsectors aiming to describe stakeholders' performance in the process of university-industry technology transfer and spin-off creation: (1) TTOs-universities, (2) commercializing companies, and (3) spin-offs-entrepreneurs. For each subsector, there are two set of variables: material stock-and-flow variables and financial stock-and-flow variables.

5.1.1. TTO-University Subsector

The TTO-University material subsector formalizes the relationships established when scientists carry out research efforts for achieving potential commercially applied new knowledge. The variables total budget for research and research efforts are central pieces in developing business ideas and new inventions for university spin-off companies. In this model, to get thriving ideas with high degree of opportunity, a Poisson probabilistic distribution is specified. The Poisson probabilistic distribution allows for allocating research results that are developed as business ideas.

5.1.1.1. TTO-University Material Stock-and-Flow Variables

The TTO-University subsector models university/scientists and TTOs activities into the process of technology transfer. The interactions established between scientists/researchers and TTOs define a set of variables used to test *Research Results* in terms of opportunity. The objective is to select *Business Ideas* that are likely to engender new knowledge-based companies. Once *Business Ideas* are selected and tested for opportunity, they are transferred to the Commercializing Company as *BI Developed Files* for patenting and commercializing purposes.

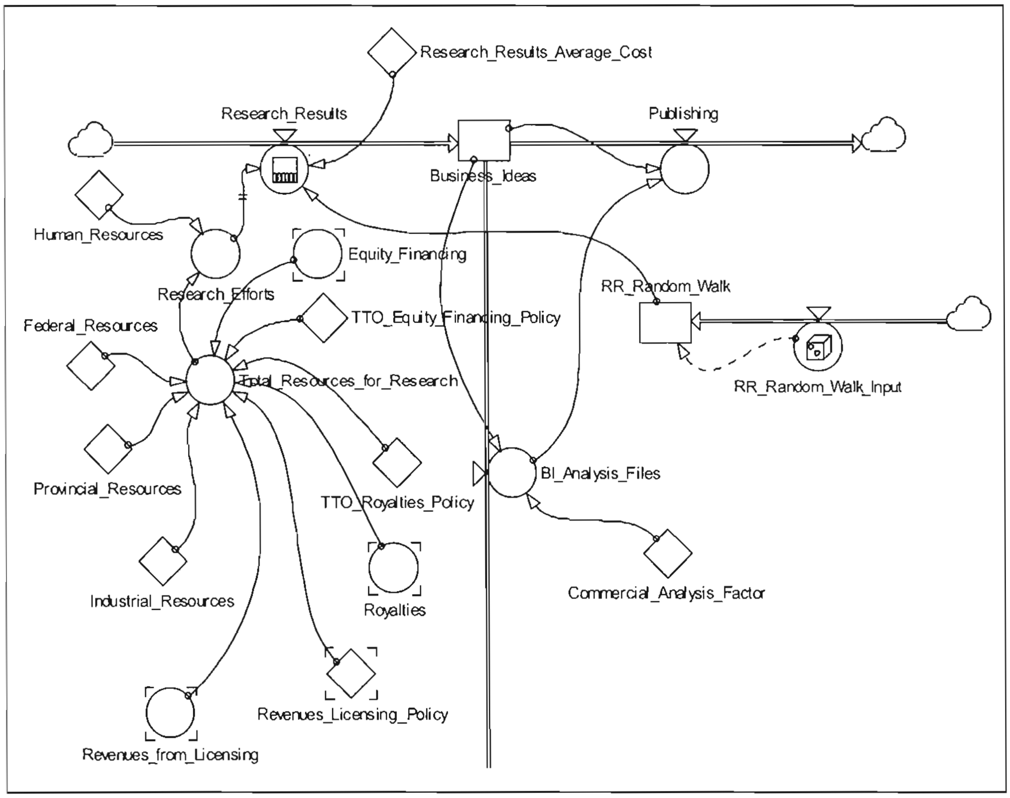
However, there are many other key variables included in this subsector that contribute to transform *Research Efforts* into *Business Ideas* (figure 12). The main variables modeled in this subsector are *Total Budget for Research* (federal and provincial resources for research, as well as industrial research resources), and *Human Resources*. Two important features are considered. First, a fraction of royalties, licensing revenues, and rents drawn from equity in spin-off companies are used for research financing purposes. The royalties invested in university spin-off equity financing are no more than 10% (Zhang 2009). Second, the variable *Human Resources* includes all kind of employees working as researcher/scientists, as well as supporting employees working in university research activities.

The variable *Research Results* is transformed into *Business Ideas* through a Poisson distribution (Landry et al. 2007; Lazaric and Raybaut 2005; Silverberg and Verspagen 2003). As Cincera (1997) and Landry et al. (2007) suggest the treatment of this variable as a Poisson distribution process is due to difficulties and uncertainty inherent to R&D expenditure mainly federal, provincial, and industrial resources to funding *Research Efforts*. This approach implies, however, a random selection process resulting in research outcomes for being tested on opportunities, and it is usually proposed as a typical solution to the estimation of the econometric models with discrete non-negative dependent variables (Landry et al. 2007). The variable *Research Results* is thus assumed to follow a Poisson distribution such as:

$$\Pr(Y_i|\lambda_i) = \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i!}$$

$$\text{with: } E(Y) = Var(Y) = \lambda$$

Figure 12. **University-TTO: Material Stock-and-Flow Variables**



The variable *Research Results* should take into account the time needed to attain results from efforts made by researchers when applying financial and human resources to research. The time delay for achieving research results is two years.

Total_Resources_for_Research=Federal_Resources+
Industrial_Resources+Provincial_Resources+
Revenues_from_Licensing(1Revenues_Licensing_Policy)+*
*(Royalties*TTO_Royalties_Policy+*
*Equity_ Financing)/2*TTO_Equity_Financing_Policy*

Research_Efforts=Total_Resources_for_Research/Human_Resources

*Research_Results=DELAYPPL(Research_Efforts, 2, 0)/Research_Results_Average_Cost)*RR_Random_Walk*

The variable *BI Analysis Files* is constructed making use of two other variables: *Business Ideas* and the same variable *BI Developed Files* delayed by six months. This equation aims to capture the fact that *Business Ideas* are transferred to the Commercializing Company as new files for evaluation, but at the same time, it takes into account that some files can be rejected and sent back to the TTO for reevaluation in terms of opportunity. However, results from research activities not transferred as new ideas for business purposes can be published as free knowledge (figure 12).

*BI_Analysis_Files=Business_Ideas*Commercial_Analysis_Factor*

Once *Business Ideas* are set up as *BI Analysis Files*, they are transferred to the Commercializing Company as *BI Developed Files* to search for patenting (section 5.1.2).

5.1.1.2. TTO-University Financial Stock-and-Flow Variables

The financial side of the University-TTO subsector explains how incomes are originated and used when developing new university spin-off companies. University-

TTOs costs are primarily financed from university subsidy and other university subsidy. However, revenues from licensing and revenues from royalties are two other important sources to financing TTOs activities. These parameters are established by universities TTOs and commercializing companies as a result of their policies agreements with researchers and other venturing investors, as well as their licensing policy.

The resources acquired by University-TTOs are used as salaries and operation costs. In turn, the variable salary costs are determined by the amount of internal and external working hours employed, as well as the internal and external salary paid by University-TTOs. Through the variables *Internal Working Hours Salary* and *Internal Working Hours*, the model captures the human resources employed in TTOs. Figure 13 shows the relations established between these variables.

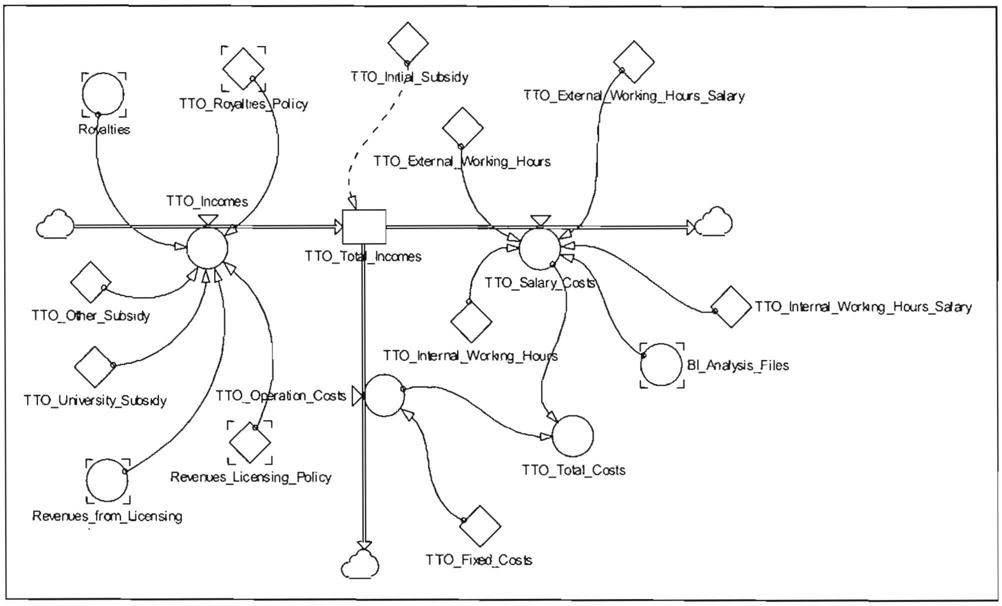
The variables *Salary Costs* and operation costs determine in turn the total cost of university-TTOs. The equations describing these variables are formulated in the following terms:

TTO_Incomes=TTO_Othery_Subsidy+TTO_University_Subsidy+
(Royalties*TTO_Royalties_Policy)/2+(Revenues_from_Licensing*
Revenues_Licensing_Policy)/2

TTO_Total_Costs=TTO_Operation_Costs+TTO_Salary_Costs

TTO_Salary_Costs=(TTO_External_Working_Hours_Salary*
TTO_Cost_External_Working_Hours+
TTO_Internal_Working_Hours_Salary*TTO_Internal_Working_
Hours)*BI_Analysis_Files

Figure 13. **University-TTO: Financial Stock-and-Flow Variables**



5.1.2. Commercializing Company Subsector

The Commercializing Company analyzes and commercializes business ideas from academia. As *BI Developed Files*, business ideas are evaluated not just in terms of opportunity, but appropriability. The objective of the Commercializing Company is thus to search for patenting new business ideas with a high degree of opportunity. The Commercializing Company is a key actor in the process of UITT given that it serves as a linkage between University-TTOs and the spin-off companies. This characteristic makes the Commercializing Company to be highly complex to model, as it includes and must take into account relations established with other stakeholders participating in the process of UITT.

5.1.2.1. Commercializing Company Material Stock-and-Flow Variables

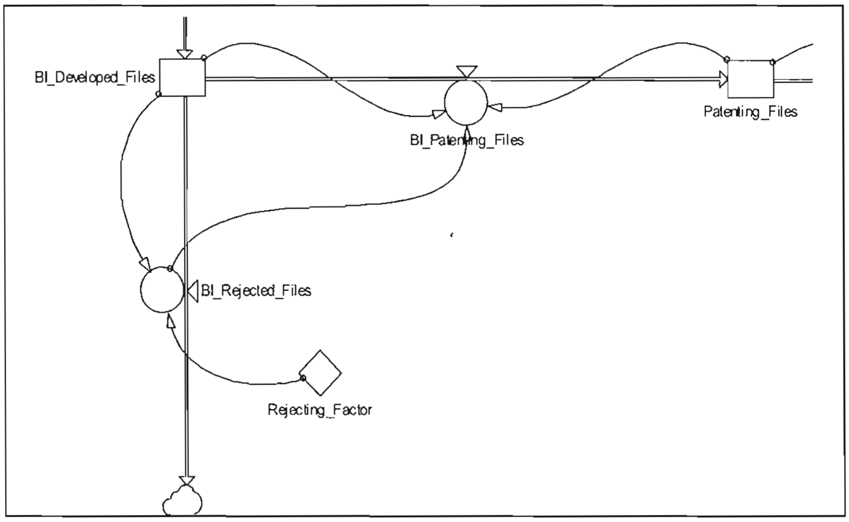
The Commercializing Company technically analyzes *BI Developed Files* to reject or accept the files as *Patenting Files*. It is important to say that *Patenting Files* can be rejected by the patent granting office for not being technically adjusted in terms of the patent application, making longer the time needed to grant a patent. In this research the time delay for patenting a business idea is two years (figure 14).

BI_Patenting_Files=BI_Developed_Files-
(BI_Rejected_Files+Patenting_Files)

*BI_Rejected_Files=BI_Developed_Files*Rejecting_Factor*

The material stock-and-flow variables of the Commercializing Company begins when the new files for commercial analysis are evaluated for development as new patents (developing files) or are rejected. To reject a file, two variables are specified: *Commercial Analysis Factor* and *Rejecting Factor*. In turn, when a file for commercial analysis is accepted, the stock variable developing files is determined. The flow variable *Developed Files* gives the variable patent granting delay that is used to determine the number of granted patents. The variable *Patent Granting Files* is modeled as a time delay variable that assumes two years to develop files as patents.

Figure 14. **Commercializing Company: Material Stock-and-Flow Variables**



Earl et al. (2004) found that in Canada only one innovation out of three thousand ideas makes it to market. However, this achievement is also in accordance with the results attained by Landry et al. (2007) and Landry et al. (2006) in the case of Canadian life science and engineering research for commercial innovation developments.

Patent_Granting_Files=DELAYPPL(Patenting_Files, 2, 0)

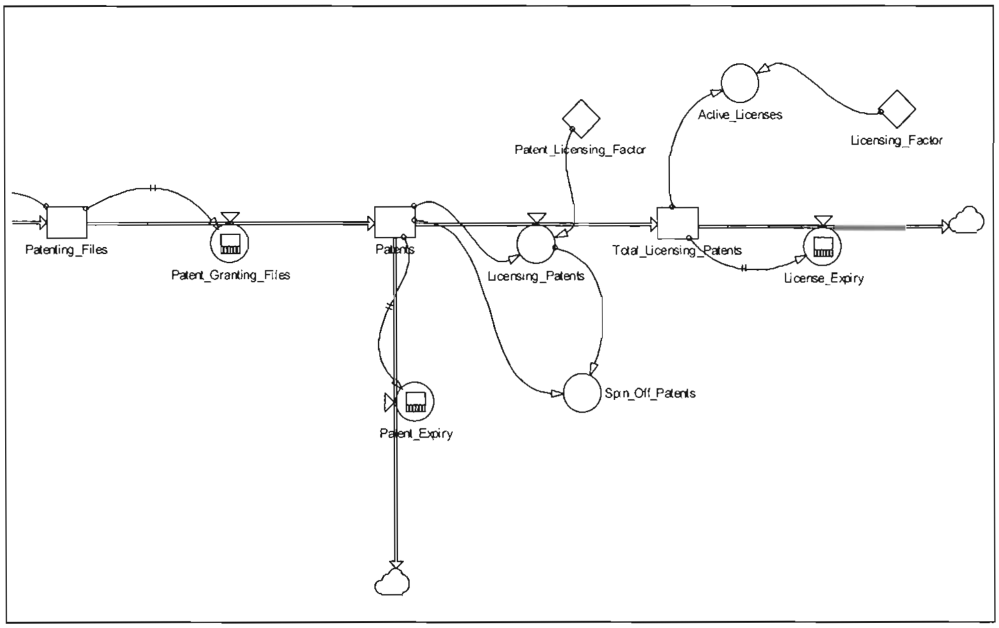
Once a patent is granted, it can be used to create a new spin-off or to license. The time period to commercially exploit a patent as a spin-off or licenses is twenty years. However, in this model it is assumed that patents are licensed for four years. The flow variable *Licensing Patents* is determined by the stock variable *Patents* and a *Licensing*

Factor that is the average number of patents licensed. After developing this process, the stock variables *Total Licensing Patents* is determined. This variable is influenced by the variable *License Expiry* that is modeled as a time delay variable. In this model, the expiry time in the reference scenario is four years, but the expiry time can be altered to evaluate other alternative scenarios. These facts are incorporated in the model as time delay variables as follows:

Patent_Expiry=DELAYPPL(Patents, 20, 0)

License_Expiry=DELAYPPL(Active_Licenses, 4, 0)

Figure 15. **Spin-Off-Entrepreneur: Material Stock-and-Flow Variables**



The variable *Licensing Patents* is extremely important as it determines the number of patents to be used as an input in the creation process of new spin-off companies. The variable *Spin-Off Patents* is determined by the total number of patents granted and the number of patents licensed. In this research, it is assumed that each spin-off patent represents a new spin-off company (figure 15).

$$Spin\_Off\_Patents = Patents - Licensing\_Patents$$

Once the variable *Spin-Off Patents* is known, it is used in the Entrepreneur-Spin-Off subsector of the model.

5.1.2.2. Commercialization Company Financial Stock-and-Flow Variables

The Commercialization Company is directly related to the process of spinning off new companies. Four variables make up the Commercialization Company Income-Expenditure side: *CC Incomes*, *CC Operation Costs*, *CC Salary Costs*, and *Development Costs*. The flow variable *CC Incomes* captures all available resources to be used for successfully developing a spin-off company by the commercializing companies. The main sources of incomes in the Commercialization Company subsector are: *CC Initial Subsidy*, *Royalties*, *Revenues from Licensing*, *Equity Financing*, and *CC Interest Incomes*. In turn, the variables *Royalties* and *Revenues from Licensing* are influenced by *Royalties Policy* and *Revenues Licensing Policy*, respectively. The following equations capture the relations established between these variables:

*CC_Incomes=(Revenues_from_Licensing*Revenues_Licensing_Policy)/2+ CC_Interest_Incomes+Royalties*CC_Royalties_Policy+ Equity_Financing*CC_Equity_Financing_Policy*

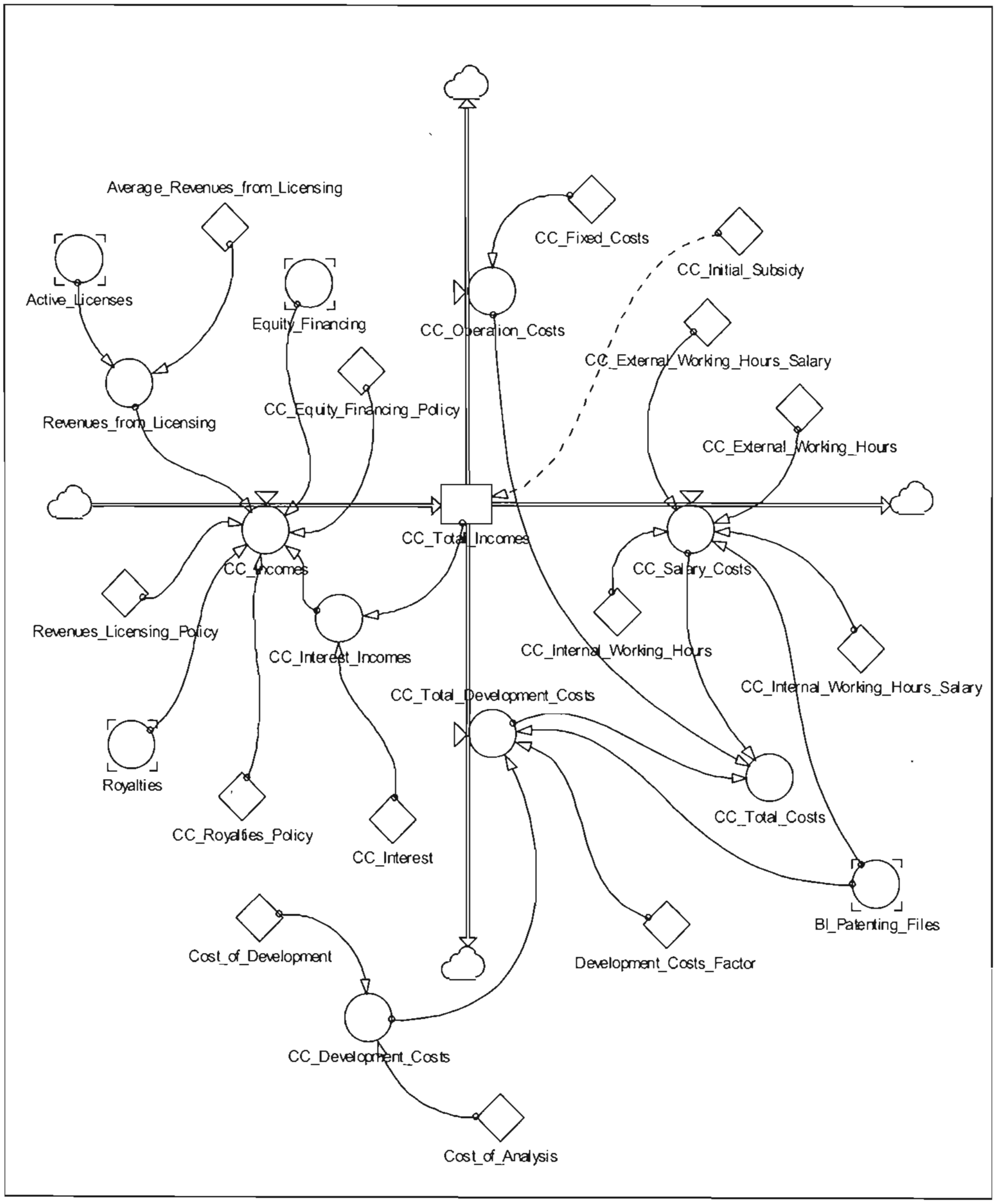
The variable *Operation Costs* in the Commercialization Company subsector is determined by the flow variable *Fixed Costs*. The flow variable *CC Development Costs* results from the variable *Cost of Development* and *Cost of Analysis*. Finally, the flow variable *CC Salary Costs* results from the variables *CC External Working Hours*, *CC External Working Hours* Salary, *CC Internal Working Hours*, and *CC Internal Working Hours Salary*. The flow variables *Operation Costs*, *Salary Costs*, and *Development Costs* are defined in the following terms:

CC_Operation_Costs=CC_Fixed_Costs

CC_Salary_Costs=(CC_External_Working_Hours
CC_External_Working_Hours_Salary+
*CC_Internal_Working_Hours_Salary**
*CC_Internal_Working_Hours)*BI_Patenting_Files*

*CC_Total_Development_Costs=(CC_Development_Costs**
*Development_Costs_Factor)*BI_Patenting_Files*

Figure 16. **Commercialization Company: Financial Stock-and-Flow Variables**



The variable *Operation Costs* along with the variables *Salary Costs*, and *Development Costs* determine the flow variable *Total Costs* in the following terms:

CC_Total_Costs=CC_Total_Development_Costs+
CC_Operation_Costs+CC_Salary_Costs

Figure 16 synthesizes the relations established between these variables in the financial side of the Commercialization Company subsector.

5.1.3. Spin-Off-Entrepreneur Subsector

The Entrepreneur-Spin-Off subsector aims to explain how spin-off companies are created. This subsector contains four stock variables and seventeen flow variables. In this sub-sector patents are developed as spin-offs or licensed patents. It is characterized by two time delays affecting patent expiration and license expiration. Active licenses are also determined in this subsector.

5.1.3.1. Spin-Off-Entrepreneur Material Stock-and-Flow Variables

The material side of the Spin-Off-Entrepreneur subsector is modeled using the number of patents received from the Commercializing Company subsector (figure 17). *Spin-Off Patents*, *Licensing Patents*, *Total Licensing Patents*, and *Active Licenses* are determined in the material side of the Spin-Off-Entrepreneur side. The following equations show how these variables are determined.

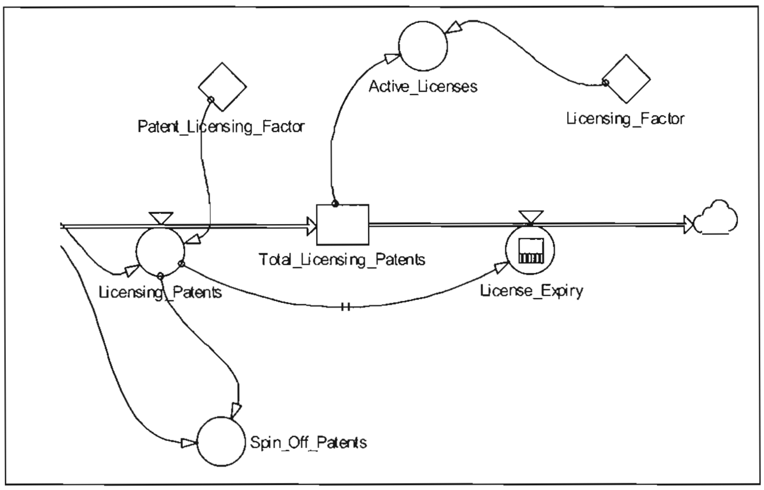
*Licensing_Patents=Patents*Patent_Licensing_Factor*

Spin_Off_Patents=Patents-Licensing_Patents

*Active_Licenses=Total_Licensing_Patents*Licensing_Factor*

License_Expery=DELAYPPL(Licensing_Patents, 4, 0)

Figure 17. **Spin-Off-Entrepreneurial: Material Stock-and-Flow Variables**



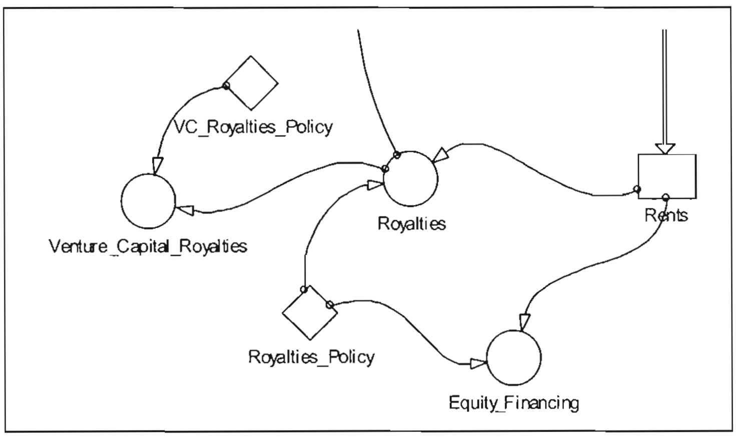
In addition, the variables *Royalties*, *Equity Financing*, and *Venture Capital Royalties* are determined from the stock variable *Rents* using of the parameters *Royalties Policy* and *VC Royalties Policy* (figure 18). The relationships established between these variables imply that rents generated from spin-off activity are used as equity financing, royalties for venture capitalists, or spin-off financing royalties.

*Royalties=Rents*Royalties_Policy*

Equity_Financing=Royalties(1-Royalties_Policy)*

*Venture_Capital_Royalties=Royalties*VC_Royalties_Policy*

Figure 18. **Spin-Off Entrepreneur: Royalty Policy Stock-and-Flow Variables**



5.1.3.2. Spin-Off-Entrepreneur Financial Stock-and-Flow Variables

The Income-Expenditure side in the Spin-Off-Entrepreneur subsector determines incomes and costs of successful spin-off companies in markets, including *Spin-Off Total Incomes*, *Spin-Off Operation Costs*, and *Spin-Off Salary Costs* (figure 19).

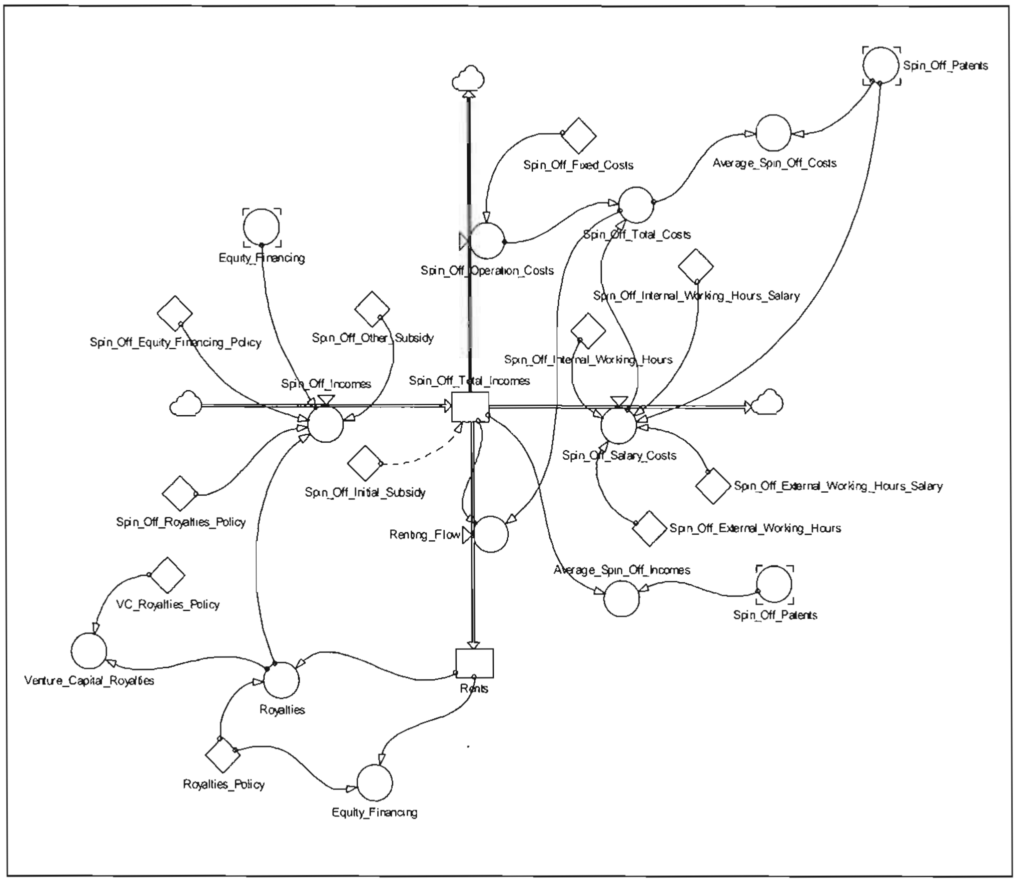
*Spin_Off_Incomes=Royalties*Spin_Off_Royalties_Policy+*
*Equity_Financing*Spin_Off_Equity_Financing_Policy*

The variable *Spin-Off Operation Costs* includes *Spin-Off Fixed Costs*. In turn, the flow variable *Spin-Off Salary Costs* includes *Spin Off External Working Hours*, *Spin Off External Working Hours Salary*, *Spin Off Internal Working Hours*, *Spin Off Internal Working Hours Salary*, and *Spin-Off Patents*. Finally, *Spin-Off Fixed Costs* and *Spin-Off Salary Costs* explain the flow variable *Spin-Off Total Costs*. The following equations explain the relationships established between these variables:

*Spin_Off_Salary_Costs=(Spin_Off_External_Working_Hours**
Spin_Off_External_Working_Hours_Salary+
*Spin_Off_Internal_Working_Hours**
*Spin_Off_Internal_Working_Hours_Salary)*Spin_Off_Patents*

Spin_Off_Total_Costs=Spin_Off_Operation_Costs+
Spin_Off_Salary_Costs

Figure 19. **Spin-Off-Entrepreneurial: Financial Stock-and-Flow Variables**



5.2. Model Calibration

Model calibration is the process of estimating the model parameters (structure) to obtain a match between observed and simulated structures and behaviors (Oliva 2003). In this process, the modeler examines differences between simulated output and data, identified possible reasons for those differences, adjusts model parameters in an effort to correct the empirical discrepancy and re-simulate the model (Khosrovian et al.

2008). Indeed, calibration explicitly attempts to link structure to behavior for testing a dynamic hypothesis. Table 17 contains the parameter name, unit, description and value to calibrate the variables of the University-TTO Subsector.

Table 17. **Model Calibration: University-TTO Subsector (Input Values)**

Parameter Name	Unit	Description	Value
Business_Ideas	Files/Year	Research results with high degree of opportunity	0
RR_Random_Walk	Prob. Dist.	Probabilistic Poisson Distribution	0.725,0.487
TTO_Total_Incomes	CAN$/Year	Subsidy, royalty and license incomes received by TTOs	0
Human_Resources	Employees/Year	Total number of employees engaged in university research activities including both scientists researchers and supporting staff	25000
Research_Results_ Average_Cost	CAN$/File	Project research average cost	2500
Federal_Resources	CAN$/Year	Financial resources invested by federal government in research projects at universities	1,955,050,123
Provincial_Resources	CAN$/Year	Financial resources invested by provinces in research projects at universities	1,655,077,330
Industrial_Resources	CAN$/Year	Financial resources invested by industry in research projects at universities	457,828,997
TTO_Royalties_Policy	Percentage	Percentage of rents earned by TTOs from royalties	0.1
TTO_Equity_	Percentage	Percentage of total incomes drawn from	0.1

Financing_Policy		equity to TTOs	
Commercial_Analysis_ Factor .	Percentage	Percentage of business idea filed for patenting evaluation	0.7
TTO_Initial_Subsidy	CAN$/Year	Financial resources initially invested into TTOs for launching TTOs	15,000,000
TTO_University_ Subsidy	CAN$/Year	Resources invested by universities for launching TTOs	15,000,000
TTO_Other_Subsidy	CAN$/Year	Other financial resources invested for launching TTOs	15,000,000
TTO_Internal_ Working_Hours	Hours/Year (EFT)	Total number of hours devote by internal TTOs staff for launching spin-offs	2,080
TTO_Internal_ Working_Hours_Salar y	CAN$/Hour	Average salary paid to internal TTOs staff for launching spin-offs	35
TTO_External_ Working_Hours	Hours/Year (EFT)	Total number of hours devoted by external TTOs staff for launching spin-offs	520
TTO_External_ Working_Hours_Salar y	CAN$/Hour	Average salary paid to external TTO staff for launching spin-offs	35
TTO_Fixed_Costs	CAN$/Year	Cost executed by TTOs in relation to administrative office performance	15,000,000

The calibration step in the simulation model process aims to compare the general model and outputs in terms of the actual behavior of the system. The purpose of modeling generates the identified reference mode so the solution is to build a formal simulation model to overcome the cognitive limitations to grasp the detailed complexity of reality and to make reliable behavioral inferences (Oliva 2003). In this sense, model calibration, or the process by which the model parameters (structure) are estimated to obtain a match between observed and simulated structures and behavior, is a stringent test of a dynamic hypothesis (Oliva 2003). Table 18 contains the parameter name, unit, description and value to calibrate the variables of the Commercializing Company Subsector.

Table 18. **Model Calibration: Commercializing Company Subsector (Input Values)**

Parameter Name	Unit	Description	Value
BI_Developed_Files	Files/Year	Business ideas analyzed for patenting	0
Patenting_Files	Files/Year	Business ideas filed for patenting	0
Patents	Patents/Year	Number of patents granted to universities/ Researchers	0
CC_Total_Incomes	CAN$/Year	License, royalty, interest and equity incomes received by CCs	0
Rejecting_Factor	Percentage	Percentage of business ideas rejected for patenting	0.4
CC_Initial_Subsidy	CAN$/Year	Financial resources initially invested into CCs for launching spin-offs	30,000,000
CC_Internal_Working _ Hours	Hours/Year (EFT)	Total number of hours devoted by internal CCs staff for launching spin-offs	2080
CC_Internal_Working _ Hours_Salary	CAN$/Hour	Average salary paid to internal CCs staff for launching spin-offs	24
CC_External_Working _Hours	Hours/Year (EFT)	Total number of hours devoted by external CCs staff for launching spin-offs	520

CC_External_Working _Hours_Salary	CAN$/Hour	Average salary paid to external CCs staff for launching spin-offs	24
CC_Fixed_Costs	CAN$/Year	Cost executed by CCs in relation to administrative office performance	5,000,000
CC_Equity_Financing _ Policy	Percentage	Percentage of total incomes drawn from equity rents to CCs	0.05
Revenues_Licensing_ Policy	Percentage	Percentage of incomes received by CCs from license revenues	0.04
Average_Revenues_ from_Licensing	CAN$/Year	Average revenues from commercially exploit licenses	3,500,000
CC_Royalties_Policy	Percentage	Percentage of rents earned by CCs from royalties	0.15
CC_Interest	Percentage	Percentage of interest incomes earned by CCs	0.01
Cost_of_Development	CAN$/File	Average cost for developing business ideas as patenting files	2,000
Cost_of_Analysis	CAN$/File	Average cost for analyzing business ideas as patenting files	2,000
Development_Cost_ Factor	Percentage	Percentage of business idea files developed as a patenting files	0.8

From a general perspective, there are three differences with respect to how TTOs and CCs are set up (Meyer and Tang 2006): (1) the TTO function either can be taken over by an independent university-owned company or carried out through a separate administrative division within the university, (2) there are important differences between the level of collaboration within university research services divisions and external partners, and (3) TTOs are either following a "general approach" or set up units dedicated to a particular technology transfer function, such as the creation of spin-offs, provision of business development services or licensing services. However, in the case of Canada, it is possible to analyze UITT and spin-off creation within a general framework including three stakeholders participating in this process: (1) university-TTOs, (2) commercializing companies, and (3) spin-offs-entrepreneurs. Table 19 contains the parameter name, unit, description and value to calibrate the variables of the Spin-Off-Entrepreneur Subsector. These values allows for generating a reference scenario to evaluate alternative policies in other alternative scenarios.

Table 19. **Model Calibration: Spin-Off-Entrepreneur Subsector (Input Values)**

Parameter Name	Unit	Description	Value
Total_Licensing_Patents	Patents/Year	Number of patents licensed for being commercially exploited	0
Spin_Off_Total_Incomes	CAN$/Year	University subsidy, other subsidies, license and royalty incomes received by spin-offs	0
Rents	CAN$/Year	Total rents generated by spin-offs as royalty and equity incomes for being granted to venture capitalists and patent owners	0
Spin_Off_Initial_Subsidy	CAN$/Year	Financial resources initially invested into spin-offs	0
Spin_Off_Other_Subsidy	CAN$/Year	Other financial resources invested into spin-offs	10,000,000
Patent_Licensing_Factor	Percentage	Percentage of patents to be licensed for commercial purposes	0.75
Licensing_Factor	Percentage	Total number of licenses licensed for each patent	2

Spin_Off_Internal_ Working_Hours	Hours/Year (EFT)	Total number of hours devoted by internal spin-offs staff	2080
Spin_Off_Internal_ Working_Hours_Salary	CAN$/Hour	Average salary paid to internal spin-offs staff	35
Spin_Off_External_ Working_Hours	Hours/Year (EFT)	Total number of hours devoted by external spin-offs staff	520
Spin_Off_External_ Working_Hours_Salary	CAN$/Hour	Average salary paid to external spin-offs staff	35
Spin_Off_Fixed_Costs	CAN$/Year	Cost executed by spin-offs in relation to administrative office performance	5,000,000
Spin_Off_Equity_ Financing_Policy	Percentage	Percentage of total incomes drawn from equity rents to spin-offs	0.4
Royalties_Policy	Percentage	Percentage of rents paid to stakeholders	0.5
Spin_Off_Royalties_ Policy	Percentage	Percentage of total incomes drawn from rents as royalties to spin-offs	0.75
VC_Royalties_Policy	Percentage	Percentage of total incomes drawn from rents as royalties to venture investors	0.6

Information for each input variable in the reference scenario for this model is presented for measurement units, description and scenario of reference. The goal is to calibrate the model in terms of assessing the viability of the financial profitability/loss of technology transfer programs can be made comparing royalty payments to estimates of TTOs costs, patent fees, legal expenses, and new research grants (Trune and Goslin 1998). However, differences between universities in the handling their intellectual property management practices may affect the cost structures and therefore the overall profitability of TTOs and their intellectual property management practices (Meyer and Tang 2006).

5.3. Model Indicators

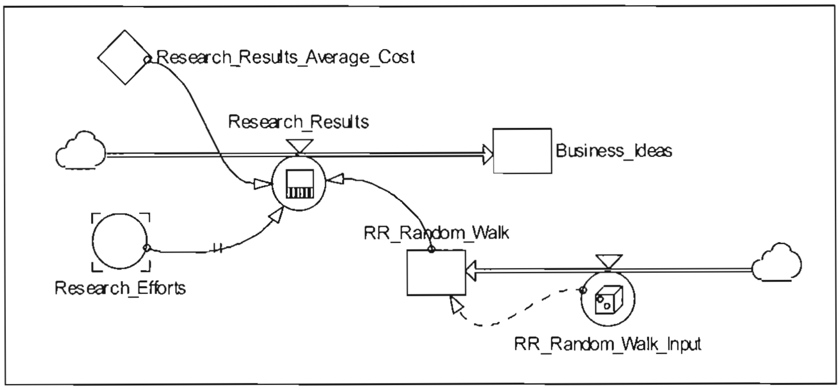
Model indicators summarize the path behavior of the model in terms of key selected variables. A selection of model indicators is important because they are an essential input for conducting sensitivity analyses. A good selection of a set of model indicators allows for superior quality in the analysis when scenarios are evaluated. In this research, fourteen variables were selected to explain stakeholders' performance in the process of UITT and spin-off creation (Table 20). Model indicators are represented through the following equations and diagrams for each stakeholder in terms of their performance and corresponding material and financial underlying dynamics.

Table 20. **Model Indicators**

University-TTO	Commercializing Company	Spin-Off-Entrepreneur
Material Variables: - Research Results - Business Ideas	Material Variables: - Business Ideas Developed Files - Patenting Files - Patents	Material Variables: - Spin-Off Patents - Total Licensing Patents
Financial Variables: - TTO Total Incomes - TTO Total Costs	Financial Variables: - CC Total Incomes - CC Total Costs	Financial Variables: - Royalties - Spin-Off Total Incomes - Spin-Off Total Costs

Four equations and three diagrams synthesize the indicators of the University-TTO subsector. The variable *Research Results* is determined from *Research Efforts* with a time delay (figure 20). In addition, the variable *Research Efforts* is randomly transformed into *Research Results* following a Poisson probabilistic distribution that allows for dealing with discrete non-negative values of the *Research Efforts* variable (section 5.1.1.1). The process of modeling R&D projects and their resulting outcomes (research results and business ideas) as a Poisson process has already been proposed by many scholars such as Blundell et al. (1995), Cincera (1997), Hausman et al. (1984), and Montalvo (1993). However, the *Business Ideas* indicator is computed by subtracting *BI Analysis Files* and *Publishing* from *Research Results*.

Figure 20. **Model Indicators: Research Results**

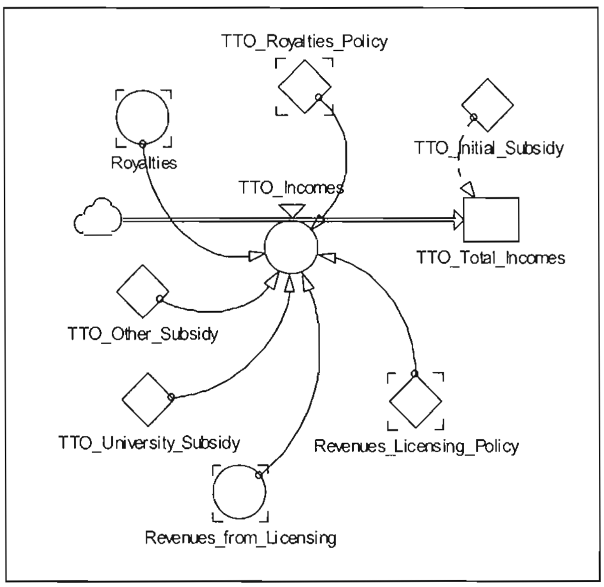


*Research_Results=(DELAYPPL(Research_Efforts, 2, 0)/ Research_Average_Cost)*Random_Walk*

*Business_Ideas=∫Research_Results*dt-∫BI_Analysis_Files*dt- ∫Publishing*dt*

The variable *TTO Incomes* is more complex to determine (figure 21). *TTO Incomes* is typically determined by the parameters *Revenues Licensing Policy*, *TTO Royalties Policy*, *TTO Initial Subsidy*, *TTO University Subsidy* and *TTO Other Subsidy*. These constraints reflect the complexity of the procedure for determine alternative policies that directly and indirectly influence stakeholders decision of participating in the process of UITT and spin-off creation. However, the indicator *TTO Total Incomes* is computed by subtracting *Salary Costs* and *Operation Costs* from *TTO Incomes*.

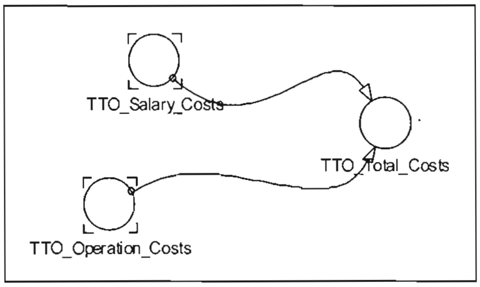
Figure 21. **Model Indicators: TTO Total Incomes**



$$TTO\_Total\_Incomes = \int TTO\_Incomes*dt - \int TTO\_Salary\_Costs*dt - \int TTO\_Opeation\_Costs*dt$$

The indictor *TTO Total Costs* is computed adding the flow variables *TTO Operation Costs* and *TTO Salary Costs* (figure 22).

Figure 22. **Model Indicators: TTO Total Costs**



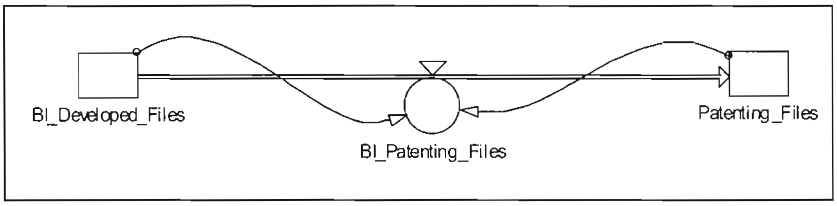
$$TTO\_Total\_Costs=TTO\_Operation\_Costs+TTO\_Salary\_Costs$$

These equations are estimated within the model representing the pathway behavior of the TTO-University block. They embody the decisions made by the TTOs in picking up outcomes resulting from research results with a high degree of opportunity.

On the other hand, the indicators related to the commercialization company subsector are drawn from five equations and four diagrams. Figure 23 shows how *Business Ideas Developed Files* are transformed into *Patenting Files*. This is however a technical evaluation process carried out by the commercialization company to transforming business ideas into patenting files. The objective is thus to find the most important and promising business ideas projects in terms of technological opportunity and appropriability to developing them as patents. The following two equations show

how the commercializing company carries out this process. *BI Developed Files* is computed subtracting *BI Patenting Files* and *BI Rejected Files* from *BI Analysis Files*. In turn, *Patenting Files* is computed subtracting *Patent Granting Files* from *BI Patenting Files*.

Figure 23. **Model Indicators: BI Developed Files**

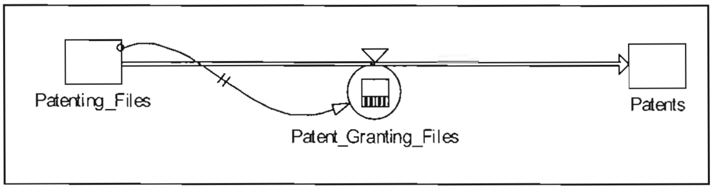


$$BI\_Developed\_Files=\int BI\_Analysis\_Files*dt-\int BI\_Patenting\_Files*dt-\int BI\_Rejected\_Files*dt$$

$$Patenting\_Files=\int BI\_Patenting\_Files*dt-\int Patent\_Granting\_Files*dt$$

Once *Business Ideas Developed Files* are filed as *Patenting Files*, patents may be granted (figure 24). The indicator *Patents* is computed subtracting *Licensing Patents* and *Patent Expiry* from the variable *Patent Granting Files*.

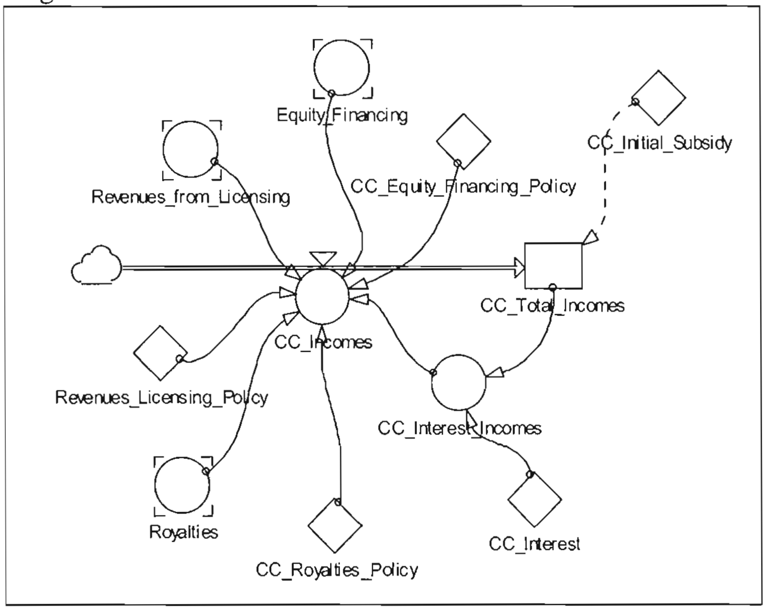
Figure 24. **Model Indicators: Patents**



$$Patents=\int Patent\_Granting\_Files*dt-\int Licensing\_Patents*dt-\int Patent\_Expiry*dt$$

The indicator *CC Total Incomes* is more complex to determine (figure 25). *CC Total Incomes* is directly or indirectly influenced by several flow variables and policy parameters: *Equity Financing*, *Royalties*, *Revenues from Licensing*, *CC Interest Incomes*, *CC Equity Financing Policy*, *Revenues Licensing Policy*, *CC Royalties Policy*, *CC Interest*, and *CC Initial Subsidy*. The constrains imposed by the parameters in this equation reflect the idea that the determination of the commercialization company incomes is a highly complex procedure directly and indirectly influenced by stakeholders decision to participate in the process of UITT and spin-off creation.

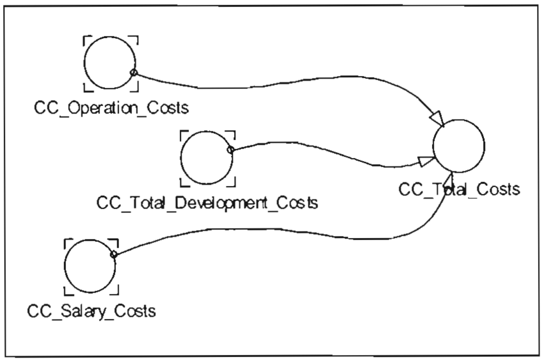
Figure 25. **Model Indicators: CC Total Incomes**



$$CC\_Total\_Incomes=\int CC\_Incomes*dt-\int CC\_Total\_Development\_Costs*dt-\int CC\_Operation\_Costs*dt-\int CC\_Salary\_Costs*dt$$

In the same way, the *CC Total Costs* indicator is determined by adding up three variables: *CC Operation Costs*, *CC Total Development Costs*, and *CC Salary Costs* (figure 26).

Figure 26. **Model Indicators: CC Total Costs**

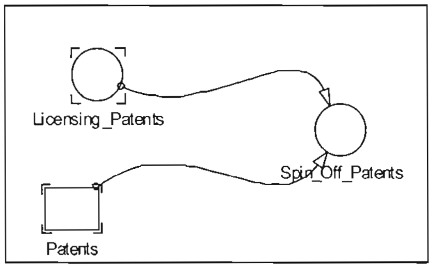


CC_Total_Costs=CC_Total_Development_Costs+
CC_Operation_Costs+CC_Salary_Costs

These equations are simulated within the model and they represent the behavior of the commercializing company subsector. They embody the decisions and efforts made by the commercialization companies to award patents to funding new university spin-offs. However, commercialization companies also manage incomes arising from university spin-off patents as a supportive financing source for research.

Finally, the indicators of the spin-off-entrepreneur subsector are drawn from five equations and five diagrams (figure 27). The variable *Spin-Off Patents* is computing subtracting *Licensing Patents* from *Patents*. It is assumed that for each non licensed patent corresponds one spin-off company. This assumption does not take into account the fact that in some cases research results and patents may be cumulative for successfully developing university spin-off companies (Denicolò 1996, 2000; Green and Scotchmer 1995; Mergers and Nelson 1990; O'Donoghue 1998; O'Donoghue et al. 1998; Scotchmer 1991).

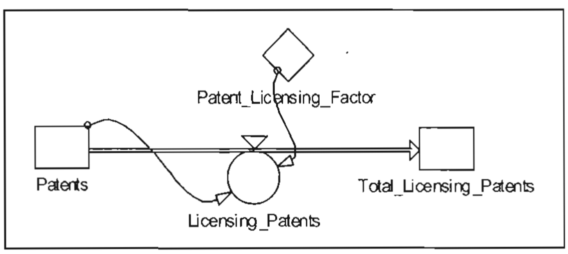
Figure 27. **Model Indicators: Spin-Off Patents**



Spin_Off_Patents=Patents-Licensaing_Patents

The indicator *Total Licensing Patents* corresponds to patents that are not developed as university spin-off companies nor are licensed for commercializing purposes (figure 28). The variable *Licensing Patents* is computed taking into account the average time period patents are licensed. The indicator *Total Licensing Patents* is thus computed by subtracting *License Expiry* from *Licensing Patents*.

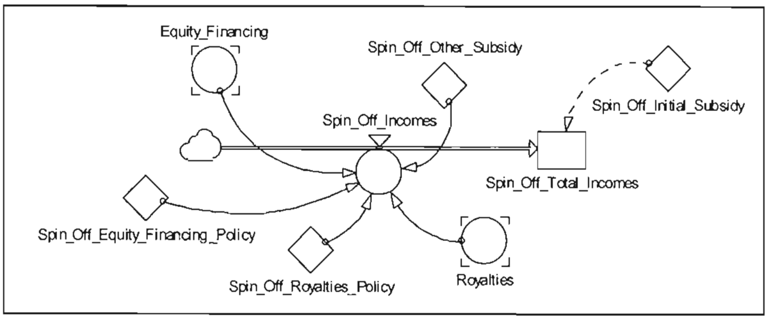
Figure 28. **Model Indicators: Licensing Patents**



$$Total\_Licensing\_Patents=\int Licensing\_Patents*dt-\int License\_Expiry*dt$$

The indicator *Spin-Off Total Incomes* is computed taking into account directly or indirectly *Royalties*, *Equity Financing*, *Spin-Off Initial Subsidy*, *Spin-Off Other Subsidy*, *Spin-Off Equity Financing Policy*, and *Spin-Off Royalties Policy* (figure 29). The *Spin-Off Total Incomes* equation shows how costs and rents originated at university spin-off companies are determined. In turn, rents will be distributed as TTO royalties, commercialization company royalties, spin-off royalties, venture capital royalties, and rents for investing as equity.

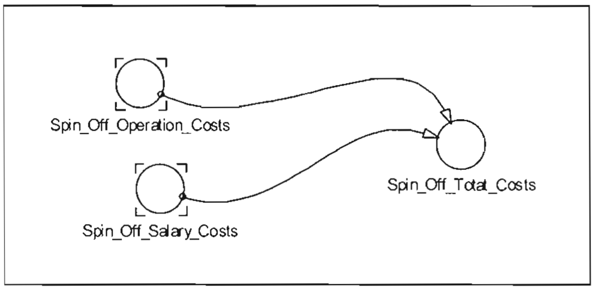
Figure 29. **Model Indicators: Spin-Off Total Incomes**



$$Spin\_Off\_Total\_Incomes=Spin\_Off\_Initial\_Subsidy+\int Spin\_Off\_Incomes*dt-\int Renting\_Flow*dt-\int Spin\_Off\_Operation\_Costs*dt-\int Spin\_Off\_Salary\_Costs*dt$$

The *Spin-Off Total Costs* indicator is computed adding the variables *Spin-Off Salary Costs* and *Spin-Off Operation Costs* (figure 30). In particular, it is expected that spin-off companies may invest in many other inputs such as raw materials, equipment, marketing, and so on, depending on the nature of the activity of each company. However, the results achieved from the simulation in this model are adequate to support the conclusions obtained in this research.

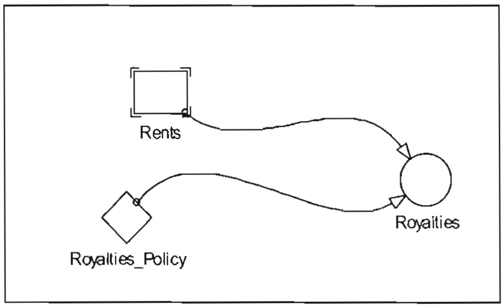
Figure 30. **Model Indicators: Spin-Off Total Costs**



Spin_Off_Total_Costs=Spin_Off_Operation_Costs+Spin_Off_Salary_Costs

The indicator *Royalties* is mainly derived from the variable *Rents* (figure 31). In so doing, it takes into account the *Royalties Policy* derived from stakeholders' decisions participating in the process of UITT and spin-off creation. As it was already stated before, the *Royalties Policy* parameter basically determines the distribution of rents (royalties) between TTOs, commercialization companies, and university spin-off companies.

Figure 31. **Model Indicators: Royalties**



*Royalties=Rents*Royalties_Policy*

These equations represent the simulated behavior of the TTO-entrepreneur subsector. They embody the decisions and efforts made by the TTO-entrepreneurs to commercially exploit patents as university spin-offs. However, TTO-entrepreneurs generate incomes through licensed patents or royalties.

5.4. Conclusion

This chapter dealt with model design. Three main topics were discussed: model description, model calibration, and model indicators. The model description made reference to stakeholders' actions linked in the process of UITT and spin-off creation in Canada. For each subsector, a set of material stock-and-flow variables and financial stock-and-flow variables were specified. In this sense, it was established how through a SD approach the interaction of stakeholders' actions and motives determine their own outcomes. It was expected that the performance of these outcomes would be influenced by some feedback and side effects, following each a specific path behavior, and thus producing a nonlinear process. Furthermore, the outcomes resulting from stakeholders' actions participating in the process of UITT and spin-off creation would generate nonlinear processes that would influence other stakeholders' actions.

Specifically, in this model, the most important relations established between stakeholders (subsectors) were the following. First, rents generated by spin-offs that influence total resources for research and TTO total incomes through the flow variables royalties, equity financing, revenues from licensing and business ideas analysis files, and the parameters revenues licensing policy and TTO royalties policy. Second, rents generated by spin-offs that influence CC total incomes and patents through the flow variables royalties, equity financing and active licenses, and the parameter revenues licensing policy. Finally, rents generated by spin-offs that influence spin-off total incomes through the flow variables equity financing and spin-off patents, and the parameter royalty policy. However, the characteristics featuring these relations were revealed through the analysis of the structure of UITT and spin-off creation phenomena.

The model was calibrated making use mainly of data released by the AUTM Canadian Licensing Survey and the AUTM Canadian Salary Survey. The data obtained from these sources allowed for defining a baseline model. As part of the calibration process, key indicators were selected in order to determine the validity of the model: (1) research results, business ideas, TTO total incomes and TTO total costs by the side of University-TTOs, (2) business ideas developed files, patenting files, patents, CC total incomes and CC total costs by the side of the commercialization companies, and (3) spin-off patents, total licensing patents, royalties, spin-off total incomes and spin-off total costs by the side of spin-off entrepreneurs.

VI. Research Results

This chapter discusses three scenarios to explore relationships between research results and the research questions raised in this study. In so doing, two different blocks of research questions on UITT and spin-off creation in Canada are addressed. In the first block the general questions underlying this research are how do uncertainty, informational gaps, and lack of receptor capabilities influence the success of spin-off companies within a non-commercial environment and conflicting objectives of key stakeholders? And how the environment affects the movements of know-how, technical knowledge, or technology transfer from one organization to another? On the second block the general questions are how different university environments and specific organizational structures affect the technology-transfer process? And what are the most significant resources and capabilities for creating successful spin-off companies?

To answer these questions, first, this chapter analyzes a baseline scenario to evaluate the process of academic spin-off creation and development. Second, two other scenarios are evaluated for alternative policies to be implemented at different levels of analysis. The answers to these questions aim to gain insight on how feedback interactions and potential side effects characterizing the complexity of the UITT influence the process of spin-off creation and development. Furthermore, the various stages through which in the process of spin-off creation and developments is carried out are characterized for being reinforcing and balancing feedbacks, and to follow a non-linear process (Eisenhardt 1989).

Section 6.1 analyzes the reference scenario. Section 6.2 contains the sensitivity analyses in terms of other scenarios. Particularly, two alternative scenarios are analyzed in this section: (1) environmental and government policy; and (2) university policy and organizational structure. In turn, the organizational structure and university policy scenario is evaluated for royalty policy changes and organizational structural changes.

6.1. Baseline Scenario

This section presents the baseline scenario developed in this research. The importance of developing a baseline scenario is to establish a reference for comparison with other alternative scenarios in terms of policies and parameter values. This procedure allows for sensitivity analyses about transferring technology policy from universities to industry by means of university spin-offs creation. However, the main advantage when constructing alternative scenarios is that it allows planning for expected outputs, and therefore it brings understanding to a situation, enhances creativity, and contains an analytical component that is qualitative (Wright et al. 2009).

Empirical studies of spin-off creation and development vary on many important dimensions. It would be possible to consider these dimensions in terms of units of analysis, stages under study and types of samples used (Landry et al. 2006; Landry et al. 2007). These features that characterize the analysis of spin-off creation makes knowledge and technology transfer a highly complex process resulting from many interactions between various actors and organizations, such as university administrators and researchers, private and public firms, TTOs, commercialization companies, venture capitalists, and other financial agents and public sector actors (Göktepe 2008).

From a theoretical perspective, several approaches were identified to consider dealing the process of UITT and spin-off creation and development. A review of prior studies suggests that at least three units of analysis may be used in the analysis of knowledge and technology transfer from university to industry (Landry 2007; O'Shea et al. 2005):

1. Macro level or government policies where environmental factors impact for commercializing academic innovations are analyzed;
2. Meso level or university policies where the influence of universities' policies, procedures and technology commercialization practices are analyzed;
3. Micro level or individual researcher analysis where the characteristics of academic researchers are analyzed.

At each level of analysis is stressed the importance of institutions (patent legislation and policy mechanisms), organizations (university administrators, and funding agencies awarding grants) and actors (TTOs, commercializing companies, other industrial liaison offices, and academic researchers) in the process of creation of new knowledge and new academic companies by patenting at universities (Göktepe 2008). At a macro level, most of the studies emphasize the importance of government policies, focusing on the importance of the patent legislation and research financing to launch new spin-offs (Landry et al. 2007). For example, the impacts of the Bayh-Dole Act (1980) on the process of UITT or changes in tax policies in countries like Canada during the 1990s are representative illustrations of this analysis. Other illustrative cases analyzed in academic papers exemplifying this kind of research on macro conditions for spinning off academic companies are: Mowery et al. (2001), Mowery and Ziedonis (2002), Sampat et al. (2003), and Shane and Khurana (2003).

At a meso level, the study of UITT and spin-off creation aims to assess the impact of university policies on patenting and spin-off creation (Landry et al. 2007). These analyses search to gain insight on how university policy initiatives can be adequate to protect the intellectual property of their researchers and to successfully promote the creation of academic spin-offs. However, the bulk of the literature on knowledge and technology transfer from university to industry belongs to this category. Illustrative references of this literature are: Bercovitz et al. (2001), Di Gregorio and Shane (2003), Franklin et al. (2001), Goldfarb (2001), Kenney (1986), Lockett and Wright (2005), Markman et al. (2004), Niosi (2006b), O'Shea et al. (2005), Pérez and Sánchez (2003), Siegel et al. (2003), and Thursby et al. (2001).

Finally, at a micro level, the studies of UITT and spin-off creation stress individual factors such as entrepreneurial character, age, experience and scientific background. Landry et al. (2007) found that these studies assess the determinants of patenting and spin-off formation using survey data collected at the level of the individual researchers. Representative studies of this approach are: Agrawal and Henderson (2002), Audretsch (2000), Azoulay et al. (2005), Bercovitz and Feldman (2004), Carayol (2005), Franklin et al. (2001), Landry et al. (2006), Landry et al. (2007), Levin and Stephen (1991), Lockett and Wright (2005), Lockett et al. (2003), Murray (2002), Niosi (2006b), Roberts (1991), Shane and Khurana (2003), Stephan et al. 2007, Thursby and Thursby (2002), and Zucker et al. (1998).

Nevertheless, Clarysse et al. (2005), Göktepe (2008), Lerner (2005), Lockett and Wright (2005), and Vohora et al. (2004) stress the importance of getting an overall approach that takes into account the entire set of variables at the three levels of analysis. Such an approach would allow for the analysis of the interconnectivity and relationships established between different organizations, institutions and individual actors affecting knowledge and technology transfer outcomes, as well as spin-off creation. In this sense, the SD approach may allow to gain insight on how the dynamics of the process of UITT generated from the interconnections between government and university policies, organizational structures, alternative patenting and licensing schemes and different stakeholders' interests influence spin-off creation and development. Moreover, the theoretical discussion on any alternative approach for analyzing UITT and spin-off creation phenomena still remains rather fragmented. In this sense, this research aims to contribute to the debate on technology and knowledge commercialization, entrepreneurship and technological innovation linking the various knowledge and technology transfer components that characterize universities and industry activities. Therefore, this research aims to gain insight on how alternative research funding schemes, organizational practices, commercializing companies and TTOs initiatives jointly determine the dynamics of UITT, university patenting activity, and academic spin-offs creation. This objective may be achieved through evaluating alternative scenarios defined from alternative government and university policies, adjusting specific parameter values, and including various academic researchers' concerns that may result in effective fomenting of spin-offs (Clarysse et al. 2005; Göktepe 2008; Lerner 2005; Lockett and Wright 2005; Vohora et al. 2004). In this research, two blocks of research questions are defined:

1. How environmental variables affect the technology transfer process, or how the environment affects the movements of know-how, technical knowledge or technology transfer from one organization to another?
2. How different university environments and specific organizational structures affect the technology-transfer process, and what are the most significant resources and capabilities for creating successful university spin-off companies?

However, these research questions support the definition of three alternative scenarios that allow the evaluation of the dynamics of the process of technology transfer and new academic spin-off companies in Canada:

0. A baseline scenario;
1. An environmental and government policy scenario;
2. A university policy and organizational structure scenario:
    2a. A royalty policy change scenario;
    2b. An organizational structure change scenario.

The definition of a baseline scenario in the case of Canada results from analyzing the dynamic path behavior of the key variables established in this chapter that characterize stakeholders' decisions in the process of UITT and spin-off creation according to their actual conditions and parameter values that define the model developed in this research. However, the results achieved from the baseline scenario, the environmental and government policy scenario, and the university policy and organizational structure scenario are shown for the years 2004, 2010 and 2015. The scenarios assume a set of propositions already tested separately in some works and academic papers under other alternative approaches: Azoulay et al. (2005), Barney (1991), Barney et al. (2001), Bercovitz and Feldman (2003), Bercovitz and Feldmann (2006), Brush et al. (2001), Carayol (In Press), Carayol and Matt (2004a), Carayol and Matt (2004b), Clarysse et al. (2005), Di Gregorio and Shane (2003), Eisenhardt (1989), Elfenbein (2007), Feldman et al. (2002), Foltz et al. (2000), Fontes (2005), Grandi and Grimaldi (2003), Gulbrandsen and Smeby (2005), Hindle and Yencken (2004), Kazanjian and Drain (1988), Kazanjian and Drain (1989), Landry et al. (2006), Landry et al. (2007), Lowe (1993), Markman et al. (2004), Mustar et al. (2006), Nlemvo et al. (2002), Orsenigo (1989), Owen and Powell (2001), Owen and Powell (2003), Payne and Siow (2003), Pirnay et al. (2003), Rasmussen (2006), Siegel et al. (2003c), Siegel et al. (2004), Siegel et al. (2007), Van Looy et al. (2004), Vohora et al. (2004), Zucker et al. (1998), Zucker et al. (2002).

Table 21 shows the baseline scenario within the actual conditions of UITT and spin-offs creation in Canada. The baseline scenario was calibrated using as reference data generated by the AUTM Canadian Licensing Survey and the AUTM Canadian Salary Survey.

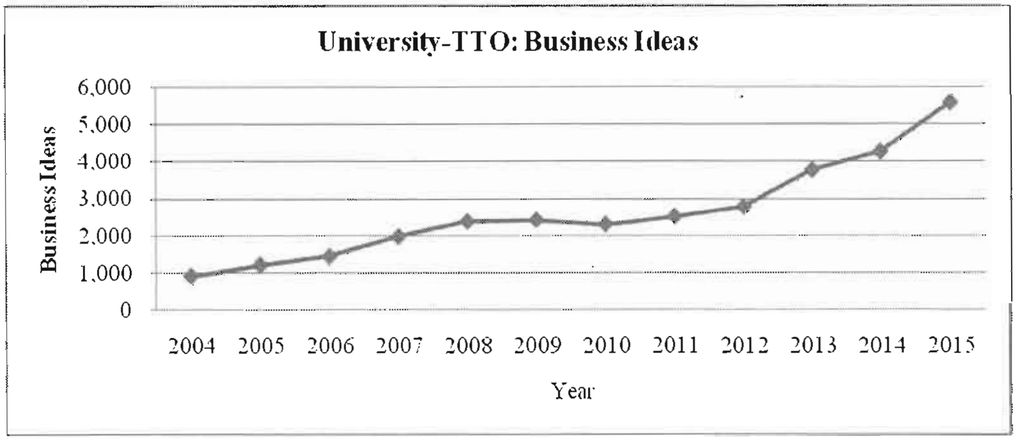
Table 21. **Scenario 0: Baseline Scenario**

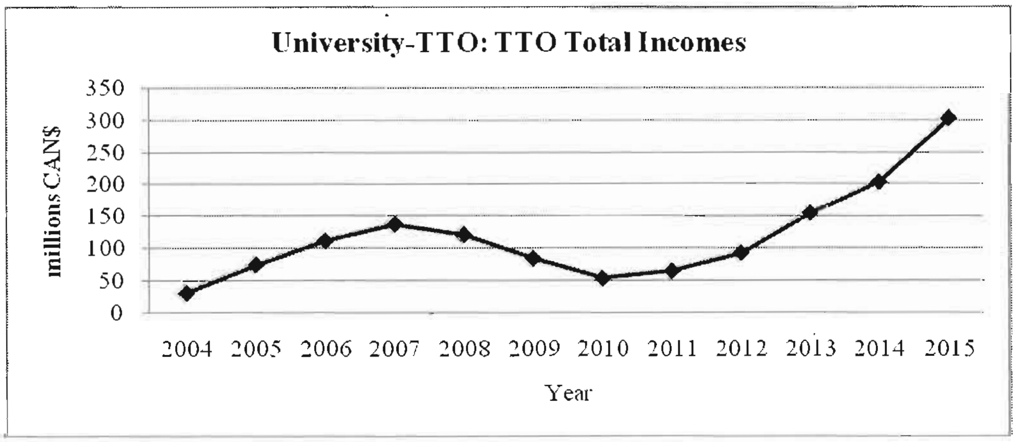
Stakeholders	Indicator Variables	2004	2010	2015
University-TTOs	Business Ideas	901	2,300	5,589
	TTO Total Incomes (000)	30,247	53,462	302,487
Commercializing Companies (CCs)	Business Ideas Developed Files	612	2,185	4,279
	Total Licensing Patents	612	986	2,842
	Patents	174	417	1,395
	CC Total Incomes (000)	31,941	532,426	1,707,533
Spin-Offs	Spin-Off Patents	43	104	349
	Royalties (000)	25,511	88,555	248,168
	Spin-Off Total Incomes (000)	56,866	184,138	508,113

These results suggest that research results and business ideas are strongly linked, as it would be expected. Research results and business ideas are core indicators for the whole process of technology transfer and spin-off creation as they are the main input for attaining this process. The value of this variable depends on the effectiveness of the financial funding sources to generate business ideas with a high degree of commercial opportunity. Nevertheless, two important features ought to be stressed. First, it would be expected that external source funding is extremely important in terms of the effectiveness for generating results from research, and thus business ideas. Second, there is an essential role to be played by subsidies when funding research in order to support these activities within universities. The two features corroborate the idea that external funding may be more appropriate to support the commercialization of knowledge and technology generated at universities.

Accordingly, University-TTOs activity is evaluated for the importance of internal (university) and external financial support (government and industry) for successfully developing academic spin-off projects. In the Canadian case, Foltz et al. (2000) and Landry et al. (2007) found that external financial support is more important than internal financial support (universities) to the process of knowledge and technology transfer, as well as patenting and developing new academic spin-offs. One explanation to this finding might be that government and industry research funding may act as incubators for patenting and spinning off new academic companies, allowing universities learning to patent and creating incentives for promising inventions (Di Gregorio and Shane 2003; Foltz et al. 2000; Gulbrandsen and Smeby 2005; Owen and Powell 2003; Payne and Siow 2003).

Figure 32. **Baseline Scenario: University-TTO**





Also, Foltz et al. (2000), Landry et al. (2006) and Landry et al. (2007) suggest that government and industry funding contributions stimulate new academic spin-offs development through the dissemination of research results and by creating opportunities to develop joint university-user research initiatives, by investing in financial and human resources in joint university-user research and/or research transfer, and developing and improving products or processes based in research results (figure 32).

It is important to mention that in many cases a higher number of publications impact positively the likelihood of spinning off new academic companies, and thus granting patents to researchers (Carayol and Matt 2004a; Carayol and Matt 2004b; Elfenbein 2007; Grandi and Grimaldi 2003; Landry et al. 2006; Landry et al. 2007; Owen and Powell 2003; Stephan et al. 2007; Van Looy et al. 2004). This outcome results from the opportunity that emerges to disseminate some spillovers generated around the process of knowledge transfer that are more likely to create new academic companies. In this sense, some studies suggest the importance of many scientists to be strongly associated with the process of patenting and spin-off formation (Carayol In Press). In the same way, Landry et al. (2007) explain that higher degrees of research novelty may carry higher commercial potential inducing researchers to protect their intellectual property through patents. Nevertheless, these authors suggest that as the degree of research novelty increases, so does the distance between research results and their applicability in new products and processes.

These principles support the idea that academic research fields are important to explain the relation between novelty, patenting, and spin-off formation. Effectively, some authors found that knowledge transfer activities, patenting and spin-off creation are more likely to happen in fields such as engineering or natural science characterized to have a higher level of opportunity (Azoulay et al. 2005; Carayol In Press; Fontes 2005; Landry et al. 2006; Lowe 1993; Orsenigo 1989; Owen and Powell 2001; Zucker et al. 1998). This is why there have been more patents granted and spin-off developments in fields linked to biotechnology-related sciences.

Patenting and spin-off formation depend on links established between research and market factors (Owen and Powell 2003). In fact, this is an important problem that should be addressed by any novel approach. Effectively, research findings are characterized by asymmetries and excludability (Landry et al. 2007). Asymmetry of information arises when users cannot precisely evaluate the commercial applicability of the research results. In this sense, the commercialization of knowledge is unlikely if researchers and users of research do not have frequent interactions, and thus considerably reducing the exploitation of commercial opportunities provided by the academic research (Landry et al. 2007). In the same manner, excludability arises either from the complexity of the research knowledge or from the tacit nature of the knowledge that is necessary to efficiently translate research findings into commercial applications (Landry et al. 2007; Szulanski 2000). In fact, researchers who attempt to launch spin-offs are more likely to have linkages with experts over and beyond the scientific community and the patent office (Landry et al. 2007).

Finally, it is important to recognize the size of the research organization or university to develop spin-offs in the process of technology transfer and spin-off creation. This subject has already been studied by many scholars that seek to explain how larger universities are more likely to receive a greater quantity of financial resources and reservoir start scientists than small and medium universities (Bercovitz and Feldman 2003; Di Gregorio and Shane 2003; Feldman et al. 2002; Markman et al. 2004; Zucker et al. 2002). This principle leaves room for analyzing how norms and incentives within universities facilitate the undertaking of commercial and knowledge transfer activities (Markman et al. 2004; O'Shea et al. 2005).

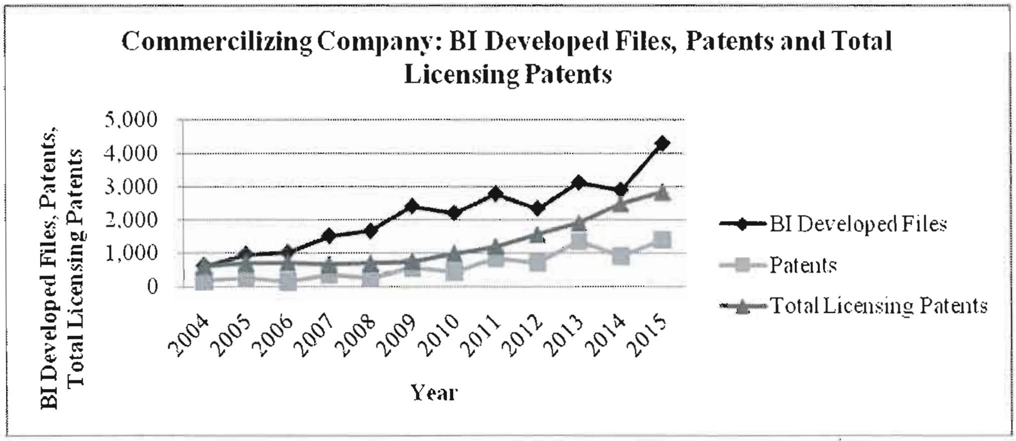
The results achieved in the baseline scenario correspond to those reported by the AUTM Canadian Licensing Survey in 2004 (AUTM 2004a) and the AUTM Canadian Salary Survey 2004 (AUTM 2004b). For example, the licensing AUTM survey reports the creation of 45 new academic companies in 2004, meanwhile this research reports 43 new university spin-offs in 2004. In the same way, the licensing AUTM survey reports 180 Canadian academic patents issued in 2004, meanwhile this research reports 174 academic patents in 2004.

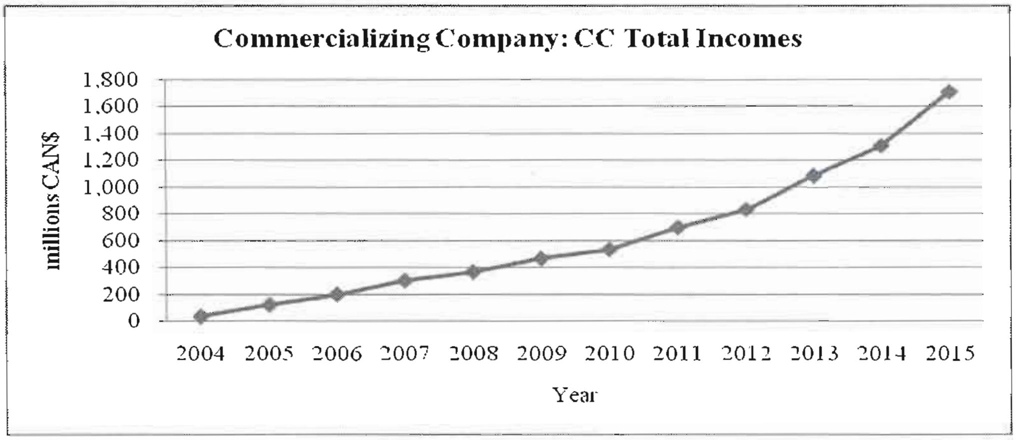
By the side of the University-TTOs axis, it is assumed that the average cost for developing a research project is $2,500, and the resources coming out from equity financing and royalties is 10% of the total incomes generated by spin-offs. This assumption is reported in the literature on this subject (Siegel et al. 2007; Rasmussen 2008).

In the reference scenario, TTOs total incomes variable shows an oscillatory path behavior. As it would be expected, the explanation to the performance of this variable may come from the fact that UITT activity and university spin-offs will become increasingly important in the next future. However, in the short term, it takes time to develop a business idea as an academic spin-off. Moreover, it would be expected the existence of bottlenecks when transferring business ideas, as business ideas developed files and patenting files, and patenting files as patents.

Commercialization companies are in charge for patent application. They receive business ideas as developed files to file for patent filing. Commercializing companies support their operations through earnings coming out from equity, royalties, subsidy from universities, and interests. In this case, it is assumed in the baseline scenario that in between 5% and 15% of total incomes generated by spin-offs go to commercializing companies in terms of equity and royalties, respectively. However, the main source of incomes received by commercialization companies come from licensing (figure 33).

Figure 33. **Baseline Scenario: Commercializing Company**





However, joint venture partnership is an important mechanism for financing university spin-offs. In relation to university-industry joint venture partnership participation, the theoretical literature on this issue is not abundant. However, the key references are the following: Baldwin and Link (1998), Beath et al. (2001), Branstetter 2003; Link and Vonortas (2002), Panagopoulos (2003), and Poyago-Theotoky et al. (2002). These scholars agree about the importance of patenting and intellectual property protection to forming research joint ventures by university and industry.

When universities and firms in industry choose to form a research joint venture, partners must also account for their opportunity cost (the profits that they sacrifices by halting the research that they conduct on their own) (Panagopoulos 2003). Consequently, the greater the opportunity cost, the harder it will be for a firm to enter into a research partnership (Panagopoulos 2003). But the importance of the above statement is that firms and universities which conduct research on new-technologies will incur lower opportunity cost, making them the most likely participants in research joint ventures given that universities concentrate their research on new technologies (Panagopoulos 2003). The objective of the potential partners would be to benefit from the profits and/or technological expertise of the other partner. Particularly, Panagopoulos (2003) suggests that firm's and research partner university's decisions on whether to join and research joint venture and how to develop an expected innovation will depend on the way both partners will allocate costs and gains, as well as on how fast technology evolves.

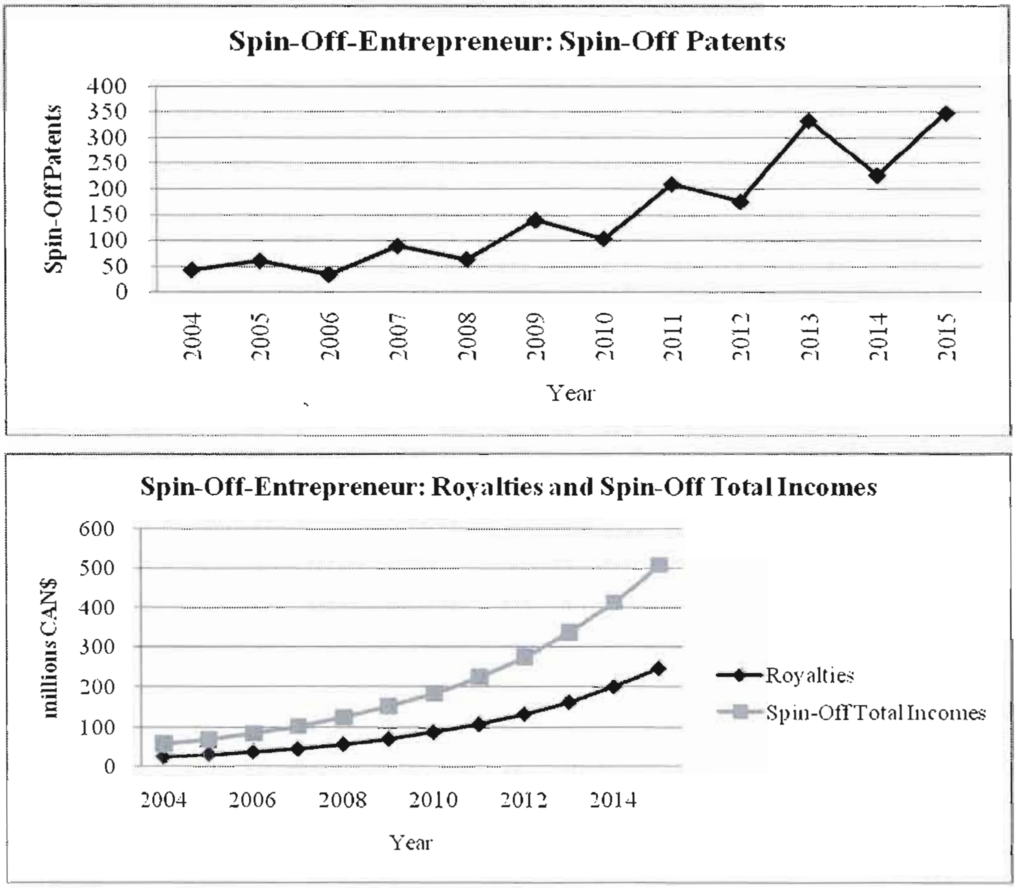
Panagopoulos (2003) demonstrates that the decision of the firm and university to form a research joint venture does not depend on the degree of the collective magnitude of innovations or on the size of the market, but on how fast technology is evolving. This principle may partially support the results achieved in this research in relation to the path behavior of key variables, such as business ideas developed files. In some cases universities and firms will find easier to form a research joint venture specialized in new technologies, or in technologies closer to science. This principle supports the path behavior of this variable resulting in the model, given that universities are most likely to partner in new technological fields where R&D is closer to science and IP protection can be acquired by means of patents (Caloghirou et al. 2000; Link and Vonortas 2002). However, it is important to keep in mind that the degree of IP protection chosen by firms and universities will depend on how fast the technology evolves (Panagopoulos 2003). Some references addressing these issues are: Branscomb et al. (1999), Siegel et al. (2003b), and Macho-Stadler (2007).

Regarding venture capital in the process of developing academic spin-off companies, it has been argued that external funding is more likely to be successful. For example, Porter (1998) suggests that an industrial cluster may support competition by increasing the productivity of companies within the cluster. In this sense, university inventions developed within a research park are more likely to obtain financial funding from joint venture capitalists, given that they may acquire higher returns. In fact, university spin-offs may profit from experience in marketing and management from other companies. Some studies have indicated that venture capital significantly promotes innovation and business growth (Bottazzi and Da Rin 2002; Kortum and Lerner 2000).

Venture capital markets are influenced by many factors (Cumming et al. 2005): legal and institutional structure, size and liquidity of the stock market, investor sophistication, and ability to supply venture capital finances to entrepreneurial firms. In the case of Canada, Wonglimpiyarat (2006) discusses the importance of venture capital market. Policies formulated by the Canadian government have allowed for supporting institutional interactions which thereby lead to strong innovative firms. Examples of these policies are tax incentives to promote individual investment. Particularly, the technology financing in the Canadian venture capital industry are in the life sciences, communications and networking, software, and communication technologies.

Once a patent is granted to a new spin-off company where university, scientists and joint venture capitalists may participate, the licensing problem emerges. At this point, the role played by TTOs and commercialization companies is important in terms of information asymmetries (information on the quality of inventions) amongst other stakeholders participating in the process of UITT, defining licensing agreements, an appropriate royalty policy, or even the critical size for the TTO in order to determine adequate income from innovation transfers (Macho-Stadler et al. 2007).

Figure 34. **Baseline Scenario: Spin-Off-Entrepreneur**



In the case of Canada, these features make spin-off patents to perform an oscillatory path behavior, depending on the external and internal conditions for conducting the creation of these companies. In this case, research efforts outcomes do not necessarily corresponds to the patenting conditions for creating academic spin-offs. These principles also demonstrate that participating stakeholders' objectives may be in conflict to each other. In short, this result suggests that uncertainty and informational gaps, derived from different stakeholder perspectives in the process of technology transfer, influence the success in academic spin-off companies emerging from a non-commercial environment. However, the concern of this research is to gain insight on how to develop good practices for successfully transferring technology from academy to industry, and thus to develop an adequate organizational structure that offers specialized services to academic and industry participants, partner searching, financing resources searching, management of intellectual property, and business development. Furthermore, a major problem identified in the literature on UITT is the difficulty universities face in inducing researchers to disclose their inventions and to cooperate in further development after the license agreement (Macho-Stadler et al. 2007). This problem has already been studied from different perspectives. For example, Jensen and Thursby (2001), Jensen et al. (2003), and Macho-Stadler et al. (1996), explain the importance of moral hazard with respect to inventor disclosure and inventor cooperation in commercialization. These authors find that universities that offer larger shares to inventors have higher license incomes. The explanation to this statement is that the incentive effect seems to work both by encouraging higher levels of effort and by attracting more productive researchers (Macho-Stadler et al. 2007).

Macho-Stadler et al. (2007) continues to explain that even when the disclosure problem is remedied through an appropriate incentive scheme, another problem arises concerning the fact that not all inventions will be patented and licensed by the university. These authors refer to this problem as the problem of asymmetric information between industry and science on the value of the inventions. The asymmetric information problem concerns to the fact that firms typically cannot assess the quality of the invention ex ante, while researchers may find difficult to assess the commercial profitability of their invention. This problem has already been studied in terms of fees, royalties, and equity to signal the quality of an invention (Beggs 1992; Gallini and Wright 1990; Macho-Stadler and Pérez-Castrillo 1991).

The organizational structure of technology transfer within science institutions has received little attention in the theoretical literature. An exception to this is the analysis developed by Bercovitz et al. (2001) which stress the importance of an organization structure within the university to explain its performance in terms of patents, licensing, and sponsored research to industry. Also within this bulk of papers, Hellmann (2005), Hoppe and Ozdenoren (2005), and Lizzeri (1999) analyze the conditions under which innovation intermediaries emerge to reduce the uncertainty problem, advantage a TTO compared to individual scientists or teams in terms of lower costs of searching for potential licensers, and lower opportunity cost of time. Furthermore, these authors show that the fixed setup costs of TTOs can be recovered if the size of the invention pool is large enough to exploit the economies of sharing expertise. In the same way, Siegel et al. (2003b) find that TTO size has constant returns to scale with respect to licensing activity, but increasing returns to scale with respect to licensing revenue. Finally, Chukumba and Jensen (2005) suggest that the size, the age of the TTO as well as the quality of the faculty significantly positively influences activities.

In relation to rents yielded by spin-off companies two variables are analyzed as key indicators: royalties and spin-off total incomes (Figure 34). As in the case of commercializing companies, the path behavior of the variables royalties and spin-off total incomes shows to be more stable. This result can be explained as a consequence of the substance contribution of licensing patents to determine rents. In this research, it assumed that 75% of total patents granted are licensed by commercial companies. However, AUTM Canadian Licensing Survey reports CAN$54 million of gross license incomes in 2004.

6.2. Other Scenarios

Two alternatives scenarios are conducted to answer the research questions raised in this study. The scenarios analyzed in this section aim to evaluate how the environmental conditions affect the technology transfer process, as well as the movement of know-how, technical knowledge, and technology transfer from universities to industry. In addition, it is recognized that different university environments and specific organizational structures affect the technology-transfer process in terms of significant resources and capabilities for creating successful university spin-off companies. Specifically, section 6.2.1 focuses on environmental and government policy evaluation, and section 6.2.2 analyzes university policy and organizational structure.

6.2.1. Scenario 1: Environmental and Government Policy

To measure alternative environmental and government policies, it is assumed an increase of 10% in federal, industrial, and provincial financial resources invested in research projects at universities. However, the importance of external resources to support research efforts, and thus research results was already stated. This scenario aims to evaluate government policies directly affecting the internal conditions of developing research activities at Canadian universities.

Table 22 shows the results achieved under the environmental and policy scenario for the indicators characterizing stakeholders' performance participating in the process of UITT and spin-off creation in Canada. The most outstanding result suggests that an increase in the quantity of financial resources for funding academic research projects may generate an increase in the number of business ideas, patents, and spin-off patents generated. An increase in the amount of financial resources invested in academic research generates a similar change in the number of patents granted to universities and academics, as well as the number of university spin-off created. However, the assumption underlying this scenario is that researchers have adequate incentives to disclose their inventions for patenting and spinning off new companies. The motivation issue amongst researchers for disclosing their inventions has already been studied by some authors, such as Pirnay et al. (2003) and O'Shea et al. (2005).

Table 22. **Scenario 1: Environmental and Government Policy**

Stakeholders	Indicator Variables	2004	2010	2015
University-TTOs	Business Ideas	991	2,529	6,146
	TTO Total Incomes (000)	11,768	26,904	289,754
Commercialization Companies (CCs)	Business Ideas Developed Files	737	3,247	6,384
	Total Licensing Patents	673	2,403	4,706
	Patents	191	459	1,535
	CC Total Incomes (000)	35,494	578,772	1,846,197
Spin-Offs	Spin-Off Patents	48	115	384
	Royalties (000)	25,385	88,000	246,159
	Spin-Off Total Incomes (000)	56,698	183,230	504,770

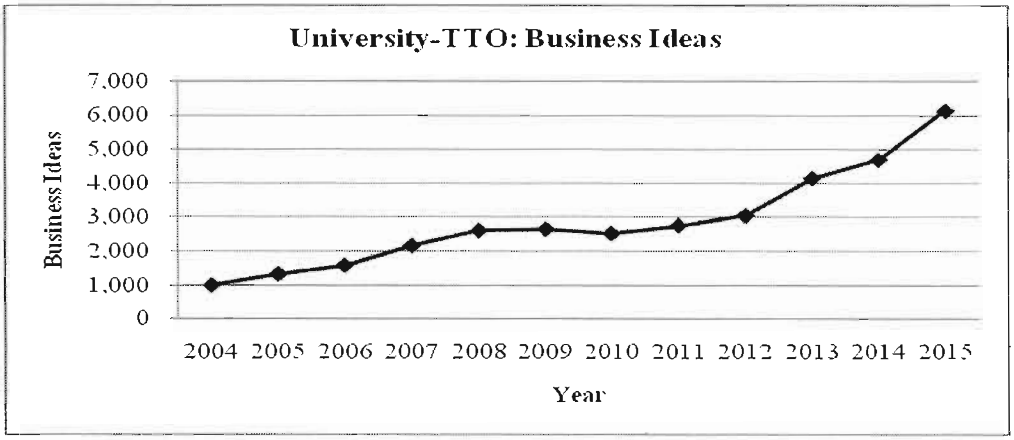
This result raises the questions as of why are some universities more effective at transferring technologies than other institutions. In the case of TTOs, Siegel et al. (2003b) and Siegel et al. (2007) conclude that TTOs' performance cannot be completely explained by environmental and institutional factors, but their organizational practices. These authors found three key impediments to effective university technology transfer: (1) informational and cultural barriers, (2) insufficient rewards for faculty members involved in university technology transfer activities, and (3) problems with staffing and compensation practices in the TTOs. In this sense, the royalty policy may continue to be the most important tool for stimulating the creation of new academic spin-offs. Belenzon and Schankerman (2007), for example, suggest that bonuses raise licensing income by increasing the quality of transacted inventions, while specifying local development objectives or imposing government constraints on licensing practices generally have a negative impact on licensing revenues. However, faculty involvement in the commercialization of a licensed university-based technology increases the likelihood that such technology may be successful (Jensen and Thursby 2001).

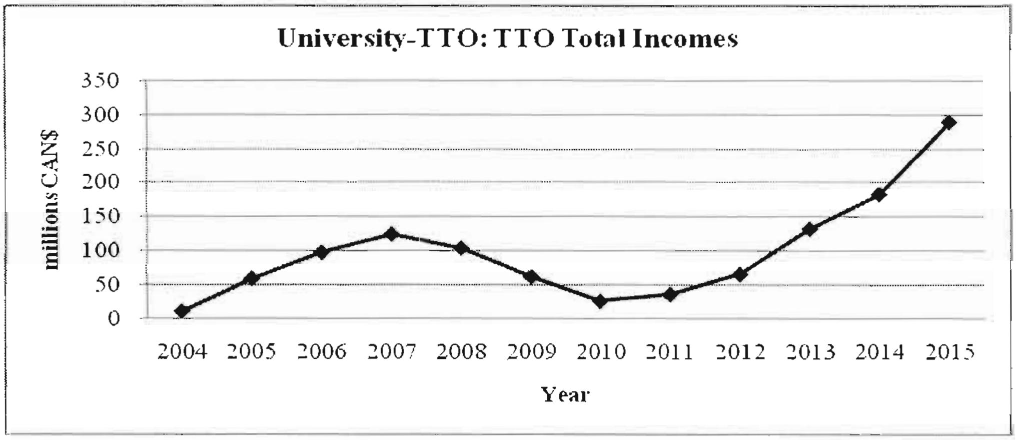
From a general perspective, an increase in the amount of external resources invested in research projects at Canadian universities makes worsening incomes at TTOs and spin-offs. An explanation to these results suggests that when there is a large quantity of business ideas developed files, bottlenecks can arise. Effectively, an increase in the quantity of resources invested in research projects at universities generates more patentable business ideas that should be accompanied by extra human and financial resources at TTOs, commercializing companies, and IP agencies to develop and evaluate business ideas patenting files and patent granting files.

These results raise the problem of the profitability of public financial resources, federal and provincial, to be invested in academic projects at Canadian universities. In this case, however, federal and provincial governments play a key role investing financial resources at universities aiming to improve the conditions to transfer new knowledge from universities to industry generating some kind of spillovers to the economy.

The variable business ideas estimated in this model was 991 in 2004, 2,529 in 2010, and 6,146 in 2015. These results suggest an average increase of 10% in this variable in relation to the results achieved in the reference scenario. However, from the perspective of the TTOs, external resources show to be extremely important to finance research projects at Canadian universities (figure 35).

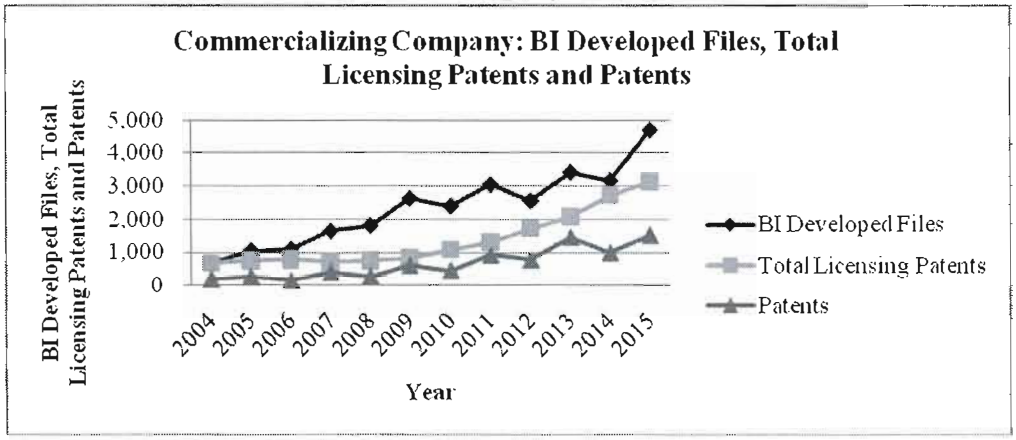
Figure 35. **Environmental and Government Policy Scenario: University-TTO**

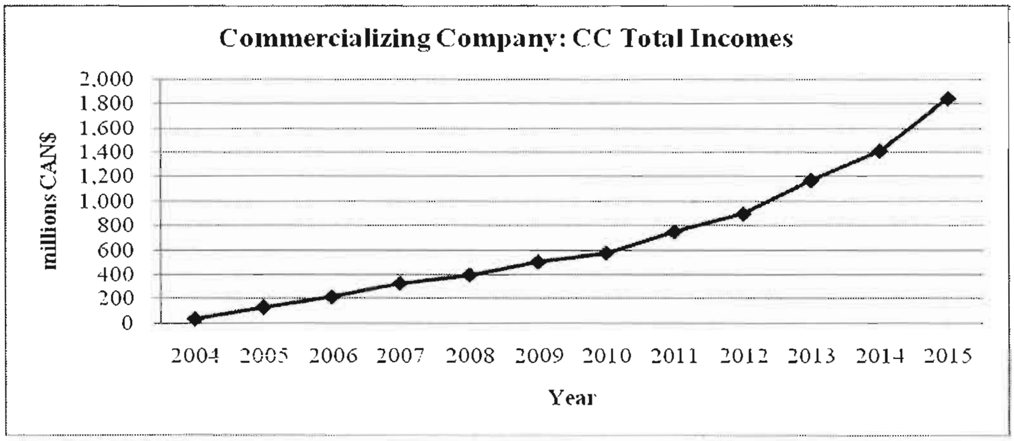




The variable TTOs incomes follows an oscillatory trajectory. Nevertheless, an increasing trend in this variable resulting from the fact that TTOs receive incomes from royalties and licensing is observed. In addition, TTOs in Canada also receive an important amount of financial resources by means of subsidy to perform technology transfer activities at universities. In 2003, for example, the Survey of Intellectual Property Commercialization in the Higher Education Sector reports that Canadian universities spent $36.4 million on IP management from different sources (Read 2005).

Figure 36. **Environmental and Government Policy Scenario: Commercialization Company**

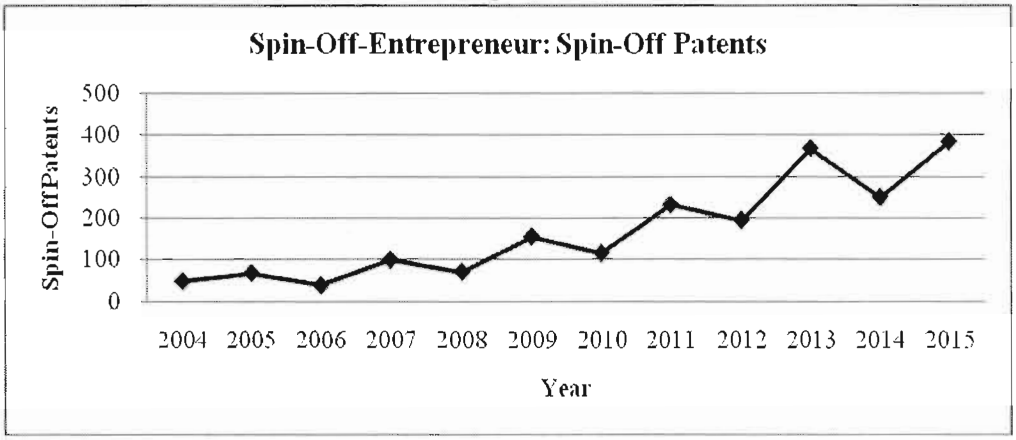


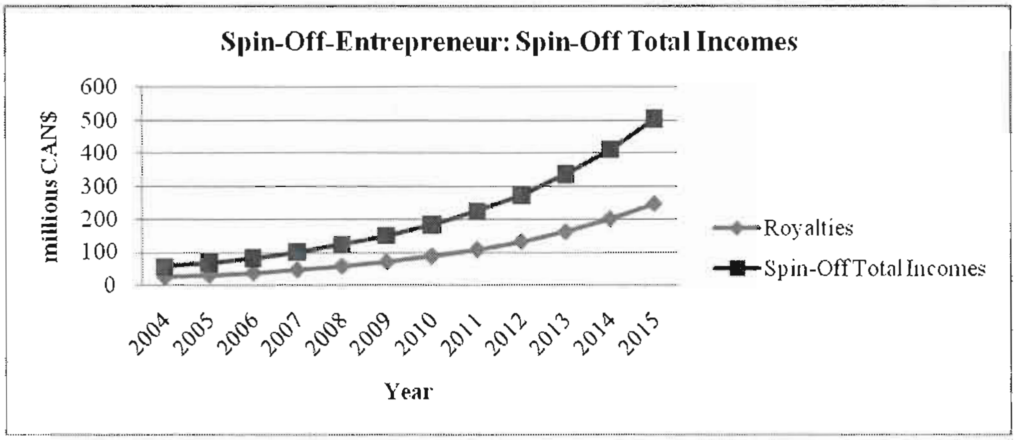


From the results achieved in this scenario in relation to commercialization companies, it is observed a significant growth in business ideas developed files, patents, and total licensing patents (figure 36). The variables business ideas developed files and patents follow an oscillatory path behavior resulting from the time delays characterizing the patent granting process. However, the variable total licensing patents demonstrated to be more stable due to the fact that in the model they remain active for twenty years, and the average time of licensing is four years (figure 41) The number of business ideas developed files estimated in this model under the environmental and government policy scenario is 737 in 2004, 3,247 in 2010, and 6,384 in 2015. In the same way, the number of patents granted in this model under this scenario is 191 in 2004, 459 in 2010, and 1,535 in 2015. Finally, the variable total licensing patents is 673 in 2004, 2,403 in 2010, and 4,706 in 2015. These results, as expected, suggest that an increase in the quantity of financial resources funding research has a positive impact on the activities developed by commercialization companies. The variable total incomes in the commercialization company subsector reports an increasing growth rate. The explanation to this behavior is due to the fact that commercialization companies receive incomes from royalties, licensing, equity, and interest.

Finally, spin-off patents follow an oscillatory trajectory path (figure 37). This behavior is influenced by number of patents granted characterized to be oscillatory too. In this model, the number of new spin-offs created was 48 in 2004, 115 in 2010, and 384 in 2015. However, for this indicator, the number of spin-offs reported by the AUTM Canadian Licensing Survey is 45 in 2004.

Figure 37. **Environmental and Government Policy Scenario: Spin-Off Entrepreneur**





6.2.2. Scenario 2: University Policy and Organizational Structure

This scenario concerns changes in university policy and organizational structure for evaluating the process of technology transfer and spin-off creation in Canada. Two different sets of variables are evaluated in relation to their impact on this process. The first set of variables concerns those affecting TTOs and CCs incomes. The second group of variables concerns to the results achieved by TTOs and CCs in terms of the number of patents granted and the number of new spin-offs created in Canada. The first group of variables includes a change in the royalty policy. The second group includes changes in the commercial analysis factor, rejecting factor, and patenting granting factor. Section 6.2.2.1 analyzes the impacts of a change in the royalty policy on technology transfer activity and spin-off creation, and Section 6.2.2.2 investigates the impacts of a change of the organizational structure on this phenomena.

6.2.2.1. Scenario 2a: A Royalties Policy Change

This scenario assumes that the value of parameter determining the royalty policy decreases from 0.5 to 0.4. This means that academic researchers and universities are more willing to actively participate in developing university spin-offs companies by means of equity. However, this policy translate into incentives for researchers to disclose their inventions, induce cooperation in bringing IP to market, and overcome asymmetric information problems related to the value of university inventions (Siegel et al. 2007).

Table 23. **Scenario 2a: University Policy and Organizational Structure: A Royalties Policy Change**

Stakeholders	Indicator Variables	2004	2010	2015
University-TTOs	Business Ideas	901	2,300	5,593
	TTO Total Incomes (000)	29,323	51,222	299,492
Commercializing Companies (CCs)	Business Ideas Developed Files	612	2,185	4,282
	Total Licensing Patents	612	986	2,843
	Patents	174	418	1,396
	CC Total Incomes (000)	31,851	544,148	2,546,419
Spin-Offs	Spin-Off Patents	43	104	349
	Royalties (000)	22,120	84,315	256,059
	Spin-Off Total Incomes (000)	61,146	217,814	651,925

Figure 38. **Royalties Policy Scenario: University-TTO**

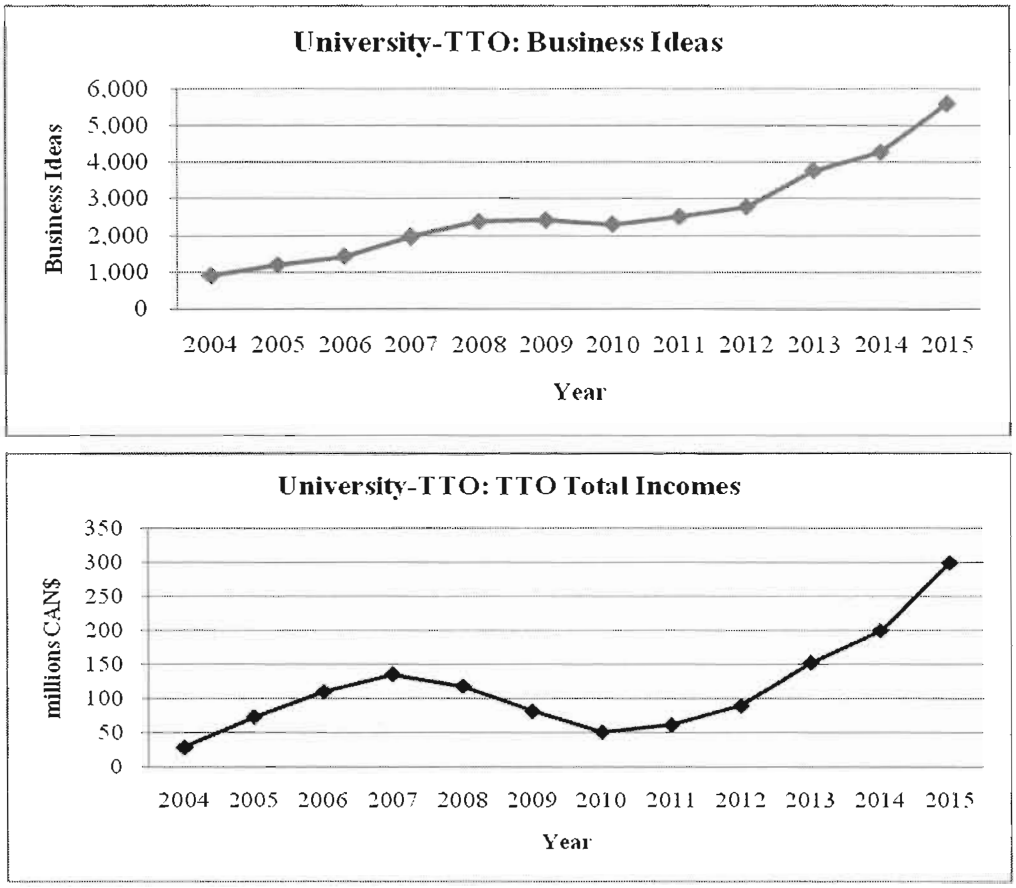
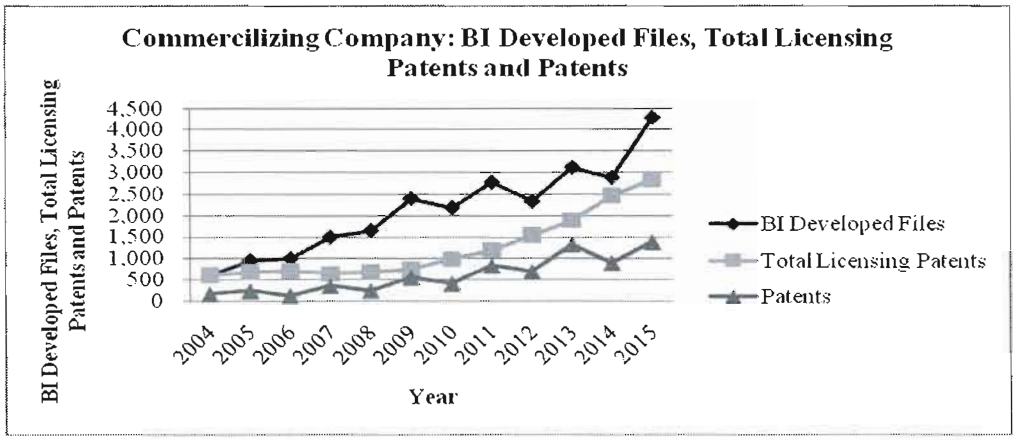
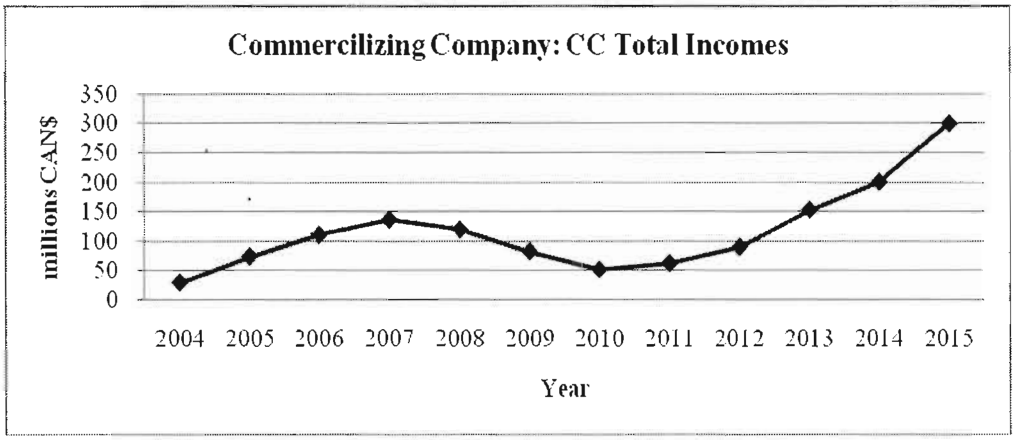


Table 23 shows the indicators estimated from the model calibrated under the assumption of a change in the royalties policy. In relation to the reference scenario, the number of business ideas, business ideas developed files, patents, total licensing patents, and spin-off patents in this scenario remains constant. One explanation for these results suggest that research results, and hence business ideas, emerge from research efforts mostly financed with federal, provincial, and industrial resources. On the other hand, it is expected that stakeholders participating in the process of technology transfer would prefer to invest in spin-offs already created. These explanations confirm that this policy slightly affects TTOs and commercialization incomes (figure 38).

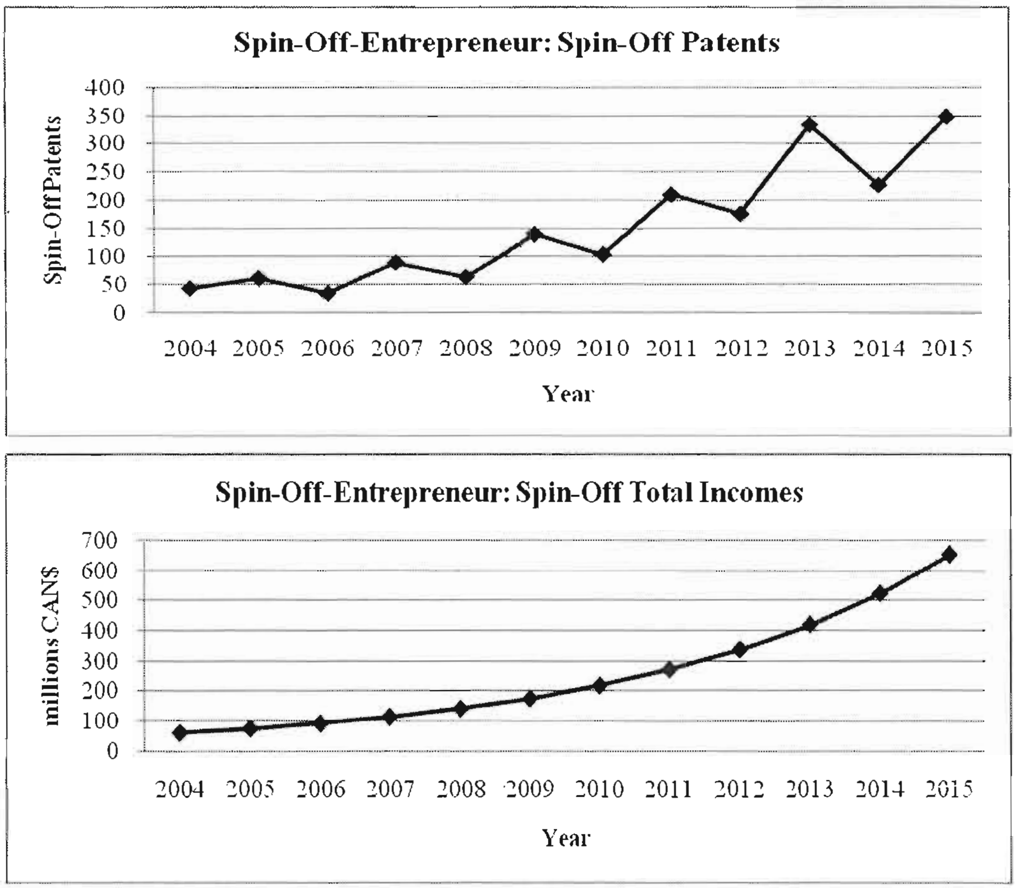
Figure 39. **Royalties Policy Scenario: Commercializing Company**





A change in royalty policy from 0.5 to 0.4 also affects royalties distribution to finance spin-offs purpose by means of equity or venture capital. In this case, for example, a change in the royalty policy would positively affect equity financing of spin-offs companies already created. This is another explanation why under this scenario only incomes received by spin-offs have a significant increase, but not incomes received by TTOs and commercializing companies (figure 39).

Figure 40. **Royalties Policy Scenario: Spin-Off-Entrepreneur**



In the case of the variable university spin-off patents, results confirm that a change in the royalty policy positively affects spin-offs incomes (figure 40). In the case of the results estimated in this model under the assumption of a royalty policy change, spin-offs incomes were \$61 millions in 2004, \$218 millions in 2010, and \$652 millions in 2015 that means a variation of 7.5%, 18.3%, and 28.3%, respectively, in relation to the reference scenario.

6.2.2.2.Scenario 2b: An Organizational Structure Change

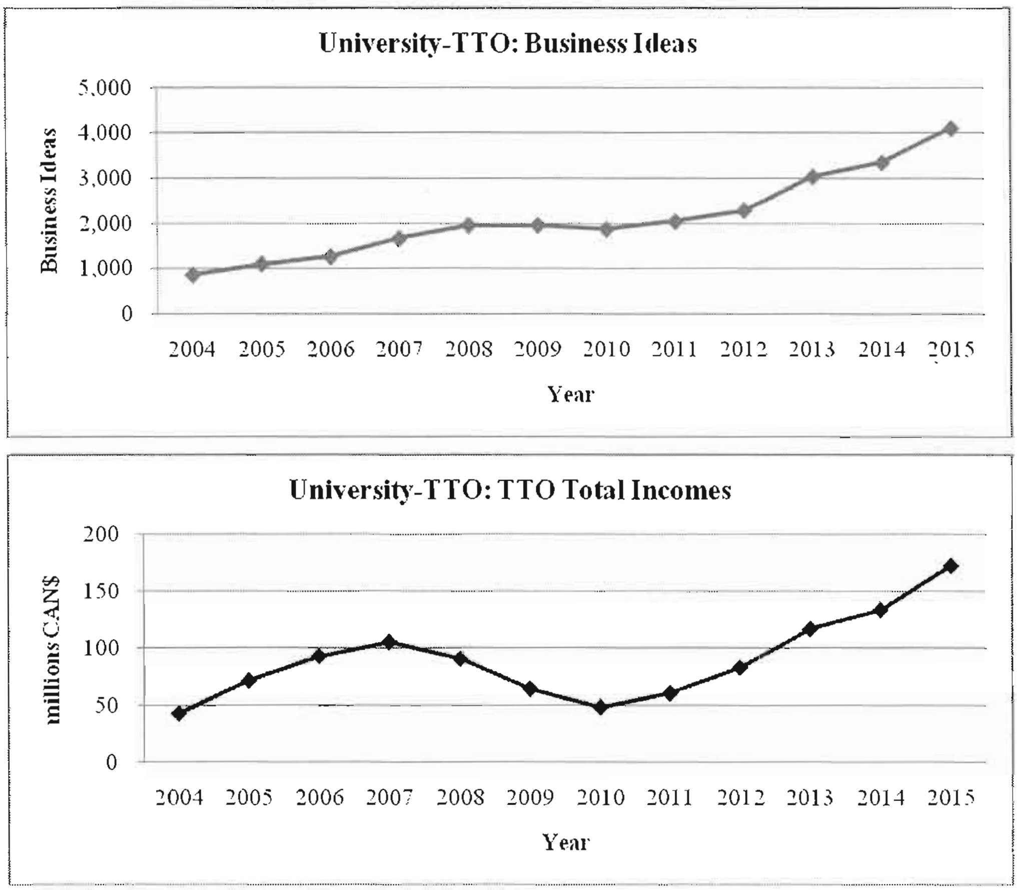
The organizational structure change scenario takes into account several changes in four parameter values. Specifically, it assumes that the commercial analysis factor changes from 0.7 to 0.6 in relation to the reference scenario. It also assumes that the licensing factor changes from 4 to 2 in relation to the same scenario. The patent licensing factor changes from 0.75 to 0.8, and the rejecting factor changes from 0.4 to 0.5.

Table 24. **Scenario 2b: Organizational Structure and University Policy: An Organizational Structure Change**

Stakeholders	Indicator Variables	2004	2010	2015
University-TTOs	Business Ideas	870	1,872	4,118
	TTO Total Incomes (000)	42,984	48,286	173,167
Commercializing Companies (CCs)	Business Ideas Developed Files	511	1,455	2,673
	Total Licensing Patents	428	679	1,575
	Patents	98	251	679
	CC Total Incomes (000)	26,994	397,823	1,238,606
Spin-Offs	Spin-Off Patents	20	50	136
	Royalties (000)	26,138	91,277	258,697
	Spin-Off Total Incomes (000)	57,655	188,528	525,033

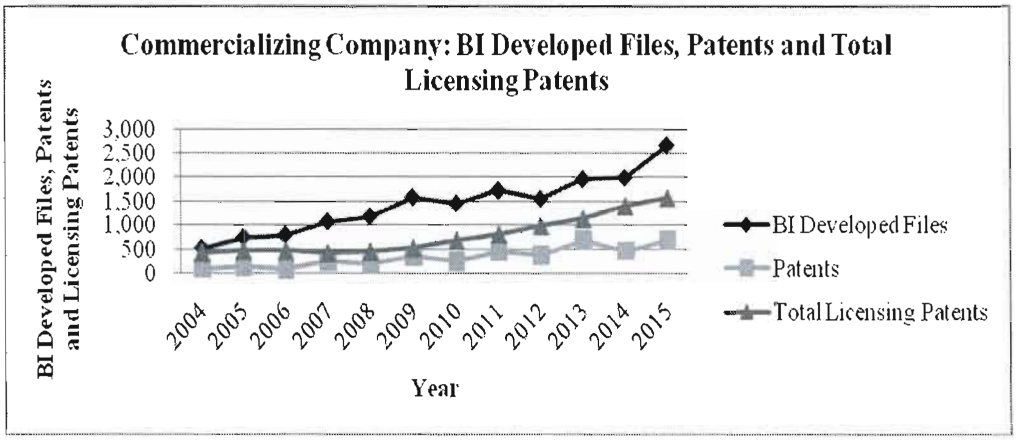
This specification allows for evaluating a less proactive activity in TTOs and commercializing companies in terms of patents and spin-offs creation. This means that the organizational structure change scenario is characterized to have less business ideas accepted as patenting files, and fewer patents to be licensed. Table 24 contains the results achieved in this scenario. From a general perspective, almost all indicators decrease in this scenario in relation to reference scenario with the exception of incomes received by spin-off companies.

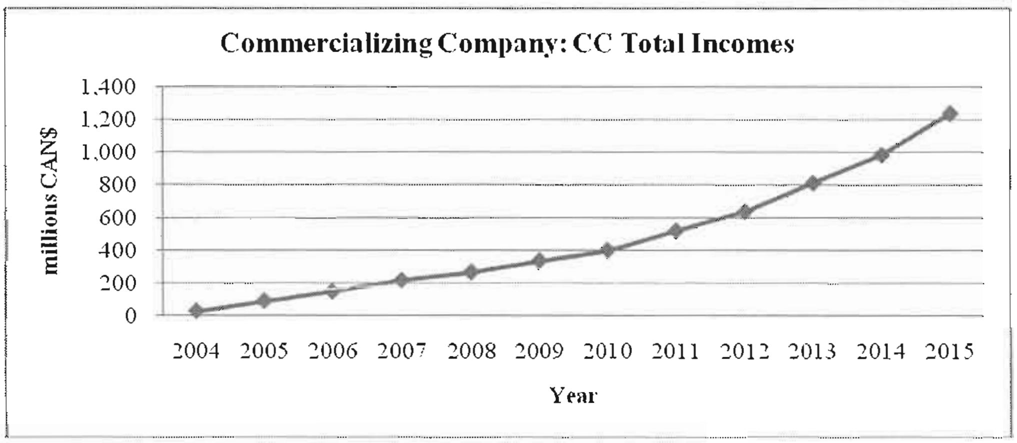
Figure 41. **Organizational Structure Scenario: University-TTO**



Business ideas decrease from 901 to 870 in 2004, from 2,300 to 1,872 in 2010, and from 5,589 to 4,118 in 2015. Consequently, these results generate fewer business ideas developed files and patents. The ultimate consequence is that the number of spin-offs reduces half the number estimated in the reference scenario. However, the total effects of the policy determining the organizational structure scenario are unambiguous in the medium and long term.

Figure 42. **Organizational Structure Scenario: Commercializing Company**





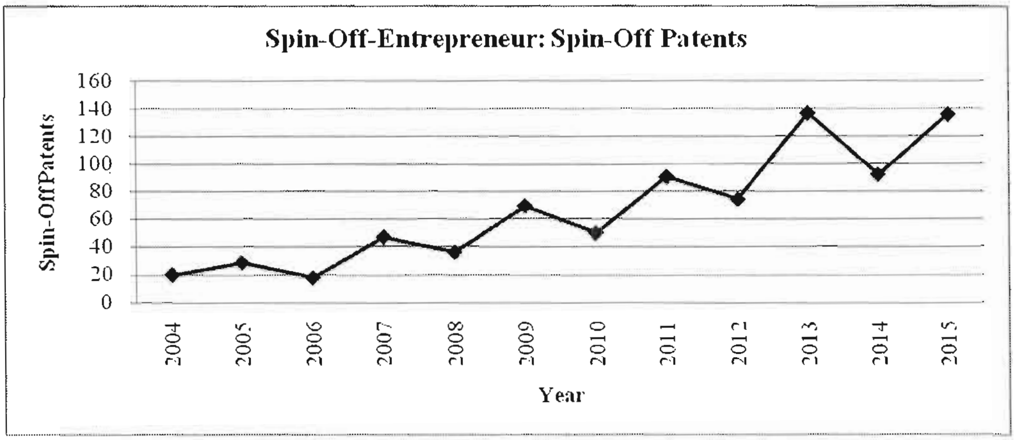
Incomes received by TTOs increase from $30 millions to $43 millions in 2004, but decrease from $53 millions to $48 millions in 2010, and also decrease from $302 millions to $173 millions in 2015. The explanation for these results is that policy affects not only the number of new spin-offs created, but also the number of patents licensed. However, there is a slightly increase in royalties that generates more spin-off incomes (figure 41).

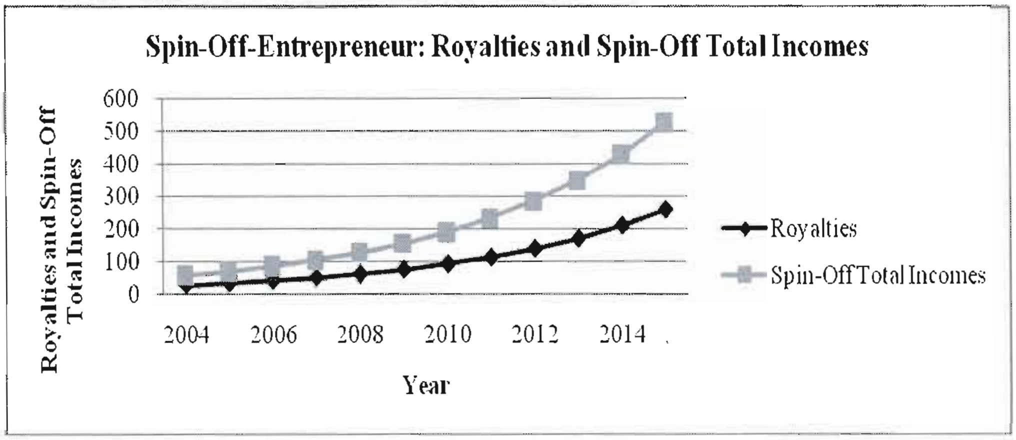
In relation to commercializing companies, as it was already stated, the number of business ideas developed files, patents, and total licensing patents decrease in the three years under this scenario (figure 42). In the same way, in relation to the reference scenario, incomes received by commercialization companies decrease from $32 millions to $27 millions in 2004, from $532 millions to $398 millions in 2010, and from $1,708 millions to $1,239 millions in 2015.

Finally, the number of spin-offs decreases in the three years analyzed in this scenario (figure 43). The number of spin-offs in relation to the reference scenario decreases from 43 to 20 in 2004, from 104 to 50 in 2010, and from 349 to 136 in 2015. However, this indicator is one of the most negatively affected by a change in the organizational structure policy.

It is important to mention that the only indicators positively affected by this policy are royalties and spin-off incomes. In effect, in relation to the reference, royalties slightly increase from $26 millions to $26 millions in 2004, from $89 millions to $91 millions in 2010, and from $508 millions to $525 millions. These results imply an increase in spin-off incomes of 1.4%, 2.4%, and 1.0% for these years, respectively. These percentages suggest that spin-offs activity will also be negatively affected in the long term. Moreover, the slightly and diminishing increase in spin-off incomes observed in these years derive from dynamics of the system that each year less spin-offs are created.

Figure 43. **Organizational Structure Scenario: Spin-Off-Entrepreneur**





6.3. Conclusion

This chapter presented the results achieved in the model of UITT and spin-off creation developed in this research. The results were estimated under three alternative scenarios: the baseline scenario, the environmental and government policy scenario and the university policy and organizational structure scenario. The indicators chosen for calibrating the scenarios were: business ideas, TTO total incomes, business ideas developed files, total licensing patents, patents, CC total incomes, spin-off patents, royalties, and spin-off total incomes. These indicators were chosen taking into account the material and financial stock-and-flow variables of all stakeholders participating in the process of UITT and spin-off creation in Canada.

The baseline scenario was calibrated in relation to the actual conditions of the process of technology transfer, and so the series obtained from this scenario matched with actual data series. The calibration process suggested that the model was reliable for describing the process of UITT and spin-off creation in Canada. However, the baseline model was then used as the basis for evaluating alternative policies under two other scenarios. The results achieved in these scenarios allowed for discussing the research questions raised in this research.

Under the environmental and government policy scenario, the objective was to evaluate how environmental variables affect the technology transfer process (know-how and technical change) from universities to industry. In this research, spin-off was considered as a fundamental form of UITT since it has important influence in regions. The question addressed in this scenario implies however that some universities are more effective at transferring technologies than other institutions. Results in this scenario were evaluated in terms of both material and financial outcomes. When the amount of external resources invested in research projects increased, incomes at TTOs and spin-offs worsen. The explanation was that the profitability problem arose in relation to extra resources already invested at universities. Effectively, when the amount of external resources has increased, organizational practices must be adapted to the new realm. It was tested however that patents, spin-off patents and business ideas developed files followed an oscillatory trajectory due to the fact that their path behavior was characterized by time delays.

The university policy and organizational structure scenario allowed for the evaluation of two different sets of variables: (1) royalties policy and (2) commercial analysis factor, rejecting factor and patent granting factor. Results in this scenario were also evaluated in terms of both material and financial outcomes. Under the first scenario, results suggested that the royalty policy affected rents (royalties) distribution, and thus the researchers' disposal for investing in spin-offs by means of equity. Results also suggested that this policy slightly affected TTOs and commercializing outcomes due to the fact that researchers might prefer to invest in spin-offs already created.

Finally, the organizational structure change scenario was evaluated in terms of a less proactive activity in TTOs and commercializing companies. As it was expected, these changes generate less business ideas developed files and patents, reducing then the number of patent spin-offs. An important conclusion in this scenario is that almost all indicators decreased in this scenario. However, in the short term and long term, TTOs incomes decreased given that the number of patents licensed also decreased.

General Conclusions

This research dealt with UITT and spin-off creation in Canada. As seen from Chapter 1, the research objectives of this research were twofold: (1) to provide an understanding of the relations established between stakeholders participating in the process of UITT throughout the creation of spin-off companies, and (2) to provide a SD model that illustrates UITT structural composition for analyzing and understanding the nature of the relations established among stakeholders participating in this process. The SD model developed in this research allowed for analyzing these practices. In fact, the two objectives could be analyzed simultaneously.

The main contribution of this research was to gain insight on the nature of the relationships established between stakeholders participating in the process of UITT and university spin-off creation regarding their decisions and goals. However, the SD approach allowed revealing the nature of these relationships and how the outcomes resulting from stakeholders' decisions would be affected by other stakeholders' actions and decisions in this process.

The first group of questions raised in this research concerned to the environmental conditions affecting the technology transfer process (movements of know-how and technological knowledge from one organization to another) from universities to industry. However, it was recognized that an important form of transferring technology from universities to industry was through patents and spin-offs creation. The second group of questions concerned to different university environments and specific organizational structures affecting the technology transfer process in terms of the resources and capabilities needed to create successful university spin-off companies.

To answer these questions, a baseline scenario and two other scenarios were evaluated. The baseline scenario allowed to establish the actual environmental conditions within technology is transferred and spin-offs are created. Two other scenarios were evaluated in terms of alternative policies aiming to support UITT and academic spin-off creation. The environmental and government policy scenario mainly evaluated changes in external funding resources for research. These changes explained however other changes in some variables characterizing stakeholders' performance in the process of UITT and spin-off creation. In the same way, the university policy and organizational structure scenario evaluated two different set of variables. The first set of variables was the one affecting the royalty policy. The second set of variables consisted in including the commercial analysis factor, rejecting factor and patenting granting factor.

The results achieved from the environmental and government scenario were evaluated in relation to the importance of internal (university) and external financial support (government and industry) for successfully developing academic spin-off projects. The evaluation of alternative financial funding for generating new business ideas suggested important conclusions. First, external sources are more important to generate research results, and thus business ideas. Second, when commercializing new business ideas, this finding confirms that external investors are more willing to invest in projects with a high degree of appropriability if research results (business ideas) are patented. Third, patents can be seen as an indicator of promising rents for external investors. Fourth, results confirmed the idea that external funding contributions stimulate the dissemination of research results by creating opportunities to develop joint venture initiatives. Finally, the importance of subsidy at the beginning when starting up a new academic firm to guarantee its success was also demonstrated.

On the other hand, as it was already mentioned above, the university policy and organizational structure scenario was evaluated for two different set of variables. First, it was evaluated a change in royalties policy suggesting a more willing participation in developing university spin-offs by means of equity. The results suggested that the variables business ideas, business ideas developed files, patents, total licensing patents and spin-off patents remained slightly constant. The explanation to these results is twofold. First, research results and business ideas emerge mostly from external funding sources. Second, stakeholders participating in the process of UITT would prefer to invest in spin-offs already created.

Finally, an organizational structure change (less proactive activity in terms of patents and spin-offs creation) was also evaluated through changes in four parameters: commercial analysis factor, licensing factor, patent licensing factor and rejecting factor. The results can be summarized as follows. First, almost all material indicators decreased. Second, royalties and incomes received by spin-off companies increased due to number of patents licensed.

However, these results were achieved through developing a SD model on UITT and spin-off creation. The remainder of this chapter present the conclusions on the main topics discussed in this thesis. To understand the process of technology transfer, three theoretical approaches were analyzed: the resource-based view of the firm, the business model perspective, and the institutional approach. In turn, the theoretical approaches studied in this research were used to develop an adequate theoretical framework to analyze this phenomenon. Five alternative theoretical models on spin-off creation were analyzed: the evolutionary schema, the entrepreneurial opportunity and entrepreneurial capacity model, the stage model an academic spin-off creation, the technology transfer office model, and the critical junctures model. An important conclusion achieved from this discussion was that these models should be seen rather as complementary when explaining UITT practices and spin-off creation. As it was already stated in the literature review of this research, these approaches share some common phases when explaining the process of UITT and spin-off creation: business ideas generation, finalization of new venture projects out of ideas, launching new spin-off firms from projects, and strengthening the creation of economic value by spin-offs.

However, each approach contributes with specific features to explain the process of spin-off creation.

In the same way, the theoretical explanations on the process of technology transfer reviewed in this thesis share common explanations that could be complementary to explain the process of technology transfer. The resource-based view of the firm and the institutional perspective, for example, form two complementary theoretical bases for developing an adequate theoretical framework to analyze the university spin-off creation phenomenon. In this sense, it was also discussed the need to develop a dynamic approach to investigate the concerns related to spin-offs emergence and growth. It was suggested, in this research, that the main concern in this process relates to conflicting objectives between participating stakeholders. Effectively, uncertainty, information gaps, lack of receptor capabilities, and conflicts of interests between stakeholders reveal to be a source of conflicting objectives when transferring technology from universities to industry. Furthermore, stakeholders' actions, motives, and perspectives are at times in contradiction or conflict between each other. Furthermore, this perspective opens up new challenges in the analysis of technology transfer. It was also recognized that spin-offs companies emanate from a non-commercial environment, and the importance to analyze the conditions for which adequate resources and competences are guaranteed in the process of spinning off new firms was stressed.

From this perspective, this study contributed to fill an important gap remaining related to the research methods used in the analysis of technology transfer since most part of studies conducted until now are largely cross sectional. It was argued that the use of SD methods is actually an adequate standpoint for analyzing technology transfer and spin-off creation. Furthermore, the SD approach facilitates the analysis of the role of feedback loops and the potential for non-linear development in that some kind of resource differences, weaknesses, and inadequacies may constrain the spin-off development process that may be exacerbated by an un-entrepreneurial university environment.

The fact is that SD principles emphasize the importance of complexity characterizing the structure of organizations. This approach allowed for knowing and characterizing the underlying structure of spinning off university companies. However, structural change and uncertainty are the most important sources of complexity in SD. When modeling using SD methods, it was recognized the importance to take into account feedback loops, the stock and flow structure, time delays, and nonlinearities characterizing the process of spin-off creation. The model developed in this research was actually constructed as a complex, multi-loops and interconnected system. Such an approach allowed modeling the process of technology transfer and spin-off creation as a process where cause and effect relationships are generally distant in time and space.

From the perspective of the SD methods, simulation allowed the possibility to evaluate change and its consequences for the evolution of a system over time. However, the simulation process using SD methods implied a problem definition, the formulation of a dynamic hypothesis, the formulation of a simulation model, a testing process, and a policy design and evaluation. The model developed in this research aimed to model stakeholders' behavior. Each actor (university-TTOs, commercializing companies and spin-off entrepreneurs) was characterized to maintain two different kinds of relationships linked through material and financial stock-and-flow variables. This approach allowed for a global perspective on how technology transfers from universities to industry.

To understand how research results were transformed into business ideas and patents for creating university spin-off companies, research results were transformed into business ideas through a Poisson distribution due to difficulties and uncertainty inherit to R&D expenditure (federal, provincial and industrial). This process implied a random selection resulting in research outcomes for being tested on opportunity. Once the model was developed, the objective was to answer the questions raised in this research. On the one side, this research explored how uncertainty, informational gaps, and lack of receptor capabilities influence the success of spin-off companies within a non-commercial environment and conflicting objectives of key stakeholders. In this sense, this research searched to gain insight on how the environment effects of the movements of know-how, technical knowledge, and technology transfer on university spin-off creation. Besides, this research aimed to get answers on how different university environments and specific organizational structures affect the process of technology transfer. A baseline scenario and two other scenarios were then evaluated in terms of alternative policies. The baseline scenario was calibrated as the actual conditions for transferring technology from universities to industry in Canada.

This model recognized that TTOs can be taken over by an independent university-owned company or carried out through a separate administrative division within the university. Besides, it was established that there were important differences between the level of collaboration with university research services divisions and external partners. Finally, TTOs were either following a "general approach" or set up units dedicated to a particular technology transfer function. However, in the case of Canada, it was possible to analyze UITT and spin-off creation within a general framework including three stakeholders participating in this process: university-TTOs, commercialization companies, and spin-offs-entrepreneurs.

Results achieved from the baseline scenario suggested that research results and business ideas were strongly linked. The value of these variables depended on the effectiveness of the financial funding sources to generate results with a high degree of commercial opportunity. As it was already mentioned before, it was established that external sources funding were extremely important in terms of the effectiveness for generating results from research, and thus business ideas. Additionally, it was established the importance of the role played by subsidies when funding research, as well as TTOs and commercialization companies activities. Accordingly, TTOs activity was evaluated for the importance of internal (university) and external (government and industry) financial support for successfully developing university spin-offs. It was concluded that in Canada, external financial support was more important than internal financial support to the process of knowledge and technology transfer, and spin-off creation.

It was suggested that one explanation for these facts might be that government and industry research funding may act as incubators for patenting and spinning off new academic companies, allowing universities learning to patent and creating incentives for promising inventions. However, these results also confirmed that government and industry funding contributions stimulate new academic spin-offs development through the dissemination of research results.

Two other scenarios were evaluated: (1) an environmental and government policy scenario; and (2) a university policy and organization structure scenario. The environmental and government policy scenario was defined assuming a 10% increase in federal, industrial and provincial financial resources invested in research projects at universities. An important result achieved in this scenario was that an increase in the quantity of financial resources for funding academic research projects generated an equivalent increase in the number of business ideas, patents, and academic spin-offs. In fact, this scenario aimed to evaluate the problem of profitability of public financial resources for investment in research projects at Canadian universities. However, it is important to keep in mind that two important assumptions were established in this research. First, all spin-off patents are developed as new university spin-offs, therefore the number of spin-off patents estimated in this model was equivalent to the number of new spin-offs created. Second, it was assumed that researchers maintained adequate incentives to disclose their inventions for patenting and spinning off new companies.

The first assumption simplified the interpretation of the results obtained in this model. Nevertheless, rejecting the second assumption implied to take into account some features impeding effective technology transfer: informational and cultural barriers between stakeholders participating in the process of technology transfer, insufficient rewards for scientists involved in university technology transfer activities, and potential problems with staffing and compensation practices in TTOs and commercialization companies.

The university policy and organization structure scenario alternative scenario was analyzed from two different perspectives. One perspective aims to evaluate changes in the royalty policy. The other perspective aims to evaluate changes in the commercial analysis factor, rejecting factor, as well as patenting granting factor. However, the two approaches allowed for gaining insight on changes in university policy and organization structure.

The results achieved under this scenario established a decrease in the value of this parameter. This assumption implied that researchers at Canadian universities were more willing to actively participate in developing spin-offs companies by means of equity. The results in this scenario confirmed that the number of business ideas, business ideas developed files, patents, total licensing patents, and spin-offs remained constant. Additionally, this result corroborated the fact that research results and business ideas emerging from a non-commercial environment revealed some kind of conflict of incentives between TTOs/commercializing companies and investors. It seems that venture capitalists and other investors would prefer to invest in spin-off companies already created, but not in developing new spin-offs. In fact, a change in royalty policy would affect royalties distribution by means of equity and venture capital. In this scenario, a change in royalty policy would affect positively equity financing of spin-off companies already created.

The results achieved in the perspective of the organizational structure scenario evaluated changes in four parameters: the commercial analysis factor, the licensing factor, the patent licensing factor, and the rejecting factor. This scenario allowed for evaluating a less proactive activity in TTOs and commercializing companies. The results confirmed that a change in the organizational structure is characterized to have less business ideas for patenting. However, the total effects of the policy determining the organizational structure scenario were conclusive in the medium and long term. However, it was appreciated a slightly increase in royalties that generates spin-off incomes. Finally, in this scenario, the number of business ideas developed files, patents, total licensing patents, and new spin-offs decreased, meanwhile royalties and spin-off incomes increased in the period of time considered in this research.

The limitations arising into this research show the need for developing analyses at firm level. Effectively, it would be interesting to get insight on how specific university spin-off companies acquire successful practices for improving their performance in markets. In this sense, literature on UITT and spin-off creation in Canada suggests that there are some specific areas where spin-offs are more predisposed to be developed.

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