UNIVERSITÉ DU QUÉBEC À MONTRÉAL

THE ADOPTION AND DIFFUSION OF BIOTECHNOLOGIES IN EMERGING COUNTRIES: THE CASE OF MEXICO

DISSERTATION

PRESENTED

AS PARTIAL REQUIREMENT OF

THE DOCTORATE OF ADMINISTRATION

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UNIVERSITÉ DU QUÉBEC À MONTRÉAL

L'ADOPTION ET LA DIFFUSION DES BIOTECHNOLOGIES DANS LES PAYS ÉMERGENTS: LE CAS DU MEXIQUE

THÈSE

PRESENTÉE

COMME EXIGENCE PARTIELLE

DU DOCTORAT EN ADMINISTRATION

PAR

JULIETA FLORES AMADOR

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ABBREVIATIONS AND ACRONYMS

AMC	Academia Mexicana de Ciencias, Mexican Academy of Sciences, Mexico
CINVESTAV	Centro de Investigaciones y Estudios Avanzados Centre for Research and Advanced Studies, Mexico
CONACYT	Consejo Nacional de Ciencia y Tecnología National Counseil for Science and Technology , Mexico
DBF	Dedicated Biotechnology Firm
DNA	Deoxyribonucleic Acid
GDP	Gross Domestic Product
GMO	Genetically Modified Organisms
HEI	Higher Education Institution
IMSS	Instituto Mexicano del Seguro Social Mexican Institute of Social Security, Mexico
IPN	Instituto Politécnico Nacional National Polytechnic Institute, Mexico
IPR	Intellectual Property Rights
ITESM	Instituto Tecnológico de Estudios Superiores de Monterrey Technology Institute of Higher Studies of Monterrey, Mexico
LBMOGM	Ley de Bioseguridad para el Manejo de Organismos Genéticamente Modificados Biosecurity Act for the Management of Genetically Modified Organisms, Mexico
NSI	National System of Innovation
OECD	Organizations for Economic Cooperation and Development
PECYTI	Programa Especial de Ciencia y Tecnología Special Program for Science and Technology, Mexico
PECITI	Programa Especial de Ciencia, Tecnología e Innovación Special Program for Science, Technology and Innovation, Mexico

PRC	Public Research Centre
R&D	Research and Development
RSI	Regional System of Innovation
S&T	Science and Technology
SNI	Sistema National de Investigadores National System of Researchers, Mexico
SME	Small and Medium Enterprises
SSI	Sectoral System of Innovation
STI	Science, Technology and Innovation
UANL	Universidad Autónoma de Nuevo León Autonomous University of Nuevo León, Mexico
UdeG	Universidad de Guadalajara University of Guadalajara, Mexico
UNAM	Universidad Autónoma Nacional de México National Autonomous University of Mexico
UAM	Universidad Autónoma Metropolitana Metropolitan Autonomous University, Mexico
USPTO	United States Patent and Trademark Office
UVTC	Unidad de Vinculación y Transferencia de Conocimiento Linkage and Knowledge Transfer Units, Mexico
VC	Venture Capital

RÉSUMÉ

La contribution à la croissance économique en raison des secteurs de haute technologie, a fait que certains pays émergents ont tenté de développer des secteurs basés sur l'innovation et la technologie, incluant la biotechnologie. Cependant, l'adoption et la diffusion des biotechnologies dans ces pays ont rencontré des difficultés de nature institutionnelle et managériale. Malgré ces difficultés, quelques innovations se sont produites, et quelques entreprises ont réussi à incorporer des biotechnologies dans leurs procédés de production. Ce constat nous amène au questionnement suivant : comment les entreprises dans des pays émergents adoptent-elles les biotechnologies modernes? Sur la base de trois approches : management stratégique, grappes de haute technologie, et politiques publiques, je vais me concentrer sur le cas du Mexique pour analyser cette problématique.

Cette recherche repose sur différentes sources d'information : des entrevues, deux questionnaires, des bases de données de publications et de brevets, et des rapports officiels et de consultation. Vingt cinq entrevues face-à-face ont été menées auprès de différents agents participants dans la biotechnologie au centre du pays. Les résultats de cette recherche montrent qu'au Mexique, les entreprises qui utilisent des biotechnologies, spécialement les biotechnologies modernes, sont normalement de moyennes et grandes entreprises bien établies dans leurs marchés. Ces entreprises ont accumulé différentes capacités à travers le temps, circonstance qui leur permet de mieux comprendre les nouvelles technologies pour améliorer leurs produits et procédés, et par conséquence rester sur le marché, leur principal objectif. Ainsi, on peut argumenter que leur modèle d'affaires est de caractère imitatif. Également, ces entreprises ont besoin d'établir des liens avec d'autres agents pour accéder aux nouvelles connaissances. Pour cette raison, elles ont établi des collaborations avec des agents qui peuvent se trouver tant au pays qu'à l'étranger. Pendant la dernière décennie, le gouvernement mexicain a essayé de mettre en place des politiques de technologie et d'innovation, mais le manque de vision à longue haleine et les contraintes budgétaires font que les résultats soient maigres. Donc, les entreprises désirant adopter des biotechnologies au Mexique, font face à des obstacles importants.

Mots clés : biotechnologie, modèle d'affaire, grappes de haute technologie, politiques de science et technologie, pays émergents, Mexique.

ABSTRACT

The contribution to economic growth by high technology sectors has stimulated some emerging countries to establish policies in order to encourage the development of those sectors, including biotechnology. However, the adoption and diffusion of biotechnologies in emerging countries seem to face several institutional and managerial obstacles. Nevertheless, some innovations have been developed and some local firms have incorporated modern biotechnologies into their production processes. Therefore, a general question is raised: how do firms in emerging countries adopt modern biotechnologies? In order to analyze this subject, I use three different literature bodies –strategic management, high technology agglomerations, and public policies-, and I take the case of Mexico.

Different sources were used to gather information: interviews, questionnaires, publications and patent databases, and institutional and consulting reports. Twenty-five face-to-face interviews were carried out with different agents in the central region of Mexico. The empirical evidence shows that enterprises using biotechnologies, especially modern biotechnologies, in Mexico are medium and large, established enterprises. They have accumulated different capabilities that allow them to improve their products and process in order to remain on the market, their main objective. Therefore, it is argued that they follow "imitation business models". They have established collaboration agreements with national and international agents to access new knowledge. In the last decade, the Mexican government has started to implement innovation and technology policies, however, the lack of a long-term vision and the reduced budget dedicated to this end, set challenges for the adoption of biotechnologies.

Key words: Biotechnology, business models, high-technology agglomerations, science and technology policies, emerging countries, Mexico.

INTRODUCTION

High technologies play an important role in economic growth – biotechnology among them. Biotechnology involves a group of technologies (i.e. genetic engineering, bioleaching, bio pulping, bioinformatics, genomics, proteomics, and others) based on advances of science of the last sixty years (i.e. biology, biochemistry, genetics) that are used in different industries. This wide and multidisciplinary knowledge base drives biotechnology firms to complement their capabilities in order to create new products. The empirical evidence in developed countries shows that most biotechnology enterprises present well-defined characteristics: close relationships with knowledge-creating organizations, collaboration between different organizations and institutions for innovating, and agglomeration in specific regions (Niosi et al., 2005; Cooke, 2007). These characteristics have an impact on the way biotechnology firms create and capture economic value (Pisano, 2006; McKelvey, 2008).

In the last two decades, some emerging and developing countries have promoted policies to trigger the adoption of biotechnologies, especially modern biotechnology. Biotechnology is seen as an instrument to overcome some of the serious problems faced by developing countries, such as those related to health, food and environment (Nature Biotechnology, 2004). However, the adoption[1] and diffusion of biotechnologies in some emerging and developing countries face shortage of financial resources, specialized workforce, and access to sophisticated institutions; these facts have implications in the manner enterprises adopt and develop biotechnologies, especially the more complex ones. Under these circumstances, attention turns toward questions about the potential to create and consolidate biotechnology clusters in emerging countries and the importance of government intervention to accomplish this task.

Recently, the Mexican biotechnology landscape has changed: some local firms have

[1] Adoption refers to use biotechnologies for manufacturing or developing products and services.

started to adopt new biotechnologies, collaboration between different agents (university, firms, and associations) are more frequent, and government initiatives have been implemented to promote the adaptation of new technologies. The general **objective** of this research is to understand firms' adoption of generic high technologies[2] (that can be used in different industries) that usually require complementary knowledge from other agents, in an institutional environment not well developed in terms of knowledge production, financing and small government support. I propose to analyze this situation with the case of Mexico, which is an emerging country that recently has started to adopt biotechnologies.

The **questions** of this research are the following:

- What kinds of biotechnology users, actual or potential, exist in Mexico, and what kinds of biotechnologies have been adopted? What business models are emerging in the Mexican-specific economic environment?

- Given that high technologies tend to agglomerate, does Mexico have the potential to create and support a biotechnology cluster? What kinds of collaboration, if any, have emerged?

- How could the Mexican public policy framework be improved in order to support the adoption and diffusion of biotechnologies?

Three closely related literature bodies are used to analyze these questions: strategic management, regional agglomerations, and science, technology and innovation (STI) policy literatures.

Biotechnologies are based on scientific discovery and involve different scientific

[2] Chapter I describe the characteristics and types of biotechnologies.

disciplines. Therefore, the industrial application of biotechnologies calls for a close relationship between scientific and managerial capabilities, which implies some difficulties given the different natures of both capabilities. The creation and capture of economic value is related to economic activities that are embedded in enterprises. When scientific researchers look for producing and capturing economic value they face different obstacles that impede them to translate their scientific knowledge into commercial products. In this sense, the strategic management literature –which includes business models, capabilities and collaboration networks— is useful to analyze why and how agents, involved in the creation and capture of scientific and economic value, interact to complement their capabilities, particularly in emerging economies where resources are scarce and relationships among different agents are not well structured.

High technology enterprises tend to agglomerate in specific regions. In the case of biotechnology, different organizations are involved in the processes related to the creation, development and commercialization of products –e.g. universities, public and private research labs, government agencies, enterprises, and associations. In order to integrate the capabilities of such different organizations, collaboration is needed. This collaboration can vary over time. In this sense, regional agglomerations and innovation literatures provide the framework to analyze what variety of capabilities can be integrated and how the agglomeration evolves over time. This analysis can improve our understanding about the complex relations between different actors needed to foster high technology agglomerations in emerging countries.

Government intervention plays an important role for the development of high technology industries. In the case of biotechnology, the creation of scientific knowledge and the translation of this knowledge into commercial products require large investments in infrastructure, the development of scientific, managerial, and

operational capabilities, and market support. Governments at different levels (national, regional and local) often design and implement a variety of policies and programs that encourage and support the activities involved in biotechnology, to create an environment that allows the interaction between agents. In this sense, public policy literature focused on science, technology and innovation is useful to analyze how governments are involved in the adoption and diffusion of biotechnologies.

This document is divided into two parts. **Part I** includes the theoretical framework, the description of the Mexican institutional environment, and the methodology of this research. **Chapter I** presents the main characteristics of biotechnologies and their implications for strategic management. In addition, this chapter shows an overview of the adoption of biotechnologies in emerging countries. The following three chapters present the different literature bodies that build the theoretical framework of this research: **Chapter II** deals with the concept of business model. **Chapter III** presents the concepts and dynamics of regional agglomerations, and **Chapter IV** presents the importance of public policies and how they encourage and support biotechnology. **Chapter V** presents the characteristics of the Mexican system of innovation. **Chapter VI** presents the integration of the concepts used in this research. In **Chapter VII** the hypotheses and methodology are presented. **Part II** includes the empirical results and conclusions of this thesis. **Chapter VIII** presents the analysis and discussion of results. **Chapter VIII** deals with the STI policies implemented in emerging countries, such China, India, Singapore, and Mexico. Finally, **Conclusions** of this research are presented at the end.

PART I. THEORETICAL FRAMEWORK AND CONTEXT

CHAPTER I
BIOTECHNOLOGY IN EMERGING COUNTRIES: AN OVERVIEW

The objective of this chapter is to present the definition and evolution of biotechnologies. This chapter is organized as follows: in section 1.1 the definition of biotechnology and its main characteristics are presented, section 1.2 deals with the characteristics of the adoption of biotechnology in developed countries, and section 1.3 shows some evidence on how emerging countries have performed the process of catching up of modern biotechnologies.

1.1 Biotechnology: definition, knowledge base and multidisciplinary nature

Biotechnology is defined as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services" (OECD, 2005: 9). In addition, biotechnology encompasses different kinds of knowledge embedded into new technologies to obtain and manipulate new molecules (Pisano, 2006). Given that "[m]odern biotechnology depends on advances in different fields of medical science, natural science and engineering… Modern biotechnology is more than knowledge [about biotechnological mechanisms]— indeed its impacts come about through the combination of increasing knowledge with techniques and instrumentation" (McKelvey et al., 2004: 25).

Some authors divide the historical evolution of biotechnologies into three generations: the 'first generation or traditional biotechnology' is characterized by the empirical application of yeast and bacteria for food processing (e.g. beer and yogurt), and selective animal breeding. It has been in use for thousands of years. The 'second generation of biotechnology' dates from the early twenty century. It was seen as an

industrial tool: "[they] become a tool in the hands of engineers when biotechnology based production process became industrialized ... [e.g.] bioprocessing in order to make biopharmaceuticals and fine chemicals such as penicillin and citric acid respectively" (McKelvey et al., 2004: 24). The 'third generation or modern biotechnology' started in the 1950s with the work of Watson and Crick, who described the structure of DNA as a double helix, these scientists set the foundation for the development of the science of molecular biotechnology (Powell et al., 1996). Then, in the 1970s, there were three main events that changed the way to obtain molecules: "Cohen and Boyer's 1973 breakthrough in genetic engineering methods enable gene reproduction in bacteria and heralded the arrival a new era. Cesar Milstein and Georges Köhler produced monoclonal antibodies using hybridoma technology in 1975, and in 1976, DNA sequencing was discovered and the first working synthetic gene developed" (Shan et al., 1994: 388). The most remarkable characteristic of the third generation is its closeness with scientific discovery: "[t]he third generation is explicitly based on underlying scientific progress whereas the first and second generation were more technological applications, without a solid scientific understanding of the underlying biological process" (McKelvey et al., 2004: 24).

Accordingly, modern biotechnology encompasses a range of different techniques. The OECD (2005, 2009: 9) suggests a list of biotechnology techniques:

- DNA/RNA: Genomics, pharmaco-genomics, gene probes, genetic engineering, DNA/RNA sequencing/synthesis/amplification, gene expression profiling, and use of antisense technology.

- Proteins and other molecules: Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signalling, identification of cell receptors.

- Cell and tissue culture and engineering: Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.

- Process biotechnology techniques: Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration and phytoremediation.

- Gene and RNA vectors: Gene therapy, viral vectors.

- Bioinformatics: Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.

- Nanobiotechnology: Applies the tools and processes of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics, etc.

Although these techniques can be applied to different industrial fields and sectors, the most dynamic sectors are those related to human health and agriculture (Kenney, 1986).

1.2 Commercial applications of modern biotechnologies

Modern biotechnology commercialization began in the 1970s in California, USA. Two enterprises are associated to the origin of the industrial use of biotechnology: Cetus and Genentech. Cetus Corporation was established in 1972 and founded by a group of scientists (P. Farley, a physician; R. Cape, a biochemist; D. Glaser, a Nobel Laureate physicist; and several others) for commercializing recombinant DNA technology (Demain, 2004). Genentech was established in 1976 and founded by Herbert Boyer (a biochemist) and Robert A. Swanson (a venture capitalist) for exploiting the commercial potential of genetic engineering science (Pisano, 2006)[3]. During the late 1970s and early 1980s, several scientists from prestigious universities

[3] Cetus was sold to Chiron Corporation in 1991, which was acquired by Novartis in 2006. In 2009, Genentech was acquired by a large pharmaceutical, Roche Group.

founded biotechnology enterprises in developed countries (e.g. Amgen, Biogen, Chiron, Genetics Institute, Genzyme). These events revealed the strong relation between biotechnology scientific discoveries and industrial applications. Therefore, enterprises looking for commercializing biotechnology products have to have scientific background, which generates a particular challenge. In Pisano's words, biotechnology enterprises are science-based businesses, which means "commercial enterprises that attempt to both, create science and capture value from it" (Pisano, 2006: 2).

What have been the implications of this scientific base for enterprises developing and using biotechnologies? The scientific base of biotechnologies has implications that affect the dynamics and organizational designs of the following organizations: universities and research centres, and new firms and large established companies.

Several authors have emphasized the importance of universities and research centres in the invention and development of biotechnologies, particularly in knowledge advancement and the formation and training of specialized workforce (Cooke, 2007; Cockburn and Stern, 2010). Since the beginning of the industrial applications of modern biotechnologies in the late 1970s, the creation of new enterprises dedicated almost exclusively to R&D activities is related with the presence of star scientists in academic and research environments. As university scientists realize that their intellectual knowledge could be translated into a product, they occasionally think of establishing an enterprise or spin-off in order to appropriate its economic value.

They often keep contact with their colleagues at universities and research labs in order to obtain information of new scientific advances, and to recruit new scientists who are trained in state-of-the-art techniques and methodologies (Audretsch, 2001). The recruitment of young scientists is important since "biotechnology is characterized

by high degrees of natural excludability, i.e. the techniques for their replication are not widely known and anyone who wishes to build on new knowledge must gain access to the research team of the laboratory setting that know-how" (Fuchs and Krauss, 2003: 4). In other words, science is the critical input for creating new biotechnology products (Audretsch, 2001; Pisano, 2006).

While the process of creation of new scientific knowledge is clearly carried out by scientists in universities and research centres, the translation of that scientific knowledge into commercial products is accomplished, most of the time, by enterprises. In this regard, some authors have suggested the existence of a 'close' relationship between the science and the market. For example, Arora and Gambardella (1990: 363) mention that "in biotechnology the distance between scientific advances and commercial application is relatively short; in many cases a new scientific discovery is almost a new product". These authors showed a very optimistic vision of the translation from science to market. Other authors are more skeptical and suggest that the translation from the knowledge generated in laboratories to its application and development into a commercial product is neither easy nor immediate.[4] For example, Pisano's (2006) analysis of the economic performance of R&D-driven biotechnology enterprises in the human health sector over the last thirty years points out the particular obstacles these enterprises face: "a science-based business entails unique challenges that require different kinds of organizational and institutional arrangements and different approaches to management" (p. 4).

The applications of biotechnologies are in constant change, given the scientific progress; therefore, several biotechnology applications are not yet standardized (Pyka

[4] For example, monoclonal antibodies were invented in 1975, 35 years later, they coming to new drugs. Genetic engineering has over 40 years. Yet, genomic therapy is still in its infancy.

and Saviotti, 2002; Pisano, 2006), and this can be seen as an opportunity for the creation of new enterprises. Therefore, countries that are concerned with the adoption and diffusion of modern biotechnologies into the industries have to consider the implications of this complex science-industry relationship. In sum, universities and research centres play an important role for creating new scientific knowledge, but the translation of that knowledge into commercial products require several managerial and institutional interventions.

Biotechnology enterprises are defined as those that apply biotechnology techniques in order to produce products or services[5]. There are two subgroups of biotechnology enterprises that are related to modern biotechnology (Beuzekom and Arundel, 2009: 10, see Figure 1.1):

> "Dedicated biotechnology firms: defined as biotechnology firms whose predominant activity involves the application of biotechnology techniques to produce goods and service and/or to perform biotechnology R&D.
>
> Biotechnology R&D firms: defined as biotechnology firms that perform biotechnology R&D. Dedicated biotech R&D firms devote 75% or more of their total R&D budget to biotechnology R&D."

In addition to these types of biotechnology enterprises, pre-existing industrial or commercial companies (such as veterinary product firms, pharmaceutical manufacturers, food additives producers or grain traders) can adopt biotechnology and develop new products on the basis of biotechnology; they thus become biotechnology users or biotechnology adopters.

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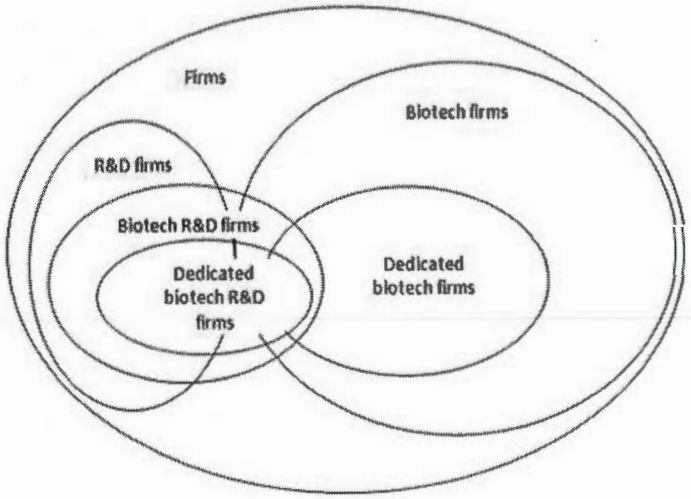
[5] The OECD (2005: 9-10) defines biotechnology active firm as a "firm engaged in key biotechnology activities such as the application of at least one biotechnology technique [e.g. DNA/RNA sequence, proteins and other molecules, cell and tissue culture and engineering, process biotechnology techniques, gene and RNA vectors, bioinformatics, and nanobiotechnology] to produce goods or services and/or the performance of biotechnology R&D".

Figure 1.1

Types of biotechnology enterprises



Source: Beuzekom and Arundel (2009:10)

Since the 1970s, thousands of new and established enterprises in different countries have adopted biotechnologies. Table 1.1 shows that the United States have the largest number of biotechnology adopters (6,213) followed by Australia, Canada, Germany, Korea, Japan, France, and Spain, which have more than 500 biotechnology adopters each, while the rest of the countries have less than 200 biotechnology enterprises.

Table 1.1

Number of biotechnology enterprises in OECD countries

Country	Biotechnology adopters	Dedicated biotechnology firms	Year
United States	6 213	2 370	2009
Spain	1095	399	2009
France	1067	676	2008
Japan	925	ND	2008
Korea	833	358	2008
Germany	663	538	2010
Canada*		583	2011
Australia	527	384	2006
United Kingdom	487	ND	2010
Switzerland	288	184	2008
Netherlands	206	72	2008
Italy	197	117	2008
New Zealand	186	93	2009
Norway	173	ND	2009
Ireland	167	71	2009
Denmark	157	66	2009
Belgium	145	122	2006
Finland	141	77	2007
Austria	121	111	2006
Portugal	105	43	2009
Sweden	100	58	2009
Czech Republic	93	69	2009
South Africa	78	38	2006
Estonia	38	31	2009
Poland	37	16	2009
Slovenia	17	9	2009
Slovak Republic	11	8	2009

*Data from BIOTECanada: www.biotech.ca/en/resource-centre/overview.aspx (Accessed on 13 February 2012)
ND: No determined.

Source: OECD (2011)

Several authors have emphasized the importance of public policies to create adequate organizations and institutional frameworks able to foster new business. Building these institutions and organization is not an easy task: emerging and developing countries have struggled to adopt and support biotechnologies.

1.3 Catching up of biotechnologies in emerging countries

According to Singh (2010: 1), "An emerging market refers to a developing market economy with low-to-middle per capita income. Countries in this category are usually undertaking a process of economic development and reform… they are in the process of moving from closed economies to more open economies… they experience rapid growth in both local and foreign investment". Therefore, the label "emerging countries" includes a wide range of countries with a variety of socio-economic characteristics. For example, Brazil, Russia, India and China are well known "emerging countries" but several agencies have built lists that include countries with very different economic growth (see Annex A).

The adoption and diffusion of biotechnologies in emerging countries vary according to the different socio-economic contexts and government intervention. Emerging and developing countries face, at different levels, scarcity in financial resources, specialized human resources and access to sophisticated institutions, machinery and instruments. These facts have implications in the local scientific progress of biotechnology areas and in the manner enterprises adopt and develop technologies, especially the more complex biotechnologies.

Emerging countries like China, India, and Brazil seem to have the potential to become important players in the creation and development of biotechnology-related products. Their governments have been actively involved in the creation of a favourable environment to adopt biotechnologies –from improving education,

training and infrastructure, passing through modernization of local industries to the creation of venture capital industries (Nature, 2005; Niosi and Reid, 2007; Prevezer, 2008). Governments and companies in other countries have attempted to develop biotechnology products and services. For instance, some efforts have been documented in Argentina, Brazil, Chile, Mexico, South Africa, South Korea, and Turkey (Bolivar et al., 2002; Nature Biotechnology, 2004; Buckley et al., 2006). However, the large investments and complexity of modern biotechnologies seem to set barriers for their adoption and diffusion (Niosi and Reid, 2007).

Among the emerging economies, two countries seem to be in an accelerated process of catching-up of modern and complex biotechnologies: China and India. The two countries have followed different strategies to adopt biotechnologies. In both countries, government has played an important role for improving scientific and technological capabilities, promoting the linkages between science and business sectors, and fostering innovation activities based on external sources and domestic efforts (Fan, 2011; Frew et al., 2008)[6]. The adoption of modern biotechnologies, particularly in the biopharmaceutical industry, has followed different patterns given the specific characteristics of each country. On the one hand, Indian biotechnology has been developed by the combination of scientific research capabilities (Mani, 2004) and legal frameworks that facilitate the adoption of biotechnologies in pharmaceutical processes (Ramani, 2002). Large and medium enterprises started to incorporate biotechnology as a strategy to maintain their position in the local market. On the other hand, China has attempted to imitate developed countries, particularly the United States, establishing several biotechnology start-ups and generating an institutional environment to develop modern biotechnologies (Prevezer, 2008). Then, large pharmaceuticals acquired innovative biotech start-ups as a strategy to maintain

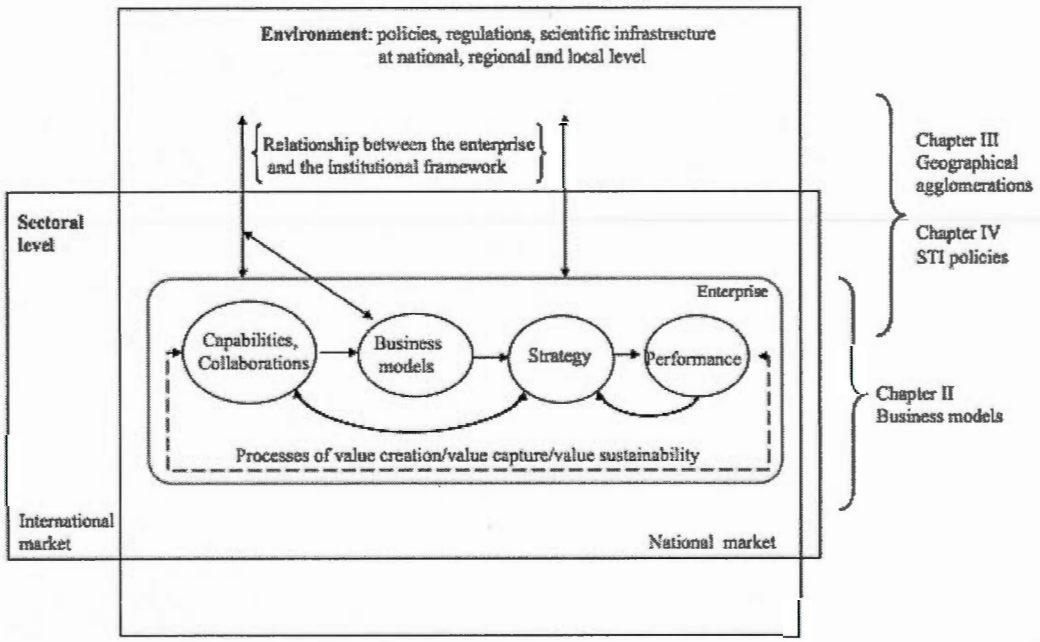
[6] See Chapter IX for details of government intervention for supporting adoption and diffusion of biotechnologies.

their position in the market. In addition, China has based its growth on the large internal market (Frew et al., 2008) while India has based its biopharmaceutical manufacturing industry upon exports (Fan and Watanabe, 2008). Given the complexity of biotechnologies, these countries still face institutional and organizational obstacles (Fan, 2011; Thomas, 2008). It seems that the patterns followed by developed countries to adopt and diffuse modern biotechnologies are difficult to implement in emerging and developing countries.

The following chapters II-IV discuss three bodies of literature that are useful to understand the specific institutional and organizational dynamic of the adoption of modern biotechnologies in emerging and developing countries. Figure 1.2 depicts the relation between the three theoretical bodies used in this research.

Figure 1.2

Relation between the theoretical bodies used in this research



CHAPTER II

BUSINESS MODELS AND BIOTECHNOLOGY ENTERPRISES

The objective of this chapter is to analyze, through the lenses of management literature, how high-technology firms, particularly biotechnology firms, deal with scientific advancement and multidisciplinary nature to create and capture economic value. The chapter is divided as follows: section 2.1 presents the definition of business model and the importance of this concept in strategy and innovation. Section 2.2 presents the different business models that have been identified in biotechnology enterprises.

2.1 Definition of business models

In the last century, technological changes and the emergence of new markets have influenced the processes by which firms produce goods and services as well as the ways customers fulfill their needs. Consequently, management literature has developed different strategy approaches[7] that include a variety of concepts and tools for helping managers to deal with changes in demand (e.g. customer needs, market scope), institutional environments (e.g. regulations and policies) and technologies (e.g. information and communication technologies) (see Annex B). Since the mid-1990s, the term 'business model' has gained relevance as a planning tool to identify the processes involved in the creation and capture of economic value. However, this term has several definitions and few theoretical efforts have been made to define its components: "a business model has been referred as to a statement, a description, a representation, an architecture, a conceptual tool or model, a structural template, a method, a framework, a pattern, and a set" (Zott et al., 2011: 1022) (see Table 2.1). A general definition includes: the value creation process that encompasses a "series of

[7] Strategy is "a plan that aims to give the enterprise a competitive advantage over rivals through differentiation. Strategy is about understanding what you do, what you want to become, and most importantly - focusing on how you plan to get there" (Harvard Business Review, 2005: xiv).

activities that will yield a new product or service, with value being added through the various activities", and the value capture process, which "requires the establishment of a unique resource, asset or position within the series of activities in which the firm enjoys a competitive advantage" (Chesbrough, 2007b: 22).

Table 2.1

Definitions of business models

Author(s), Year	Definition
Timmers, 1998	The business model is "an architecture of the product, service and information flows, including a description of the various business actors and their roles; a description of the potential benefits for the various business actors; a description of the sources of revenues" (p. 2).
Amit & Zott, 2001; Zott & Amit, 2010	The business model depicts "the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities" (2001: 511). Based on the fact that transactions connect activities, the authors further evolved this definition to conceptualize a firm's business model as "a system of interdependent activities that transcends the focal firm and spans its boundaries" (2010: 216).
Chesbrough & Rosenbloom, 2002	The business model is "the heuristic logic that connects technical potential with the realization of economic value" (p. 529).
Magretta, 2002	Business models are "stories that explain how enterprises work. A good business model answers Peter Drucker's questions: Who is the customer? And what does the customer value? It also answers the fundamental questions every manager must ask: How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?" (p. 4).
Morris et al., 2005	A business model is a "concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets" (p. 727). It has six fundamental components: Value proposition, customer, internal processes/competencies, external positioning, economic model, and personal/investor factors.
Johnson, Christensen, & Kagermann, 2008	Business models "consist of four interlocking elements, that, taken together, create and deliver value" (p. 52). These are customer value proposition, profit formula, key resources, and key

	processes.
Casadesus-Masanell & Ricart, 2010 Teece, 2010	"A business model is . . . a reflection of the firm's realized strategy" (p. 195). "A business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value" (p. 179).

Source: Zott et al. (2011: 1024)

Given the diversity of business model definitions, different contents and elements have been identified as part of business models. For example, Shafer et al. (2005) present the following elements: strategic choices, value creation and capture, and value networks. While Onetti et al. (2010) assert that a business model has elements related to the firm's objectives/mission, strategy, and financial aspects, they emphasize the importance of the allocation of resources, the kind of activities performed by the firm, and the location of activities in the definition of a business model:

> "[T]he way a company structures its own activities in determining the focus, locus, and modus of its business... Focus decisions concern the allocation of company resources to different activities... Locus decisions refer to where the different activities of the company are located... this decision has to be made for each activity the company has chosen to focus... The modus decisions of the business model designs the way a company operates in selecting the management methods for each activity... which activities to manage in-house and which ones to outsource" (Onetti et al., 2010: 32).

Therefore, this concept seems to integrate firm's capabilities with the strategic decisions about activities' location and relationship with partners. In addition to these elements, some authors have mentioned the dynamic character of business models. Given that a business model encompasses aspects of the strategy and decision making processes, this implies evolution and adaptation over time: "an organization's

business model is never complete as the process of making choices and testing business models should be ongoing and iterative" (Shafer et al., 2005: 207; Francis and Bessant, 2005; Chesbrough, 2007a). Actually, the dynamism of the business model can become an important element for value sustainability: firms have to renew their business model to maintain their competitiveness (Davenport et al., 2006; McKelvey, 2008; Teece, 2010). Over time, firms face internal and external changes that push them to modify and improve their products and processes to reach and maintain competitive positions. Internal changes can be generated by the recombination or acquisition of new assets or capabilities (Helfat and Peteraf, 2003) while external changes caused by economical and institutional environments provoke the firm to respond (McKelvey, 2008). In both cases, the firm's capabilities will be affected, and business models would be modified in a reaction to business opportunities such as penetration of existing markets, expanding markets, or creating new markets (Francis and Bessant, 2005).

There are at least four relevant external factors that influence a business model (Mckelvey, 2008):

- Technological advances: they help to open up 'technological opportunities'; in turn they will become market opportunities,
- Public and private interfaces: collaboration between public and private organizations could be difficult to manage,
- Public policy, institutions and regulations: how and why institutions set the framework of competition,
- Demand and consumer: the way in which demand can be expressed.

Firms could respond to external changes, but also they could be part of that change through experimentation, by modifying their internal resources: "As soon as they

[firms] run into problems or see new business opportunities, most firms are willing to experiment. Thus they will change their internal resources... in order to respond to new business opportunities and to solve political and technological challenges" (McKelvey, 2008:14).

Here it is important to mention the difference between strategy and business model. These concepts are closely related but they have different purposes: "while strategy provides differentiation and competitive advantage, the business model explains the economics of how the business works and makes money" (HBR, 2005: vxi). According to Davenport et al. (2006:182)

> "a business model is concerned with creating value for the *customer,* therefore, it underlies the *rational* for being in business and seeks to obtain innovative knowledge from outside stakeholders (*networking*). A strategy is concerned with *competition*, therefore it develops a *plan* of how to put a business model (differentially) into action, and consequently, strategy involves the *internalization* of re-shaping of knowledge".

In other words, business models are 'more generic' than a business strategy (Teece, 2010: 180).[8]

The relevance of business model in innovation relies on the fact that global competition and technological innovation urge firms to look for new organizational setups and new ways to interact with their institutional environment. In this sense, business models can be seen as tools to ensure firm's competitive advantage (Davenport et al., 2006; Teece, 2010).

"A good business model will provide considerable value to the customer

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[8] Internet version of newspapers can help to illustrate the difference between business model and strategy. The business model of these companies is simple: to put information on Internet and obtain revenue for advertising. There are at least two different business models for newspapers: having complete access (e.g. La Presse Montreal) or having a limited access (e.g. Le Devoir). Many newspapers have adopted one of these business models, however no all of them have the same market success. The competitive advantage of these newspapers relies on their strategies, for example, kind of contents, reputation of the columnists, and supplements, which are more difficult to imitate.

> and collect a viable portion of this in revenues. But developing a successful business model (no matter how novel) is insufficient in and of itself to assure competitive advantage. Once implemented, the gross elements of business models are often quite transparent and (in principal) easy to imitate –indeed, it is usually a matter of a few years –if not months- before an evidently successful new business model elicits imitative efforts. In practice, successful business models very often become, to some degree, 'shared' by multiple competitors" (Teece, 2010: 179).

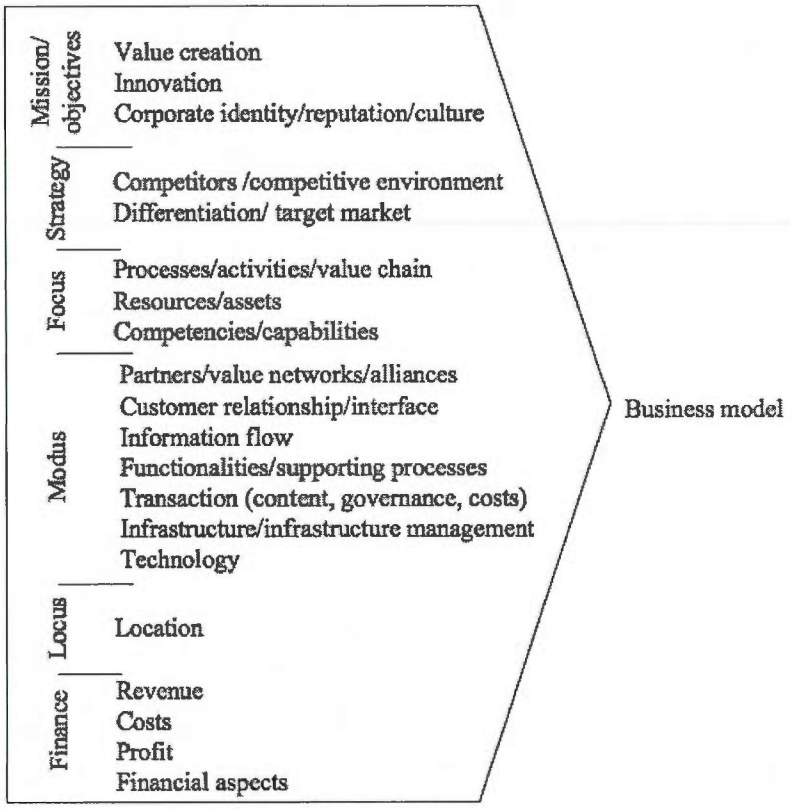
Here it is important to mention that even when the 'gross elements' are transparent, in the case of biotechnology, it seems that there are some business models that are not easy to replicate (see section 2.2). Therefore, the business models become a competitive advantage: "if not easily replicated by competitors, they can provide an opportunity to generate higher returns to the pioneer, at least until their novel features are copied" (Teece, 2010: 181).

2.1.1 Components of business models: capabilities and collaborations

Summarizing the definitions presented in the previous section, a business models encompasses aspects of mission, strategy, allocation of resources, relationships with other agents, location of activities, and financial aspects (see Figure 2.1).

Figure 2.1

Components of business models



Source: Onetti et al. (2010); Teece (2010)

In this research, only two components of business models are analyzed, namely capabilities and collaborations, since the focus is on the importance of scientific discoveries and the interaction of different actors in the development of high technology products.

Capabilities and innovation

The strategic management literature has emphasized the heterogeneity of firms. This heterogeneity is based on the creation and development of competences and dynamic capabilities, which are key elements to achieve and maintain a strategic position in the market. Resources *per se* do not contribute to the competitiveness of the firm. Their combination is what makes them useful to improve the firms' performance (Penrose, 1995). Depending on their contributions, some specific resources become valuable assets to the firm, and therefore, they are the main components of the firm's competences (Foss, 1996; Teece et al., 1997). Competences can be found at individual and organizational levels. Foss (1996:1) defines a competence as "a typical idiosyncratic knowledge capital that allows its holder to perform activities –in particular to solve problems– in certain ways, and typically do this more efficiently than others". Therefore, knowledge becomes an important asset to the firm, which is built through a continuous repetition of activities and remains in the firm's memory as routines (Nelson and Winter, 1982). These particular routines are 'distinctive activities' well performed by the firm (Teece et al., 1997). Firms can have a variety of competences, some of these competences are 'core competences', which allow the firm to develop core products: "core competences are the collective learning in the organization, specially how to coordinate diverse production skills and integrate multiple streams of technologies" (Prahalad and Hamel, 1990: 82).

In addition, firm's competences are not limited to the firm's boundaries. Firms interact with other organizations, especially in environments in constant change such as those of high technologies; therefore firms have to develop abilities to integrate, build, and reconfigure internal and external competences (Cohen and Levinthal, 1990; Teece et al., 1997: 516; Helfat and Peteraf, 2003).

Collaboration and innovation

Different approaches have been developed to explain industrial organization. According to economic theory, markets and hierarchies were considered to be efficient forms of organization, and other forms were expected to be temporary (e.g. collaboration networks, alliances). Nevertheless, in the last decades, the development of complex technologies and products has required the participation of different organizations (firm and non-firm) on a more permanent basis. Basically, the objective of collaboration is to access specific assets that can contribute to the firm's economic success. This subsection presents two approaches that deal with temporary collaborations and its relevance for innovating: transaction costs and networks of learning.

Transaction cost approach

Markets for specialized assets rely on the assumption of a clear division of labour according to the value chain, in which each firm has specific capabilities/assets. However, this market of specialized assets involves information asymmetries, tacit knowledge, and intellectual property uncertainty that could generate transaction costs (Williamson, 1979; Pisano, 1991). The transaction costs approach suggests that vertical integration helps avoid uncertainty and opportunism from other agents in the market. However, in some high-tech industries the collaboration between different agents seems mandatory to survive in the market (e.g. the collaboration between a dedicated biotechnology firm (DBF) and a large pharmaceutical company). High technologies are closely related to scientific knowledge, and these – particularly in biology and related disciplines – have a rapidly moving frontier; therefore incumbent firms may not have the sufficient absorptive capabilities to internalize such large amounts of new knowledge (Cohen and Levinthal, 1990; Pisano, 1991).

Networks of learning approach

Another approach that has contributed to the understanding of collaborations between firms is networks of learning (Powell, 1990; Powell et al., 1996). This approach is based on the social character of knowledge and its accumulation over time (Nelson and Winter, 1982; Nonaka, 1994).

A network is a form of coordinating economic activity, a form of governance that allow collaboration among different actors facilitating the exchange of information, the access to valuable assets (e.g. knowledge, know-how), the production of goods and services, and the sharing of risks (Powell, 1990). The concept of network is based on the socialization of individuals and it involves the mutual support among parts (Powell, 1990). As the network evolves, the actors' interdependence increases, therefore, they often prefer to remain in the network rather than to exit (Powell, 1990). Networks vary according to their structure, governance, and industry. These elements are the result of historical events (Powell, 1990; Smith-Doerr and Powell, 2005).

How do networks impact learning and innovation processes? According to Powell et al. (1996), the locus of innovation is found in networks of learning rather than in individual firms. The main argument of this approach is that since no single firm can have all the resources needed for the creation, production, and market of new products, and since the amount of available useful new knowledge increases exponentially, firms often collaborate with other organizations (e.g. universities, government agencies, and other firms) in order to obtain complementary knowledge, resources and capabilities (Powell et al., 1996). For example, collaborative R&D allows individuals to expand their sources of knowledge (Powell et al., 1996; Oliver, 2001). This argument fits well with the process of R&D in complex (high) technologies because they involve many resources such as specialized knowledge, technological and managerial capabilities, and funds.

Knowledge is the main input for the innovation process (Nelson and Winter, 1982). Nonaka (1994) mentions that there are two main types of knowledge: tacit knowledge that is difficult to transfer, deeply rooted in action, commitment, and involved in a specific context (know-how, crafts, skills); and explicit or codified knowledge that is discrete and is captured in blueprints, documents, manuals and models. Knowledge is based on the interaction among individuals; therefore, organizational knowledge can be understood in terms of a process that "organizationally" amplifies the knowledge created by individuals, and crystallizes it as a part of the knowledge network of an organization (Nonaka, 1994). In addition to internal knowledge, firms can benefit from external sources to increase their competences: "a firm's value and ability as a collaborator is related to its internal assets, but at the same time, collaboration further develops and strengthens those internal competencies" (Powell et al., 1996: 119). In other words, the collaboration among different organizations allows people to be aware of other activities or other projects that could improve their performance. Therefore, the external sources of knowledge are relevant for innovation; but the firm should have absorptive capacity to benefit from external knowledge (Cohen and Levinthal, 1990). In words of Oliver (2001): "the evaluation and utilization of this [external] knowledge is a function of prior related knowledge which includes basic skills such as shared language and knowledge of the technological and scientific developments in the field" (p. 468). Consequently, networks of learning make possible the diffusion of knowledge, the inter-firm learning and the exploration of complementarities among firms, which is crucial in high technologies given their complexity and multidisciplinary nature (Pyka and Saviotti, 2000:15).

In sum, although the transaction costs approach suggests that firms with specialized assets (e.g. scientific knowledge or regulatory capabilities) should attempt a vertical integration strategy to acquire capabilities and reach a competitive position in the market, the increased complexity of high technologies calls for collaboration

networks between different actors that allows firms to explore and complement capabilities to become a competitive agent.

2.2 Business models in biotechnology

The creation, adoption and commercialization of biotechnology-related products rely on collaboration networks that involve different actors. Prominent actors are dedicated biotechnology firms (DBF), which have been under the spotlight in the last three decades because of their role as a mechanism of translation from scientific results to high quality products, particularly in the human health and agriculture sectors of developed countries. However, in recent years, some authors have questioned the performance of DBFs as a mechanism to generate and capture economic value (Pisano, 2006). In addition, the financial crises of 2000-1 and 2008-10 have reduced considerably the availability of venture capital (Nature Biotechnology, 2010), which has affected the establishment and survival of biotechnology start-ups. This section seeks to describe how firms generating and adopting biotechnologies create and capture economic value. These elements will allow setting the basis to discuss the implications for the adoption of biotechnologies in countries, like Mexico, which has underdeveloped organizations to support the adoption of complex biotechnologies.

Firms vary according to the combination of their capabilities, strategies, their reaction to external environments (e.g. institutions) (Nelson, 1991; McKelvey, 2008), and their kinds of collaboration networks in which they participate. In the case of biotechnology enterprises, scientific discoveries in different disciplines imply more complexity and diversity. This scientific advance has two main implications: 1) the population of enterprises remains heterogeneous because the different industrial applications; and 2) the number of organizations involved in the discovery and

commercialization processes to achieve new products seems to increase (McKelvey, 2004; McMeekin et al., 2004). Consequently, biotechnology enterprises vary in the way they create and capture economic value.

2.2 Definition of a business model for biotechnology enterprises

Since the early 1980s, several scholars and practitioners have analyzed the creation and growth of firms using biotechnologies. In the last decade, some authors have started to focus on 'biotechnology business models'; i.e. how firms do business in biotechnology.

There is not a specific concept of business model for biotechnology. However, some authors have used a general concept that includes 'a detailed description of the activities carried out by the biotechnology firms' (see Table 2.2). As mentioned in Chapter I, the early adoptions of biotechnologies for industrial products were carried out in developed countries and particularly in the pharmaceutical and agricultural sectors. Based on these experiences, authors have identified two well-defined business models in biotechnology firms: classic dedicated biotechnology model and large, vertically integrated company business model.

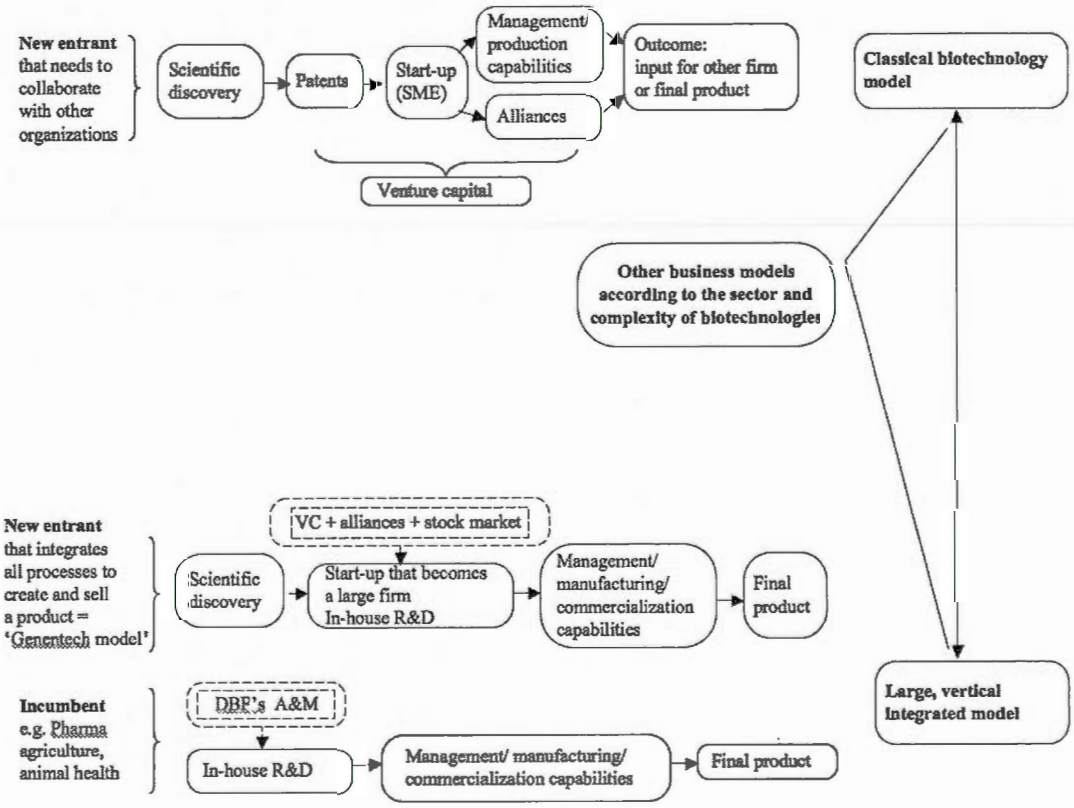
> "In the classical biotechnology model, scientific discoveries and technological inventions have been quickly developed within entrepreneurial firms, usually based upon venture capital. They compete through **their specialized scientific knowledge**, often sold to large companies, and also compete through their flexibility such as quick commercialization, **alliances**, and keeping up to date with scientific and technological breakthroughs. These firms invest heavily in research and development (R&D) – but often have difficulties making money off their internal knowledge resources…
>
> "In the large, vertical integrated company business model, **economies of scale** and the use of **integrated resources** have been characteristic. These firms have integrated everything from research and development (R&D)

> to production to marketing and after sales monitoring. They have competed through finding the next 'blockbuster drug' in pharmaceuticals and through having large segments of the market in other industries like medical devices." (McKelvey, 2008: 9, bolds added)

Although human health and agriculture are the main areas in which biotechnologies have been applied, industrial applications of biotechnologies (e.g. enzymes, biopolymers, plastics) are becoming more prevalent (BIO, 2010): "modern biotech firms do many different things, and hence there are not a traditional sector in the sense of selling more or less homogeneous and competing products" (McKelvey, 2008: 16; McMeekin et al., 2004). Therefore, a range of biotechnology business models has emerged between the 'classical biotech firm', and the 'full vertically integrated' or 'Genentech model' (see Figure 2.2 and Table 2.2).

Figure 2.2

Range of biotechnology business models



Source: Own elaboration.

Generally, the image of a biotechnology enterprise is related to the classical business model (small enterprises almost entirely dedicated to R&D activities), and actually, several countries are attempting to generate and support this kind of enterprises (see Table 1.1 in Chapter I). However, there are very few successful cases of large, vertical integrated models like Genentech and Genzyme, which initiated from the classical business model. For instance, in 2010 only 16 biotechnology enterprises in

the United States were considered 'commercial leaders' (firms with revenues greater than USD 500 million) (Ernst & Young, 2011: 43).[9] The large-scale model implies high risk given the huge investments in clinical assays, drug approval, manufacturing and marketing. Additionally, two factors have affected the possibilities for small and medium DBFs to become large integrated firms: international financial crises and the incorporation of biotechnologies into the R&D labs of large, established firms. The financial crises of 2000-1, and 2008-10 have reduced the availability of venture capital, as the stock market exit became very difficult (Nature Biotechnology, 2010). In addition, established companies in pharmaceutical, food and chemical industries as well as seed traders have invested in establishing their own biotechnology R&D facilities in order to acquire and develop state-of-the-art biotechnologies capabilities that allow them to vertically integrate themselves, improve their processes and develop new products (Nature Biotechnology, 2010). Thus, the large-scale model – the Genentech model- that of a DBF growing to become a large corporation, is almost entirely precluded. The integration of biotechnology in large established industrial firms is taking place through two different processes: the acquisition of existing DBFs, and the creation of new biotechnology R&D labs within the corporations. While this convergence process takes place in advanced OECD countries, the number of large industrial and commercial firms able to adopt biotechnology is reduced in developing and emerging countries.

So far the analysis of biotechnology enterprises' business models has been focused on the human health sector in developed countries. These studies reveal a variety of business models, and also show evidence of the different elements that influence those models (Table 2.2). For example, Fisken and Rotherford (2002) analyze the development of capabilities and risk management of biotechnology firms and identify

[9] This list does not include Genentech, which was acquired by Roche Group in 2009. And Genzyme appears in the list but Sanofi acquired it in 2011.

four business models: full integrated, product, platform/tool, and hybrid (product and platform). Mangematin et al. (2003) propose two different business models according to the biotechnology firms' market scope and its influence on the growth path: firms that target niches within local markets; and firms that target larger national and international markets. Nosella et al. (2005) mention five business models evaluating the different position firms have in the value chain: "new biotechnology firms (NBF), integrated companies, involved in the process from research to commercialization, integrated companies which sell products to other companies, manufacturing companies (which carry out the final stage of innovation, from industrial development to production and commercialization), and services companies" (p. 854). McKelvey (2008) suggests ten different business models in the human health sector according to two dimensions: emphasis on the internal or external capabilities and the focus on market or technology competition. According to the objectives of collaboration, Greiner and Ang (2010) suggest that hybrid business models perform more exploration activities than product focused business models and technology platform business models, which carry out more exploitation activities. Therefore, the elements involved in biotechnology firms' business model can be summarized in capabilities, collaborations, and competitive environments or market.

Table 2.2

Biotechnology firms' business models

Authors(s), Year	Definition	Variables	Business models
Fisken and Rotherford (2002)	"A business model is a description of how your company intends to create value in the market place. It includes that unique combination of products, services, image and distribution that your company carries forward. It also includes the underlying organization of people and the operational infrastructure that they use to accomplish their work (Chesbrough & Rosenbloom, 2002)" (p. 199)	Inter-firm collaborations of biopharmaceutical firms in Europe.	Product business model Platform or tool business model Hybrid business model
Mangematin et al. (2003)	"A business model describe a category of firm in relation to the market it targets, its expected growth, its modes of governance, and the organization of its activities" (p. 622)	The logic of the development of French firms: The size of innovative projects, and the kind of alliances.	Fast growing firms Firms that are not expected to become worldwide leaders.
Nosella et al. (2005)	"The value creation priorities of the firm with respect to the utilization of both internal and external resources for the propose of creating value for and with customers (Walling, 2000)"(p.853)	Types of segments and rules of competition (p. 854). All sectors using biotechnologies in Italy.	*Research firms*, *Integrated companies* which are involved in all processes from research to commercialization, *Integrated companies which sell products to other companies*, *Manufacturing companies* which carry out the final stage of innovation, from industrial

			development to production and commercialization, *Services companies* which provide research and analysis services
McKelvey (2008)	"Business model refers to how firms do business –how they compete and make profits by using their competencies and resources to tell goods and services in the market".	Impact of institutional factors (markets, public policies, public-private interface, and advancement of science) on biotech firms in the human health sector. Focus on developed countries.	*Competing on technology:* Platform model, Contract research, Information, Hybrid technology, Pure tool and component, *Competing on market and customers:* Service–provider, Market maker, *Speculative business models:* System integrator, Open source, Orchestrator.
Greiner and Ang (2010)	"A common understanding is that a business model provides an integrated description of a firm and the ways it generated revenues. It also helps define how firms manage their transactions with stakeholders such as customers, partners, investors and suppliers"	Analysis of biotech firms' alliances in the human health sector in USA and Europe.	Product-focused Technology platform-focused Hybrid

Source: Own elaboration.

Capabilities in biotechnology enterprises

As mentioned above, firms need different capabilities to generate new products and react to environments. In general, these capabilities can be categorized, for example, in technological, operational, and managerial capabilities. However, in the particular case of biotechnology, scientific capabilities are crucial to understand complex biology systems, in which other disciplines have been joined for analyzing and discovering –for example mathematics, neuroinformatics, bioinformatics, and molecular genetics (Hayden, 2010; Abbott, 2010).

In addition to scientific capabilities, technological and managerial capabilities are needed to develop, manufacture and commercialize biotechnology-related products. Technological capabilities are those capabilities that firms perform to produce goods and services. They allow firms to identify, use, and modify technologies (Kim, 1997). Managerial capabilities allow the firm to organize its activities and its relations with other organizations (Fisken and Rutherford, 2002) to obtain complementary capabilities or assets (Teece, 1986). Therefore, the establishment of collaborations between biotechnology enterprises with other organizations (e.g. venture capital firms, government agencies, universities and research centres) becomes critical for the performance of these enterprises.

These capabilities are required to explore new products and processes, but are not enough to manage a successful dedicated biotechnology firm (DBF). Other capabilities are needed to evaluate information about markets and environments. These other capabilities include those of assessing markets and future income flows from those markets, devising a financial strategy by understanding the different sources of finance (venture and angel capital, bank loans, capital markets, government subsidies, tax credits, reimbursable loans and other public funds, as well

as foundations such as the Wellcome Trust, the Gates Foundation and hundreds of others). Also, DBFs need to acquire legal competencies required to patent, transfer technology (in and out) and obtain the necessary national approvals for new drugs (e.g. FDA in the United States, the European Medicines Agency, Health Canada) or the use of biotechnologies without affecting crops and environment. And of course, DBFs managers need to understand some industrial economics to decide the types and quantities of their production, potential markets and market share, number of actual and future competitors, pricing policies and the like. DBFs are born with a very restricted set of competencies. Successful firms are those that arrive to incorporate these other complementary competencies during the first years of their existence. Often, venture capital firms help biotech firms to incorporate these complementary competences (Hollway, 2010).

Collaborations in biotechnology

Biotechnologies involve a mix of codified and tacit knowledge (McKelvey, 1998). This knowledge is embedded in few scientists who have the ability to acquire and create this knowledge and "the information about the potential commercial market for viable products resulting from that knowledge" (Audretsch, 2001: 40). In the last decades, other scientific disciplines have been added to the creation of new biotechnology techniques. This has two implications for biotechnology innovation: on one hand, "the rapid development of different research fronts makes it difficult for large firms to joint multiple research decisions" (Oliver, 2001: 472), it means that small and medium DBFs have an advantage derived from their unique scientific knowledge; on the other hand, biotechnologies imply a specific challenge; because as the frontiers of science move forward, new techniques are discovered, and knowledge becomes more complex and difficult to manage (Oliver, 2001; Pisano, 2006). Therefore, a network of different actors is necessary to create and commercialize

biotechnology-products. This network includes universities, public research labs, venture capital firms and other sources of funds, DBF, large, established companies, government agencies.

What are the organizations and institutions that shape a 'biotechnology network'? Since the beginning of the adoption for commercialization of biotechnologies in the 1970s, the relationship between firms –developing or adopting biotechnologies— and knowledge-creating organizations has played an important role for the diffusion of biotechnologies. Nevertheless, some other organizations and institutions are necessary to nurture and support the development and commercialization of biotechnology-related products. These organizations are embedded in institutional frameworks, which in turn, influence the way firms adopt business models (see Figure 1.2 in Chapter I). The institutional framework promotes and facilitates the experimentation of different business modes and the evolution of those according to the characteristics of the adoption of biotechnologies: scientific knowledge base, multidisciplinary, and large investments (Pisano, 2006; Cockburn and Stern, 2010). Therefore, the increasingly multidisciplinary of biotechnologies, the complexity of living organisms, and the changes in demand and institutional context (e.g. laws) make possible a diversity of business models away from the classical dichotomy (McKelvey, 2008).

CHAPTER III
GEOGRAPHICAL AGGLOMERATIONS

Empirical research has demonstrated that high-technology firms tend to agglomerate in specific geographical areas (Saxenian, 1994; Swann et al., 1998, Niosi et al., 2005). Firms tend to agglomerate given the positive externalities that they can obtain within specific areas: knowledge spillovers, pools of qualified human resources, specialized services and access to funding among others (Braunerhjelm and Feldman, 2006). This chapter deals with the following questions: how do biotechnology agglomerations emerge? What are the elements and factors that allow the development of such agglomerations over time? In order to answer these questions, section 3.1 presents three different concepts of agglomerations. The dynamics of agglomerations are presented in the section 3.2, and section 3.3 describes the dynamics of biotechnology agglomerations.

3.1 Concepts of agglomerations

Different concepts have been developed to analyze the agglomeration of firms in specific geographic areas. At least three concepts have dealt with the study of biotechnology agglomerations: The most popular is the concept of ***cluster*** (Porter, 2000); this concept emphasizes the participation of different actors in a related industry within a geographical area. The concept of ***regional system of innovation*** focuses on the analysis of relationships between different agents in a specific region (Cooke and Morgan, 1998). In the last years, the concept of ***anchor tenant*** has emerged in regional agglomeration and innovation literatures (Agrawal and Cockburn, 2003; Feldman, 2003). This concept helps to identify the main attractor(s) to the agglomeration. The definitions of these concepts are presented in the following paragraphs.

Cluster

Porter (2000) defines a cluster as follows:

> "[A] geographically proximate group of inter-connected companies and associated institutions **in a particular field**, linked by commonalities and complementarities. The geographical scope of cluster can range from a single city or state to a country or even a group of neighbouring countries. Clusters take varying forms depending on their depth and sophistication but most include end-product or service companies; suppliers of specialized inputs, components, machinery, and services; financial institutions; and firms in related industries. Clusters also often involve a number of institutions, governmental of otherwise, that provide specialized training, education, information, research and technical support (such as universities, think tanks, vocational training providers); and standards-setting agencies. Governments departments and regulatory agencies that significantly influence a cluster can be considered part of it. Finally, many clusters include trade associations and other collective private sector bodies that support cluster members" (p. 254, bolds added).

This definition attempts to encompass the extensive range of participants that agglomerate in a determined geographical area, however, this concept does not deal with the dynamics followed by the group of different organizations in order to understand why and how they agglomerate, what are the forces of attraction and whether the attraction process is limited in time and geography or through the saturation of organizations (Martin and Sunley, 2003). Moreover, the concept does not deal with the precise types of organizations and institutions involved in these dynamics, the geographical limitation of the cluster, and the kinds of complementarities that are needed and produced. For example, some authors consider clusters of enterprises while others consider clusters of industries (Prevezer, 1997; Porter, 2003).

Feldman and Braunerhjelm (2006: 3-4) underline that cluster formation follows an evolutionary process based on endogenous resources: at the beginning, some

triggering (historical-social-political) and entrepreneurial events spark the emergence of a clusters; then the creation of competitive advantages and the establishment of adequate institutions create agglomeration forces –like labour market pooling, supplier specialization, knowledge spillovers, entrepreneurship, local demand- which in turn, influence internal socio-economic dynamics; finally, the evolution of the industry and local competition defines the future of the cluster: either to become 'the place to be' or to accept the stagnation or decay. Although a random event can trigger the emergence of clusters, the most important issue is what happens later and how to support the development of that cluster (Feldman and Braunerhjelm, 2006). In this sense, some authors have emphasized the role of government intervention through public policies to promote and support the development and growth of the cluster (Carlsson, 2006) (see Chapter IV).

Regional systems of innovation

Innovation is a complex process that involves knowledge as the main input and learning process as the strategic activity for competitiveness (Lundvall, 1992; Asheim and Coenen, 2005). The concept of national system of innovation emphasizes the roles of knowledge, learning and networks in the innovation process at the national level. Since the 1980s, scholars have underlined the special characteristics of regions in terms of industries, institutions, resources, and human capital: "within industrial and industrializing countries, innovation takes place in a few metropolitan areas and regions" (Niosi et al., 2005: 4). Thus, the regional system of innovation (RSI) approach highlights the importance of an institutional environment that enables systemic linkages to encourages innovation within the region:

> "Regions which posses the fully panoply of innovation organizations set in an institutional milieu where systemic linkage and interactive communication among the innovation actors is normal, approach the

> designation of regional innovation systems. These organizations can be expected to consist of universities, basic research laboratories, applied research laboratories, technical transfer agencies, regional public and private (e.g. trade associations, chambers of commerce) governance organizations, vocational training organizations, banks, venture capitalists, and interacting large and small firm. Moreover they should demonstrate systemic linkages trough concertation programmes, research partnerships, value-adding information flows, and policy action lines from the governance organizations. This system combine learning with upstream and downstream innovation capability, and thus warrant the designation regional innovation systems." (Cooke and Morgan, 1998: 71).

Given the importance of knowledge in the innovation process, Cooke (2004: 3) defines the RSI as "interacting knowledge generation and exploitation sub-systems linked to global, national and other regional systems for commercializing new knowledge". The knowledge generation subsystem involves public and private research laboratories, universities and colleges, and technology transfer agencies. The knowledge exploitation subsystem involves mainly firms. The interaction between the two sub-systems allows the creation, use and diffusion of knowledge as well as defines, through time, the patterns of behaviour (e.g. norms and laws) among the actors in the regional institutions. In turn, these institutions affect the way in which the innovation takes place (Asheim and Coenen, 2005; Niosi et al., 2005).

Cooke (2002: 143) underlines that "the regional and, more particularly, local levels become most important for the evolution of clusters, including the concentration of critical research mass, the formation of networks, development of cluster interactions and even the commercialisation of products". In addition to regional conditions, the national and international levels also play a role. For example, the regulatory regime is implemented at the national level, while commercialisation, links to large companies, customers, and even venture capital, are frequently global (Cooke, 2002).

Anchor tenant

Agrawal and Cockburn (2003) developed the anchor tenant[10] concept to explain the relationship between university research and industrial R&D in a regional, high-tech context. An anchor tenant (AT) organization is defined as follows:

> "[A] large, locally present firm that is: (1) heavily engaged in R&D in general and (2) has at least minor absorptive capacity in a particular technological area [...] the presence of an anchor tenant firm enhances the regional innovation system such that local university research is more likely to be absorbed by and to stimulate local industry R&D" (Agrawal and Cockburn, 2003: 1229).

According to these authors, the main attribute of the AT is that it can create knowledge and participate in technology markets within the region. The AT also facilitates the process of technology transfer from university research into industrial R&D, for example, if a large, established firm (AT) is engaged in R&D activities in a particular technological area, this firm create demand for scientific research services from the local university; at the same time the AT firm must have the absorptive capacity to internalize the scientific knowledge created in the universities or public research labs.

Feldman (2003) adopts the concept of anchor tenant to explain the location and specialization of firms using and developing biotechnologies in a specific region. Some authors have underlined that biotechnology "is developing differentiated and unique capabilities in specific location" (Feldman, 2003: 316; Niosi and Bas, 2001; Cooke, 2007). Feldman (2003) suggests that a possible reason of this 'unique capabilities' is the role played by anchor tenant organizations. She enhanced the concept of AT and proposed that regional anchors may include knowledge-creating organizations and established firms:

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[10] "The classic 'anchor tenant' is the large department store in a retail shopping mall that creates demand externalities for the other shops. Large department stores with a recognized name generate mall traffic that indirectly increases the sales of lesser-known stores" (Agrawal and Cockburn, 2003: 1229)

> "Established firms may provide expertise and knowledge about specific applications, product markets, and technical development trajectories that move generic scientific innovations in a particular direction, which over time, may distinguish the specialization of the industrial cluster [...] Once the region is noted to have developed an expertise, others that work on the application or in the product market may be encouraged to start firms in the region. Over time, a cluster may develop around that specialized expertise" (Feldman, 2003: 312).

Feldman (2003) argues that although research universities have been the source of knowledge spillovers in biotechnology, a "university alone may not be sufficient to anchor a developing industry in a location" (p. 321). She mentions that the difference between science and technology affects the location dynamics:

> "Science, as the pursuit of new knowledge, is originated in universities... technology develops ideas from science to commercial applications... [Therefore] we expect that as industry develops and science is translated into commercial applications, the locational dynamics may change to emphasize industrial and technological attributes" (Feldman, 2003: 321).

In other words, she proposes that in the early stages of biotechnology agglomerations, universities play an important role in creating scientific knowledge and defining technological capabilities of the location (concentration and specialization); then, as industry evolves, other assets and capabilities are needed and other agents, such as small and large firms, may become more important.

These three concepts –cluster, regional system of innovation and anchor tenant- analyze different issues in the agglomeration phenomenon. The concept of cluster focuses on identifying the main actors in the agglomeration. The concept of regional system of innovation also identifies the different actors within the agglomeration but also underlines the interactions between those actors and the institutional context. The concept of anchor tenant focuses on the organizations that are main attractors to the agglomeration. In the following sections, these concepts are used to describe and

analyze the dynamics taking place in biotechnology agglomerations.

3.2 Dynamics of agglomerations

Empirical research has shown that firms within agglomerations are better performers than non-agglomerated firms, and they develop competitive advantages in production and innovation terms (Saxenian, 1994; Swann et al., 1998). Agglomerations seem to follow a life cycle pattern that could be represented by different stages: birth or creation, development or growth, sustaining, and dead or saturation (Feldman and Braunerhjelm, 2006; Menzel and Fornahl, 2009).

3.2.1. Specialization versus diversification

The development of high technology industries relies heavily on scientific discovery, which involves face-to-face communication and interaction in order to facilitate content transmission. In general, the transmission of this type of knowledge and its effects on the agglomeration process and economic growth have been associated with at least two types of externalities (Glaeser, 1992): the first one is Marshall-Arrow-Romer (MAR) externalities, in which cluster specialization in a specific industry is a key element to ensure economic growth. The second one is the Jacobs-Rosenberg-Bairoch (JRB) externalities, in which the role of diversity of knowledge and ideas across industries within clusters encourage and foster economic growth, especially in large cities.

On one hand, the MAR externalities suggest that knowledge spillovers occur among firms in the same or similar industry, and they benefit from the concentration of skilled workers, source of ideas and sharing the use of expensive machinery (Marshall, 1947). On the other hand, JRB externalities suggest that knowledge spillovers occur more frequently in cities where people from different industries

interact and help to generate new ideas and innovation. Solving problems allow new work 'to be added directly onto older work' (Jacobs, 1969: 55).

Scholars have analyzed the impact of specialization and diversification on the development of regions and agglomerations. These studies underline that both externalities are important for economic growth, especially in high technology industries (Feldman and Audrestch, 1999; Beaudry and Schiffauerova, 2009). However, the importance of each type of externalities differs along the industry lifecycle (Feldman et al., 2005; Beaudry and Schiffauerova, 2009; Merzel and Fornahl, 2009):

> "In the **initial stage** of the innovative process an **increased diversity** and variety propels the creation of novelty, inventive ideas, creative concepts and radically new designs. When the **industry matures** and the design reaches a critical mass on the market, the product becomes standardized and the knowledge involved in the innovation **process highly specialized.** Firms then may greatly benefit from learning from the solutions and mistakes of other firms in the same industry in a region with high concentration of their own industry. Finally, it is the high concentration of the mature industry, which decreases the region's ability to innovate, rejuvenate and restructure, and which inevitably leads the region into a lock-in." (Beaudry and Schiffauerova, 2009: 325, bolds added)

Therefore, inter-industry externalities are important at the initial stages, later specialization may become more important. However, if the agglomeration becomes too much specialized it may decline along with its engine industry. Thus, it seems that high technology enterprises prefer diversified agglomerations, where they have access to different sources of ideas and knowledge.

3.2.2 Agglomeration lifecycle

Menzel and Fornahl (2009) identify two dimensions in agglomeration lifecycles:

quantitative and qualitative (Figure 3.1). According to these authors, the quantitative dimension refers to the number of enterprises and employees comprised in an agglomeration, while the qualitative dimension is related to the heterogeneity of knowledge within an agglomeration.

Considering the quantitative dimension, the lifecycle of agglomerations can be characterized as follows (Menzel and Fornahl, 2009: 218): in the first stage, emergence, socio-economic events trigger the establishment of few enterprises. In the growth stage, the successful experience of the early entrepreneurs encourages the establishment of a second generation of enterprises, and employment increases. Then, in the third stage, sustain, the agglomeration maintains the employment on a high and constant level. Finally, in the decline stage, the agglomeration cannot generate new employment and the establishment of new enterprises is rare.

When considering the qualitative dimension, Menzel and Fornahl (2009) suggest that the heterogeneity of knowledge may evolve over time as follows:

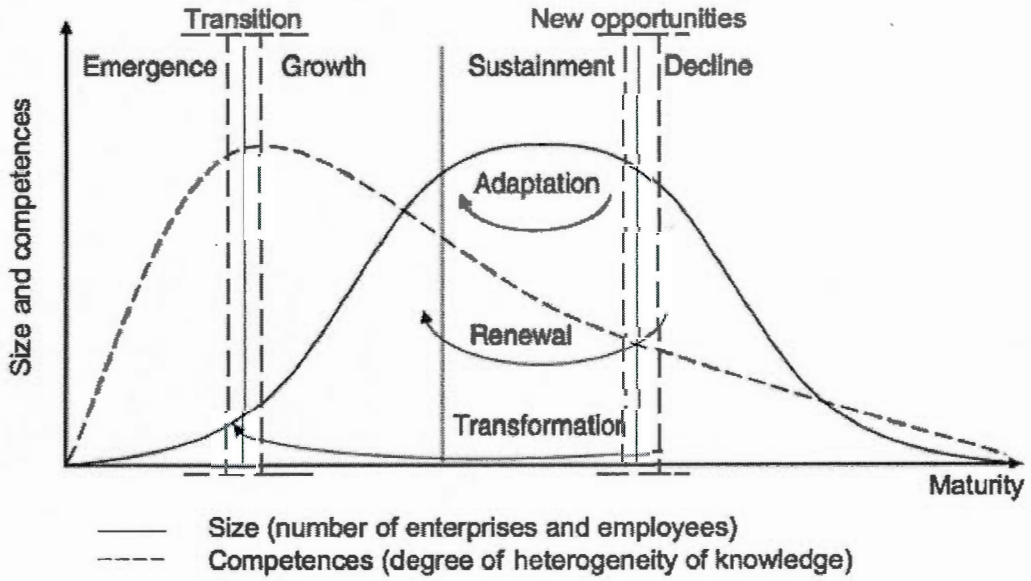
> "As a cluster emerges… the heterogeneity increases strongly because every new company ventures into new technological areas of the cluster. In the growth phase, the technological path becomes increasingly focused. The heterogeneity decreases until the cluster has matured and a distinct development path has taken shape. However if the cluster is focused too narrowly, it loses its capacity for renewal and decline" (p. 218).

This scenario is focused on the agglomeration of firms in one industry or related industries, thus, this scenario is one among several possible others. An agglomeration can adopt other technologies to avoid specialization, for example, agglomerations in large cities (e.g. Mexico, San Paolo, Buenos Aires), which host several industries, may not become more specialized over time. Therefore, the heterogeneity of the knowledge is closely related to the two types of externalities presented in the above

section (MAR and JRB externalities). Industrial agglomerations are not generated spontaneously; socio-economical conditions trigger their establishment in specific geographical areas, often in large cities where cross-fertilization of knowledge and ideas facilitate innovation (Jacobs, 1969). Particularly, high technology enterprises may prefer large cities where knowledge externalities across industries can occur, which is crucial for these industries (Beaudry and Schiffauerova, 2009).

Figure 3.1

Dimensions of an agglomeration



Source: Own elaboration based on Menzel and Fornahl (2009: 218)

In addition to the triggering events, an important issue is how to create an environment that supports the establishment of start-ups and attracts new complementary agents for the agglomeration's development. It seems that two other stages can be added to the traditional ones –emergence, growth, sustainment, decline:

transition and new opportunities (see Table 3.1 and Figure 3.1). These new stages suggest an active role of the government in generating conditions to increase the business opportunities and the heterogeneity of knowledge (see Chapter IV).

Consequently, the agglomeration lifecycle may evolve in the following way: when an agglomeration **emerges,** the heterogeneity of knowledge is high, and different technological approaches are adopted. In addition, only few start-ups are founded and there is not collaboration with other organizations. In this stage, government may not be involved for supporting agglomeration. Later, at the **'transition'** stage, from emergence to growth, the number of start-ups increases at the same time that a critical mass arises and defines the technology profile of the agglomeration (Menzel and Fornahl, 2009). Some start-ups that spin-off from other organizations begin to generate synergies. At this point, the creation or improvement of an institutional environment plays an important role to shape the future collaborations that could bring complementary resources and capabilities to enterprises (Feldman et al., 2005). At the **growth** stage, a second wave of new start-ups appears adopting the defined technological profile, and enterprises and potential partners within the agglomeration start to collaborate. The sustainment stage is reached when the number of enterprises is stable and enterprises have established dense networks of collaborations with partners inside and outside the agglomerations. After the sustainment stage, agglomerations have to be ready to undertake new opportunities of development and avoid declining. Menzel and Fornahl (2009) mention that there are three different ways in which an agglomeration can rejuvenate: 1) by the adoption of incremental changes in the technological path, 2) renewal through the integration of new technologies into the agglomeration, and 3) transformation, in which the agglomeration moves into a completely new technological field (p. 219). In order to benefit from these new opportunities, it is necessary, in all cases, that the agglomeration does not have a total technological specialization or lock-in, if this is

the case, enterprises in the agglomeration will not be able to incorporate new knowledge and technologies, and innovate (Wolf and Gertler, 2006). Therefore, in the **'new opportunities'** stage, governments play an important role implementing programs that support the creation, adoption and the commercialization of new technologies; otherwise, the agglomeration will decline.

Table 3.1

Characteristics of an agglomeration's lifecycle stages

Stages	Entrepreneurial activities	Experience/ Learning	Technological distance	Collaborations	Government involvement
Emergence	Few start-ups	Little experience	Wide technological distance	No collaborations	
Transition	**Increasing number of start-ups**	**Levering learning**	**Start to define a technological path**	**Synergies only between spin-offs and parent organizations**	Improvement of supporting infrastructure
Growth	Second generation of entrepreneurs	Firms move in the same direction	Diminish technology distance, more focused orientation	New potential partners	
Sustain	Neither high growth nor remarkable decrease in the number of companies			Dense collaborations inside and outside of the agglomeration	
New opportunities	**Incorporating new knowledge**		**Adaptation, Renewal, Transformation.**	**Generate new knowledge and/or bring it from outsider partners**	**Support to adopt new technologies and generate new markets**
Decline	Start-ups are rare	Competences are contained in few companies	Little technological distance (lock-in)	Closed and homogeneous collaboration networks	

Source: Own elaboration based on Feldman et al. (2005) and Merzel and Fornahl (2009).

3.3 Biotechnology agglomerations

The first biotechnology agglomerations emerged in the United States and the United Kingdom, where there was and still exists a favourable environment. This environment includes a scientific base, funding organizations, entrepreneurship, well-defined legal frameworks and policy incentives (Chiaroni and Chiesa, 2006, Cockburn and Stern, 2010). During the last decades, some emerging countries have attempted to create biotechnology agglomerations, however, as it will be presented, this is not an easy task given the complex knowledge base of biotechnologies, the way entrepreneurs can generate and obtain value from science, and the intervention of the governments to create and improve infrastructure that support the advancement of science and generate business opportunities (see Chapter IV).

3.3.1 Organizations and institutions

The creation of an agglomeration in a specific geographical area depends on its particular organizations and resources, and the historical events trigger a stimulus — internal or external (Prevezer, 1997; Chiaroni and Chiesa, 2006). Later, the growth of a biotechnology agglomeration depends on organizations and institutions that allow the growth of the local enterprises, and the entrance of new enterprises. The following paragraphs describe the organizations and institutions involved in the dynamics of biotechnology agglomerations

Organizations

Several authors have emphasized that biotechnology innovations involve different organizations such as university, DBFs, large, established firms, venture capital, and government agencies (Niosi et al., 2005; Cockburn and Stern, 2010). These actors interact in order to create and/or acquire diverse resources such as knowledge, funding, specialized inputs and management guidance (Niosi et al., 2005).

Universities and research centres are the main generators of new scientific knowledge. In the case of biotechnology, discoveries imply a high degree of 'natural excludability', which means that often, new techniques are not well known and only certain researchers and their teams have access to that know-how (Fuchs and Krauss, 2003: 4). This 'tacitness' influences the agglomeration effect; scientists and R&D researchers of firms (small and large) need to be geographically close to each other (in the same region or city) to ensure good communication (Audretsch and Feldman, 1996).

Organizations also include business firms. In the specific case of biotechnology, small and medium-size firms have played an important role in knowledge and technology transfer from universities to industry (Audretsch, 2001). Often, star scientists, who are convinced that their intellectual knowledge could be translated into a product, found these enterprises. Innovative biotechnology products can be final goods or services for the end-user market (e.g. human health) or specialized inputs for large chemical and pharmaceutical companies (e.g. enzymes) (Niosi and Bas 2003). Large companies also play an important role as consumers and source of funding when a complex biotechnology product is going to be developed (Cooke, 2001). These large companies are much more acquainted with markets, regulatory agencies and other key institutions than small-dedicated biotechnology firms are.

Funding organizations are crucial for the development of biotechnology firms. They include venture capital firms, angels, research foundations (public or private), stock markets and other. Venture capital firms support start-ups not only with investments, but also with managerial guidance. For instance, they help small firms to acquire capabilities needed to manage efficiently intellectual property and alliances (Gompers and Lerner, 2001). Stock market and governmental funding institutions also participate in the funding of DBFs (Cooke, 2002). Venture capitalists and angels provide funds in the first years of the DBF when the start up is working in basic

research, prototypes and proof of concept, as well as conducting initial market tests and building manufacturing plants. As the DBF evolves and grows, the research costs increase (it requires more research personnel, more sophisticated inputs, larger facilities, and more expensive market tests), thus alliances and stock markets become key sources of funding (Pisano, 2006).

Institutions

Key institutions in biotechnology involve the rules, norms and laws established in order to improve the competitiveness of industries using biotechnologies and avoid uncertainty and risk (North, 1990: 3-10; Pisano, 2006). Institutions (as rules) are established by government agencies as well as formal and informal collaborations between different organizations. The most salient institutions in biotechnology aim at investments in science, regulating intellectual property, and facilitating collaborations between organizations to complement resources and capabilities.

Because biotechnology is based on scientific knowledge and is often generated in universities and research laboratories, governments supporting the creation and adoption of biotechnologies have to make large investments dedicated to scientific activities (Chiaroni and Chiesa, 2006). These investments encompass the creation or revamping of public research centres and the formation and training of specialized workforce. Often, governments face a difficult task in allocating investments for the different agglomerations since the amounts required are so large (Cooke, 2002; Niosi et al., 2005). Moreover, in some industries, such as biopharmaceutical, the time and investment required to achieve a biotechnology products is so long, it often takes decades (Pisano, 2006).

Government agencies define the intellectual property regulations within a country or region. Intellectual property instruments, particularly patents, are seen as incentives to translate scientific knowledge and appropriate economic value from that. In

biotechnology, national governments decide what is patentable and what is not, a decision that looms large on the structure of the national biotechnology sector. In the case of biotechnology, intellectual property rights often are incentives to encourage star scientists to generate spin-offs from which they could receive profits in return for their intellectual contribution (Zucker et al., 1998). Scientific knowledge could be codified into a patent, which also may be a mean to obtain funding through licenses sold to other enterprises (Niosi et al. 2005, Pisano, 2006). Patents are also commercial and novel quality indicators of scientific knowledge; they help enterprises to obtain VC funding. Given that financial agents cannot accurately evaluate the future value of the DBF's R&D in its first years, patents are seen as quality indicator of their research output (Rothaermel, 2002).

Formal and informal collaboration among different actors allow them to reach and enhance their resources and capabilities (Powell et al., 1996). The generation of scientific knowledge requires a constant flow of information and face-to-face feedback among scientists, which can be seen as informal or non-contractual collaboration (Cooke, 2007). Formal collaborations are exemplified in alliances and research contracts between, for instance, small and medium enterprises and large companies. The most salient characteristics of DBFs is that they often spin-off from knowledge-creating organizations and they start as small firms. Most of the times, star scientists, who are engaged in scientific breakthroughs, establish or participate in the foundation of these spin-offs, and they do not have the management capabilities to conduct expensive clinical trials, obtain approvals, produce and commercialize their products (Rothaermel, 2002). Thus, DBFs establish alliances with large companies that have the assets to put new products into the market as well as to get funding to conduct clinical essays and obtain drug approval (Rothaermel, 2002). Large firms establish alliances with DBFs (or simply acquire them) in order to obtain research results that allow them to conduct more ambitious R&D projects as well as

to replenish their product pipelines (Pichaud, 2002).

Table 3.2 summarizes the organizations and institutions involved in biotechnology agglomerations, their function and their importance for the development of biotechnology products.

Table 3.2

Organization and institutions of biotechnology agglomerations

Organizations	Functions	Importance for biotechnology
Universities and research centres	Generate new scientific knowledge, Training of human resources.	Biotechnology implies 'high degrees of natural excludability' (Fuchs and Krauss, 2003: 4). Given the mix of codified and tacit knowledge, only few scientists have the ability to acquire and create new knowledge in this area (Audretsch, 2001: 40)
Firms using biotechnologies	Responsible for manufacture and developed products and services.	There are different types of biotechnology firms: • Dedicated biotechnology firms (DBF) are essentially R&D companies and generally small and medium-size. They have been considered as knowledge and **technology transfers** from universities to industry (Audretsch, 2001) • Pre-existing industrial or commercial companies (e.g. pharmaceutical, food additives producers or grain traders) that adopt biotechnology and **develop new products on the basis of biotechnology**. Innovative biotechnology products can be final products for the end-user market (e.g. human health drugs) or specialized inputs for other industrial companies (Niosi and Bas, 2003).
Funding organisations	Public and private organisations provide funds at different stages in the generation of new products,	Translating scientific results (from biotechnology areas) into commercial products requires huge investments. As a DBF evolves, it requires more research

	from supporting basic scientific research through establishment of firms to commercialization of final products or licenses.	personnel, sophisticated inputs, and larger facilities, thus venture capital, alliances and stock markets provide the financial resources (Pisano, 2006; Cooke, 2007).
Institutions[11]	Functions	Importance for biotechnology
R&D investments	Government investments to promote and support scientific activities and create and revamp knowledge-creating organisations.	The scientific advances of the different disciplines related to biotechnologies require large investments that facilitate the access to qualified human resources, specialized inputs and sophisticated equipment (Chiaroni and Chiesa, 2006).
Intellectual property rights	Government organisations define the intellectual property regulations within a country or region.	Patents can be seen as incentives to push forward the establishment of new biotechnology firms and to attract private investors (e.g. VC, Private Equity, and large companies) (Zucker et al, 1998)
Collaborations	Governments often establish institutional frameworks to enable and encourage formal and informal collaborations between different actors (public or private) to complement resources and capabilities.	The generation of scientific knowledge requires a constant flow of information and face-to-face feedbacks among scientists, which can be seen as informal or non-contractual collaboration (Cooke, 2007). Formal collaborations are exemplified by alliances and research contracts between different agents (Rothaermel and Deeds, 2004; Pichaud, 2002).

Source: Own elaboration.

Some authors have used the concept of cluster to analyze biotechnology agglomerations and they have defined the scope of the definition in different ways. For example, Prevezer (1997) defines clusters as "groups of firms within one industry based on one geographical area" and suggests that the mechanisms for clustering include "both the phenomenon of a critical mass of one sector of an industry developing in one place... and the force of attraction that a core sector of an industry has on auxiliary sectors of that same industry in that location" (p. 255). Feldman and

[11] Institutions involve the rules, norms and laws established in order to improve the competitiveness of the firms creating, adopting and commercializing biotech-related products and help to avoid uncertainty and risk (North, 1990: 3-10; Pisano, 2006)

Braunerhjelm (2006: 1) propose a simpler definition of the cluster: "regional concentrations of related firms and organizations". In both cases the general concept of cluster falls short to explain the dynamics of the emergence and development of cluster, the types of organizations and institutions involved in these dynamics, the geographical limitation of the cluster, and what kind of complementarities are needed.

3.3.2 Dynamics of biotechnology agglomerations

Enterprises performing high-technology activities tend to agglomerate in specific geographic areas. Often these agglomerations evolve gradually; there is a process of attraction, creation and addition of organization and institutions over time. Given that one of the objectives of this research is to evaluate the potential Mexico has to develop a biotechnology agglomeration, this section portraits the agglomeration dynamics based on the experience of developed countries (particularly in the case of the biopharmaceutical sector).

Emerging stage

In the **emergence stage**, at least three situations can trigger an agglomeration. The first one is when the specific geography area or city had already the conditions to encourage star scientists to found new enterprises for exploiting a new technology (e.g. San Francisco Bay area, Cockburn and Stern, 2010). The second one is when an external shock (e.g. changes in policies and regulations) pushes the establishment of new firms (e.g. Washington DC, Feldman et al., 2005). Finally, the third one is when an agglomeration is created by a government mandate (e.g. Biopolis in Singapore). Whether the triggering factor is internal or external to the geographical area, these new firms are often few and small- and medium-sized. In all cases, research universities and research centres are a necessary condition to found a science-based agglomeration. High-level research organizations host scientists that work in different areas or fields developing cutting-edge knowledge and exploring new techniques. In a

systematic view, the **RSI approach** suggests that in this phase, there is a process of critical mass development. Scientific relationships and collaborations among different knowledge-creating organizations allow the generation of a continuously nurtured flow of ideas (Braunerhjelm and Feldman, 2006). This collaboration is based on particular norms and values (culture) shared in a specific geography area (Owen-Smith and Powell, 2006; Cooke, 2007) and allow scientists to be in contact with flows of information and tacit knowledge (Audretsch and Feldman, 1996; Fuchs and Krauss, 2003). For that reason, at the early stages of a biotechnology agglomeration, knowledge-creating organizations and their scientists are key players **as anchor tenants** (Feldman, 2003). At this stage, few scientist-entrepreneurs found companies; the ones that exist are located around the university or research centres to access to new knowledge and skilled personnel (Kenney, 1986; Zucker et al., 1998; Niosi and Bas, 2003).

During the **transition stage** first-ties appear: formal collaborations emerge and other organizations contribute to the creation and growth of small enterprises in the locality. DBFs often have scientific capabilities but they have neither sufficient funds nor the managerial skills to develop their products, obtain the necessary approvals from governmental regulatory bodies, and put their products into the market. Thus, VC firms (and also, angels and government R&D subsidies) represent a source of seed funding in the first years of DBFs' life –where research is crucial—and provide managerial support to arrange alliances and manage intellectual property. VC investments are attracted by the potential of DBFs, which often is reflected in the number and quality of patents (Chiaroni and Chiesa, 2006). Alliances with large companies also provide DBFs with other resources and capabilities to develop distribution and marketing capabilities and put their products into the market. These firms collaborate with DBFs because they see the potential commercialization of products or the utility of the new technologies in the production processes. These

alliances imply that the cooperating enterprises share the same knowledge base. In this case, the incumbents do not need to establish research facilities in the agglomeration (Prevezer, 1998; Niosi and Bas, 2003). At this stage, where a critical mass is reached and first-ties start to appear, the agglomeration begins to define its technological profile.

Alliances and VC support are not enough to support knowledge generation and diffusion. An appropriate institutional environment has been created where other public and private organizations and institution emerge to encourage technology transfer and the creation of new enterprises, and to facilitate the growth of already established enterprises:

- Government institutions (e.g. departments of economic development) can improve the climate of business (R&D tax credit, investment tax credit), and eventually attract other organizations and supplementary funds;
- Technology transfer offices can help to launch new start-ups with potential investors (e.g. contact with VC);
- Research hospitals that contribute to the system by conducting preclinical research and commercialization;
- Technology parks;
- Institutes to support new start-ups;
- Associations that group biotech firms and diffuse information about the industry applications (Cooke, 2002; Niosi and Banik, 2005)

These organizations "made it easier for new firms to appropriate knowledge inputs and sell knowledge-intensive products in well-defined markets" (Niosi and Banik, 2005: 355). Over time, these organizations develop patterns of behaviour that define local institutions helping to improve the institutional environments. At the same time,

the locality is acquiring its core competencies—"those that create value for markets outside the region, that are co-specialized, and difficult to imitate" (Niosi and Bas, 2001: 32). In this phase, the agglomeration begins to define agglomeration capabilities.

As mentioned before, DBFs often need to sell their products and services in order to obtain additional funding (even if they have financial support from angels or VC firms). The customer or the commercialization organization could be a large company established (or not) in the same location; this has two implications for the origin and growth of the agglomeration: (1) this large firm may be attracted by the specialization of the agglomeration originated by research organizations; or (2) it was already in the region before the establishment of DBFs and had started to collaborate with the local universities, thus contributing to define the technological trajectory of the agglomeration (Feldman, 2003). As a result, relationships between universities, DBFs and incumbents may produce geographical synergies (e.g. alliances or other types of collaborations). In this way, the definition of the technological profile of a biotechnology agglomeration depends either on the lines of research of the universities, or on the technology chosen by the large firm, both can be seen as anchor tenants (Feldman, 2003).

Growing stage

The growth phase of the biotechnology agglomeration's life cycle is based on the increment of the number and size of the DBFs and the attraction of other agents' activities (more alliances, and more VCs may establish in the area). At this stage, it seems that the scientific base of the agglomeration is a main factor of attraction. However, a word of caution is needed, although some authors suggest that scientific capabilities become specialized and those represent the strength of the agglomeration given the reinforcement of the knowledge base (Prevezer, 1997; 1998). Too much

specialization can lock-in the agglomeration and hinder or delay the undertaking of a new cycle of growth[12]. Therefore, as the scientific base is nurtured by universities and research centres, at the same time, they have to generate new knowledge in other areas that will allow the agglomeration to venture in other fields: "add new work to old work" (Jacobs 1969) (see section 3.2.1).

The growth of a DBF within an agglomeration often depends on the collaboration with incumbents in its own sector, which have more experience in regulatory and commercialization issues. Once the earlier DBFs create their market or demonstrate their research potential, new entrants will be encouraged. These new entrants may or not be scientists, but they will be attracted by the knowledge base and the infrastructure of the agglomeration (Chiaroni and Chiesa, 2006). Here it is important to mention that not all the sectors using biotechnologies grow at the same rate, because new entrants and incumbents are more attracted to agglomerations focused on human health sectors. Other sectors using agricultural, chemical or environmental biotechnology applications are either less developed, or large incumbents absorb most of the research spillovers emerging from DBFs using these biotechnologies (Prevezer, 1997). Consequently, regions hosting biotechnology firms in agriculture or environment sectors face difficulties for attracting other agents.

The expertise of large, established firms becomes crucial to complement the scientific knowledge of the agglomeration. Therefore, at the growth stage, large companies can become anchor tenants. According to Feldman (2003), "the presence of large established entities create some of the well-known advantages of agglomeration economies such as pools of skilled labour and demand for specialized inputs, which may benefit smaller start-ups" (p. 323). These start-ups (DBFs or firms related to the

[12] For example, if a cluster is unable to jump from one (declining topic) such as ag-bio to the next (e.g. food additives), its specialization plays a dirty trick. Gertler and Vinodrai (2009: 256) mention the case of Saskatoon, Canada.

industry) may be encouraged by the interaction among different actors located within the area, for example, "potential entrepreneurs may take ideas out of the established anchor and form new firms" (ibid). Thus, the location will benefit from a renewed base of entrepreneurship (Chiaroni and Chiesa, 2006). Romanelli and Feldman (2006) suggest that "only those regions which generate a community of entrepreneurial activity... that is, firms that are started by entrepreneurs with experience in other entrepreneurial firms in the same industry, may be capable of long-term cluster persistence." (p. 111).

Sustaining stage

In the sustaining stage, institutional frameworks and the presence of different agents enable the agglomeration to reach 'well functioning' systems of innovation and entrepreneurship (Feldman et al., 2005; Chiaroni and Chiesa, 2006). Feldman et al. (2005) suggest the following characteristics of the maturity phase:

> " [T]he creation of the regional public sector financing and grant-giving programmes. Government policy creates further incentives for investment. Incubators and other technology partnerships are created to promote the growth of the industry. Mergers and acquisitions begin to thin out the companies. Successful entrepreneurs also move from their initial start-up to start other companies, becoming serial entrepreneurs with deep roots in the community. Additionally, venture capitalists relocate to the area or open branch offices... The maturing cluster spurs policy changes as governments seek to attract and provide a flourishing environment for even more high technology development (Feldman et al., 2005: 134)

Institutional conditions that allow the interaction between different organizations are needed to maintain the competitive advantage of a region (Cockburn and Stern, 2010). In addition, the foundation and support of new DBFs could reinforce an agglomeration (Niosi and Bas, 2003). Funding also plays a crucial role for the firms' growth; the availability of public and private funding ensures the maintenance of the

agglomeration, especially in those related to human health sector (Cooke, 2002).

As mentioned before, DBFs aim at different markets according to different applications. In the case of DBFs in human health, the market encompasses local hospitals, private clinical organizations, and public and private healthcare systems (government). The presence of these actors in the region contributes to the growth of the DBFs. The interaction between DBFs and users within the region facilitates the learning process; this allows enhancing the core competence of the region. Moreover, enterprises within an agglomeration can interact with organizations located abroad. According to Niosi and Bas (2001: 33) "the core competencies of the region include the propensity and capacity to cooperate and learn from other institutions... being closely related to and made of knowledge, they increase with practice, usually procuring sustained advantage to regions as well as firms".

Finally, in the case of the health care sector, Cooke (2005) and Niosi and Bas (2003) mention that urban cities that put together all the actors involved in the value chain of new drugs (discovery, testing, production and commercialization) are called megacentres. The actors that converge in the megacentre require different, sophisticated inputs, especially in R&D areas. Thus, Niosi and Bas (2003) mention "R&D, particular in health science, has moved from a narrow discipline focus to a more wide trans-disciplinary one, the new biotechnologies and more traditional pharmacology combine in the development of new drugs" (p. 791). This suggests that urban cities with more diverse capacities seem more likely to grow than more specialized ones (Niosi and Bas, 2001).

CHAPTER IV
TECHNOLOGY POLICIES

High technologies –biotechnology among them- play an important role in economic growth. Consequently, governments interested in supporting economic growth have intervened to encourage the creation and support of high-tech industries through public policies, particularly science, technology, and innovation policies (STI) (Nelson, 1993; Dodgson and Bessant, 1996; Cimoli et al., 2009; Cockburn and Stern, 2010). High technology industries are characterized by continuous technological change, large investment in R&D, and a strong growth rate (Oakey et al., 1988). In addition, the support of these technologies relies on a coherent, sophisticated and long-term government commitment (Cimoli et al., 2009; Cockburn and Stern, 2010). The chapter is divided as follows: section 3.1 presents the theoretical arguments that support the intervention of government in order to achieve technological innovation and show the relevant dimensions and characteristics of public policy focused on innovation, section 3. 2 deals with the design and implementation of STI policies, and section 3.3 presents the experience of emerging countries in formulating and implementing public policies to support the creation and development of biotechnologies.

4.1 Public policies

4.1.1 The role of government

In the economics literature there are two main approaches that explain the importance of innovation in economic growth: the neoclassical approach and the evolutionary approach (Lundvall and Borras, 2005; Castellacci, 2007). On one hand, the neoclassical approach downplays policy intervention; such intervention is justified only when there is a market failure (e.g. lack of incentives to invest in knowledge production). On the other hand, the evolutionary approach underlines that

technological innovation does not follow a linear model with well-defined consecutive phases within the firm; on the contrary, in order to achieve technological innovation different organizations and institutions[13] take part –for instance, firms, universities and government organizations (Lundvall, 1992; Nelson, 1993). Knowledge flows and learning processes are embedded in these organizations and institutions (Lundvall, 1992). Although these elements are created and accumulated in both, individuals and organizations, as routines, skills and capabilities (Nelson and Winter, 1982), the mechanisms required to create and diffuse technological knowledge and stimulate the learning process often are supported and coordinated (in order to give some coherence of the system) by government agencies (Dalum et al., 1992). Thus, the importance of the government's role on the innovation process relies in its capacity to create and maintain a coherent system: "[public sector] is involved in direct support of science and development, its regulations and standards influence the rate and direction of innovation, and it is the single most important user of innovations developed in the private sector" (Lundvall, 1992: 14). According to Dalum et al. (1992: 302-7), the government's role is to devote national efforts both in terms of resources and institutional capabilities to build specific competencies based on the formal education system; to nurture investment in R&D implementing legal frameworks that facilitate the appropriability of economic value; and to ensure the creation and diffusion of relevant knowledge facilitating networking and cooperation.

In sum, the role of the government is to provide an institutional environment that allows the interaction between different actors and support innovation activities that contribute to economic growth. Some questions arise: how should governments

[13] Innovation processes involve organizations and institutions. North (1990: 3-10) define them as follow: institutions are 'the rules of the game in a society or, more formally, the humanly devised constraint that shape the human interactions'; these institutions can be formal and informal: formal institutions are characterized by codified rules, for example laws, while informal institutions are simply habits or social norms. Organizations are 'groups of individuals bound by some common purpose to achieve objectives'.

participate? What is the policy framework that could guide policy makers to develop programs in order to support innovation? The following paragraphs deals with these questions.

4.1.2 Dimensions and characteristics of public policies

According to Metcalfe (1994) "technology policy is much more than a matter of supporting R&D expenditures, it covers the whole spectrum from invention to diffusion and from basic research to the mastery of specific technological competencies" (p. 936). In doing that, policy makers could recognize the complementary assets that allow firms to create and capture economic value, and also facilitate the diffusion of innovations.

Niosi and Bellon (1995) underline that "public policy can be a comparative advantage if there exists a good definition of development programs and a good definition of tasks, but especially there must be a good articulation between partners involved in the tasks... it has implication with the rules and practices of institutions...the positive effects of policy can be achieved only if there is a good articulation" (p. 213-4). In order to identify the elements that allow the establishment of an appropriate institutional environment, scholars have analyzed different dimensions and characteristics of the policies focused on encouraging technological innovation. These dimensions involve types of policies, scope, and relation with the environment. These elements have implications for the design and implementation of public policies.

Dimensions

Dodgson and Bessant (1996) suggest that the aim of public policies is "[to] assist firms to improve awareness of why and how to invest in technology and to overcome the complexities and uncertainties of innovation so as to enhance their own and their

nation's competitiveness" (p. 3). Policy initiatives focused on supporting innovation as competitive advantage have to consider carefully the firms' needs in terms of accumulation and combination of technological resources, in order to create distinguished competences.

Dodgson and Bessant (1996) distinguish three types of policies that help governments to achieve innovation: science, technology, and innovation policies; each of them has different objectives, but they complement each other.

Table 4.1

Types of public policies

Policy	Objective	Main features
Science policy	Development of science and the training of scientists.	Scientific education Research in universities and government labs Basic research. Focus in big issues, e.g. space, nuclear power.
Technology policy	Enhancement and development of technology.	Support for creation of 'strategic' or 'generic' technologies, e.g. IT, biotechnology, nanotechnologies.
Innovation policy	Improvement of the capacity to innovate of firms, networks, industries and entire economies. Facilitate the interaction between different actors.	Facilitating diffusion of technology Encouraging "transfer sciences" SME focus

Source: Dodgson and Bessant (1996: 4-5).

Another dimension of public policy is related to industrial scope. Teubal (1997) suggests two different types of policies according to their scope: horizontal technology policies (HTPs) and vertical (targeted) technology policies. This author mentions that these types of policies are complementary to each other:

"**HTP** are a category of technology policies whose objective is to promote

> technological development *per se*, irrespective of industrial branch or even technological area... They also complement more specific, **vertical** or even more selective policies aimed at specific industrial branches and technological areas. Their importance derives from being central components of government inducement of technology-based structural change in a wide variety of conditions" (Teubal, 1997: 1163, bolds added)

Metcalfe (1994) mentions that the importance of distinguishing between horizontal and vertical policies "relies in that each technology has a different dynamic of knowledge accumulation and the generating activities are located in different communities and institutions" (p. 936). Thus, policy makers have to consider the characteristics of the industry and the socio-economic dynamics within the country or region.

Another important dimension is the creation of a human capital market. According to Niosi (2010: 92) "[The] adoption, diffusion and use of technology depend not only on the amount of human capital but also on its institutions... government policy has to create both supply and demand". Therefore, governments interested in technological development often create incentives to improve the quality and volume of human resources (supply) and ensure the use of those resources for technological and economical development (demand). On one hand, universities have to conduct teaching and research activities that allow researchers to generate not only new knowledge but also publication, patenting and licensing. On the other hand, innovative firms require R&D activities, which demand highly skilled personnel.

Table 4.2 presents a variety of incentives that can be implemented by public and private organizations in order to leverage the human capital market.

Table 4.2

Incentives to create a human capital market

Building the supply of human capital	Building the demand of human capital
• Grant loan systems for students	• Tax allowance and credits for the R&D for private firms
• Research grants and fellowships	• R&D subsidies for private SMEs
• Immigration and skilled labour	• R&D loans for private firms
• Import of foreign teachers	• Subsidies aimed at the attraction of foreign R&D laboratories
• Incentive to graduate university programs	• Intellectual property laws (patent, copyright, industrial design, trademarks)
• Tax exemptions to foreign researchers	• Tax deduction for venture capital
• Academic research funding councils	• Public venture capital
• Accelerated immigration for foreign university students	• Public R&D laboratories

Source: Niosi (2010: 98)

Another dimension is focused on the relationship between the environment and the design of public policies. According to Sabatier (1986), there are two approaches that identify these relationships: top-down and bottom-up.

> "The essential features of a top-down approach are that it starts with a policy decision by governmental (often central government) officials and then... [they will] evaluate the factors affecting policy outcomes and program outcomes... The bottom-up approach... starts by identifying the network of actors involved in [an activity]... identifying the local, regional, and national actors involving in the planning, financing, and execution of the relevant governmental and non-governmental programs" (Sabatier, 1986: 32).

In other words, although the government plays an important role as designer and coordinator of different policies, sometimes the socio-economic interactions between

different actors give place to unexpected opportunities and demands. In this sense, socio-economic organizations can influence the design of public policies.

In sum, the successful incorporation of technological change in economic growth has been based on the implementation of different types of public policies. These policies need to have coherence in terms of objectives and mechanisms. Therefore, policy makers have to consider the characteristics of strategic industries and the socio-economic dynamics within the region or the country.

Design and implementation of technology policy

The above paragraphs have shown the importance of government intervention in the innovation process and the different dimensions that policy makers have to consider for encouraging and maintaining technological innovation. Here, the interest turns to the analysis on how public policy is designed and implemented.

The design and implementation of public policies is a dynamic and evolutionary process (Niosi and Bellon, 1995; Teubal, 1996, 1997; Carlsson, 2006). The particular historical, economical and political characteristics of a country determine the behavioural pattern of actors involved in the innovation system; at the same time, these actors define the design, implementation, continuity, and terminate of the public policies. Dodgson and Bessant (1996) suggest that the experience of other countries can help policy makers to design the main programs of science, technological, and innovation policies; however, it is important to consider the specific characteristics of each country or region. According to Niosi and Bellon (1995: 222-3), the phases of the technology policy's life can be compared with the natural life cycle; it means, birth, development, and selection (in terms of policy's continuity). In the birth phase, the policies are designed according to the commercial and technological environment, trying to cover the firms' demands; in this phase, there may be little coherence among the different initiatives. In the development phase, the policies find a market, and

policies become more coherent. Government seeks to avoid duplication in order to create an efficient system. In the selection phase, the results of the policies are evaluated and government decides to continue with the policy or to end it. According to Teubal (1996, 1997), government organizations also learn by the experience ("learning by doing"), this implies that the design and implementation of new policies may be improved over time. Niosi (2002) mentions that not all policymakers learn, and that the slow-learning motion of government policy designers characterizes many developing countries.

Public policies have to be monitored and evaluated in order to decide whether the programs, institutions and mechanisms are well designed and coordinated. In addition, the socio-economic conditions change over time, thus policy makers have to adjust these policies or create new ones according to those conditions.

Evaluation procedures for STI policy

As mentioned above, government plays an important role in promoting incentives for the creation of new knowledge and the performing of R&D activities. Therefore, STI policies have to be designed according to the particular socio-economic dynamics and technology assessment (Kuhlmann 2002). In addition, the specific conditions of countries, regions and industries have implications in the design, implementation and evaluation of public policies. The process of knowledge creation, and the translation of this knowledge into commercial products involve the participation of several actors with different objectives. Therefore, Gheorghiu and Roessner (2000: 658) suggest that evaluation has to consider three focal points:

- Evaluation of publicly supported research carried out in universities and public sector research organizations,

- Evaluations that focus upon linkages, including those of programs seeking to

promote academic-industrial and public-private partnership, and

- Evaluation of diffusion and extension programs.

In order to perform these evaluations, government has to develop a strategy that allows it to identify the benefits and weaknesses of those policies. In this sense, Kuhlmann (2002) defines the research and innovation policy evaluation as "methodology based analysis and assessment of the appropriateness of research and innovation policy assumptions and targets of the related measures and their impacts, and of the goal attainment". In addition, the evaluation of public policies has to include the definition of clear objectives (Gheorhgiu and Roesnner, 2000; European Court of Auditors (ECA) and Colling, 2007). Thus, government requires an evaluation strategy that includes the objectives, methodologies and diffusion of results:

> "An evaluation strategy provides the conceptual framework within which evaluation activities are designed, planned, executed and used... such a strategy should consider the main legal, organisational and methodological issues surrounding programme evaluation. This includes what evaluations are to be carried out, by whom and when, how data are to be collected, what methodological approaches are to be used and how findings are to be communicated and followed up." (ECA and Colling, 2007: 23)

Therefore, an important step is to establish a government agency and design the organizational structure of this agency to carry out evaluations at different levels of aggregation and at different time horizons (ECA and Colling, 2007; Gheorghiu and Roessner, 2000). The creation of panels of experts is an important element to decentralize an evaluation process: "a separate body from the one implementing the program" (ECA and Colling, 2007: 28). Methodologies are another important element in the evaluation process; these have to be developed according to the objectives of STI policies. The design of methodologies encompasses decisions about

what kinds of data to collect, and when and who has to be interviewed (Gheorhgiu and Roesnner, 2000; ECA and Colling, 2007). The final objective of policy evaluation is "to provide relevant information and analysis that can be effectively used for programme management and policy making" (ECA and Colling, 2007:47). Government and evaluation agencies have to ensure the dissemination of information toward stakeholders (Gheorhgiu and Roesnner, 2000; ECA and Colling, 2007).

STI policies and agglomerations

High technologies show two important characteristics: high tech enterprises concentrate in specific geographical areas and they often contribute to economic growth. Therefore, some governments have shown interest in designing technology policies that allow them to develop high-tech industries and to achieve competitive advantage that could be reflected in economic growth. Since the 1990s, empirical research has concentrated in a new policy model, which is focused on innovative regions in high-technology industries: "These studies concentrate on the analysis of well performing regions, dealing with the questions of why such industries concentrate in particular locations, which kinds of linkages and networks exist, and to which extent knowledge spillovers can be observed" (Tödtling and Trippl, 2005: 1204). However, some regions 'do not learn or do it in a slow pace' (Niosi, 2002), this limits the creation of relevant organizations and institutions. As mentioned above, the formulation and implementation of public policies relies in a coherent system of organizations and institutions coordinated by the government. Niosi (2002: 296) identifies some obstacles that impede the flow of knowledge and inhibit the learning process: organizational and institutional inertia, inadequate system rules, lack or limited number of key institutions, weak coordination among units, and lack of information flows. These obstacles are more frequent in developing countries where the scarcity of resources limits the performance of institutions, or even worse, key institutions are absent, especially those institutions focused on science,

technology and innovation (Niosi, 2010). Consequently, underdeveloped governmental institutions are not able to formulate and implement adequately public policies oriented to promote technological development and catching up, affecting the formation and training of human capital, and the creation of a critical mass that allow the local progress of science and the creation and diffusion of new technologies.

4.2 Technology policy in emerging countries

Governments in industrial and some emerging countries do intervene to design and implement policies that help firms to acquire and develop technological and managerial capabilities to generate competitive advantages. Given that emerging countries face scarcity of resources, the question is how governments of these countries should design and implement public policies to adopt and develop new technologies and innovations.

Teubal and colleagues have developed different approaches[14] in order to explain how government could intervene to promote technological improvement and innovation. These approaches underline the relevance of two basic processes:

- Learning is a social process (Nonaka, 1994): in advanced OECD nations, government often intervenes in order to create an institutional environment to support the interaction between agents, in turn this will allow the creation of capabilities and competitive advantages.
- Evolutionary selection of firms (Nelson and Winter, 1982): the way government supports firms should vary over time; in a first phase, enterprises depend heavily upon government support, in a second phase enterprises usually become independent from public backing.

[14] Building technological infrastructure approach (Justman and Teubal, 1995); Emerging catalytic policy approach (Teubal, 1996); Horizontal technology policies approach (Teubal, 1997); Market-stimulating technology policies approach (Lall and Teubal, 1998); Innovation and technology policy approach (Teubal, 2002); Evolutionary targeted approach (Avnimelech and Teubal, 2008).

Summarizing the different approaches proposed by Teubal and his colleagues (see Table 4.3), there are at least three elements that policy makers should consider for designing and implementing policies in a dynamic way:

- Infrastructures,
- Capabilities (this implies the rejuvenation of the business sector and the creation of new markets)
- Industrial scope

All these elements are often accompanied by institutional adaptation.

Table 4.3

Evolution of public policies focused on innovation.

First phase	...	Second phase
The role of government is catalytic and involves the following generic tasks:		The role of government diminishes in direct support to firms but consolidates the structure and environment to produce innovations:
• Creating basic technological infrastructure, • Stimulating the business sector to adopt new technologies, • Diffusing relevant and non-proprietary information and creating markets to support R&D activities, • Implementing horizontal/neutral policies.	...	• Supporting the creation of advanced technology that contributes to innovation, • Creating multi-agent structures (e.g. clusters, markets, sectors, industries), • Implementing vertical /targeted policies.
Institutional adaptation and innovation		

Source: Own elaboration based on Justman and Teubal (1995), Teubal (1996, 1997, 2002); Lall and Teubal (1998); Avnimelech and Teubal (2008)

First phase:

According to the analysis made by Teubal and his colleagues, at the first phase (infant) government plays a catalytic role. Setting a basic infrastructure is relevant because it allows the 'assimilation of technology progress' by business organizations (Justman and Teubal, 1995). The main objective of a basic infrastructure is to provide **technological services to firms** (specially SME) and to diffuse information in order to support 'the efforts of [technological] absorption' of enterprises (Teuba, 1997). These activities are crucial for **developing local capabilities in developing countries**. The government should stimulate the business sector to adopt new technologies and capabilities that come from external sources (technologies already used in developed countries). Local enterprises could be potential users of improved technologies, however, most of the times they do not have access to relevant information or they are not familiar with the most advanced technology (modernization). Therefore, institutional adaptation, new or revamped government agencies (new organizations) and institutions (laws and regulations), often help enterprises to overcome obstacles related to diffusing information and adopting advanced technologies. According to Teubal (1997, 2002), institutional adaptation depends on positive feedbacks; however, the author does not mention how government can establish feedback mechanisms. In addition, this phase is characterized by the implementation of horizontal/neutral technology policies. These policies support the creation of markets, especially markets that are 'missing or particular difficult to create in developing countries' (e.g. financial services) (Lall and Teubal, 1998: 1370). The objective of these policies is to support firms in order to obtain technological and managerial capabilities.

Second phase:

When firms have developed some managerial, operational and technological capabilities, they could upgrade the level of technological complexity. Consequently, governments invest in advanced technological infrastructure. This infrastructure

"serves high-tech, leading-edge industries, providing necessary R&D inputs to the specific innovations of development projects of user firms. The necessary capabilities... are not available anywhere initially and must be created" (Justman and Teubal, 1995: 264). The creation of sector-specific capabilities implies the implementation of vertical or targeted policies, which are focused on specific industries. Once governments have made a strategic choice, they must allocate the national resources in a limited number of industries or generic technologies (multi-agent structures) (Avnimelech and Teubal, 2008). Again, governments support the innovation activities through institutional adaptation and innovation.

Although the framework proposed by Teubal and colleagues seeks to propose a way to design and implement technology policies, they do not mention how to assess the accuracy of programs. The authors mention that positive feedbacks are needed and government agents and policy makers would and should learn over time[15] (Teubal, 1997; Lall and Teubal, 1998). In this sense, some authors have suggested evaluation procedures for STI policies (e.g. Gheorhgiu and Roesnner, 2000; ECA and Colling, 2007)[16], while some international organizations such as the OECD have suggested the creation of indicators to monitor and evaluate programs and policies.

4.2.1 Importance of industrial policy

Economic growth depends on the establishment of new industries or sectors (Rodrik, 2004). In this sense, governments may formulate a strategy to identify and support specific industries (Teubal, 2002; Cimoli et al., 2009). This choice has to be in line with macro-economic policies, "including exchange rates, taxation, fiscal policies, public investments, governance of the labor market, and income distribution" (Cimoli

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[15] An adequate pattern of restructuring requires the following: objective evaluation routines within government, policy capabilities within government, and the political power to shut down programs (Teubal, 1997:1182-3); 'policy learning' (Lall and Teubal, 1998).

[16] See 'Evaluation procedures for STI policies' in the Section 4.1.2 of this Chapter.

et al., 2009: 11).

How is industrial policy designed and implemented? The role of government in industrialized countries has been to facilitate the mechanisms to develop technological capabilities and managerial skills through coherent policies and programs (Rodrik, 2004). In order to formulate and implement these policies, governments have worked closely with business and industrial organizations to establish priorities, formulate mechanisms to achieve the expected results, and to react to market and political threats, as well as scientific and technological discontinuities (Evans, 1997; Rodrik, 2004). Thus, it can be said that close relationships between business circles and government institutions facilitate feedback mechanisms and allow the improvement of economic organization. Unfortunately, in developing countries (and some emerging countries) there is a porous state structure, characterized by the lack of relevant information and corruption (low autonomy of bureaucrats); however, in some countries there are some "pockets of efficiency" that could promote growth through public industrial policies (Evans 1997; Rodrik, 2004).

How is government involved in the creation of new industries? The creation of a new industry often depends on the strategic choice of governments (Lall and Teubal, 1998; Rodrik, 2004). Two elements are needed to successfully create a new industry: 1) choosing strategic industries, and 2) supporting the emergence of new markets (supply and demand). Government often is in charge of setting 'national objectives' and of allocation resources mechanisms; which implies making choices and taking risks. Regarding the creation of new markets, on the supply side, government supports the searching of new ways of doing product or the creation of new products; while on the demand side, government supports the use of those new products (Dalpé et al. 1992; Lall and Teubal, 1998). Considering the two phases of STI policies described above, in the first phase, governments tend to facilitate the process of 'discovery' in which entrepreneurs can find new technological processes and/or

products, and establish coordination mechanisms that allow firms to perform independently in a second phase (Lall and Teubal, 1998; Rodrik, 2004). Here it is important to emphasize the character of the STI policies: they support the creation of processes, for example, processes to achieve technological capacities and managerial skills (e.g. learning processes) more than specific outcomes (e.g. increase the volume of exports) for short-term (Doner and Ritchie, 2003; Rodrik, 2004).

4.3 STI policies and Biotechnology

New industries: the promise of biotechnologies

Biotechnology involves a group of technologies that can be applied to different industries. Biotechnology *per se* is not an industry. Modern biotechnologies can be seen as an essential component of new industries like biopharmaceuticals, bioagriculture, bioenvironmental services, and bioinformatics. Biotechnology applications in industrial fields are perhaps a unique situation in which scientific knowledge is very likely to have an industrial application (Pyka and Saviotti, 2002)[17]. Therefore, governments interested in supporting the development and adoption of new biotechnologies in different industries (e.g. human or animal health, agriculture, or environment) have to consider: large investments in R&D, the importance of scientific advances, and the establishment of relationships between SME developing and using biotechnologies and large, established companies (like pharmaceutical, chemicals, and seed traders). These elements do vary in each industry, and the government support may affect in different degree the performance of each industry.

STI policies supporting biotechnologies

STI policies targeting the creation and development of biotechnology capabilities can

[17] Particularly interesting is the way in which this group of technologies has affected the pharmaceutical industry by providing new techniques that may help in the drug discovery process, or may even constitute the core of a new drug (Pisano, 2006).

be categorized according to the level of formulation and implementation (national and sub-national level) (Cooke, 2007) and their objectives (support of scientific, technological, and commercialization capabilities) (Arundel, 2003). National public policy is in charge of the macroeconomic environment and the scientific and technological policies in general terms, while the regional public policy often encourages the agglomeration of organizations and institutions related to specific industries: "national governments are mainly responsible for delivering science policy and basic research funding, while regional governance system (including private and public sectors) deliver innovation programmes. These are usually near-market incentives to firms to build innovation networks, access co-funding and engage in joint marketing to enhance innovating potential and competitiveness" (Cooke, 2007:109). Table 4.4 summarizes the objectives of public policies at the national and regional level.

Table 4.4

Objectives and themes of national and regional STI policies for biotechnology

Type of policy	National	Policy themes applied for either national or regional governments	Regional
Science	Education and basic research in all fields (e.g. human health, animal health, agriculture, environment).	Funding for scientific research and formation and training of specialized workforce: S&T advisory body, S&T awards from government.	Creation of 'Centres of Excellence' in specific scientific applications
Technology	Infrastructure to support the coordination between agents in strategic or generic technologies.	Intellectual property laws, Training and guiding inventors.	Promote and facilitate university-industry linkages in competitive R&D projects.
Innovation	Facilitate the diffusion of technology and the creation of markets.	Attraction of risk capital (venture capital, angels, private research foundations) Tax incentives/Tax credits, Technology acquisition by the government, Technology commercialization funds.	Attraction of investors and strategic partner to support the commercialization of specific technologies.

Source: Own elaboration based on Dodgson and Bessant (1996), Cooke (2007), Niosi and Bas (2004).

National and regional policies complement each other. National government is responsible for STI policies focused on fostering strategic sectors using biotechnologies in the economy, while sub-national levels allocate funds and support efforts regarding biotechnologies according to their resources and size. In this sense, Cooke (2007) suggests the design of a 'regional science policy' where regional administration plays an active role in demanding public research funds and looking for the support of national and international organizations (e.g. foundations such as

the Welcome Trust, venture capital) to generate 'Centres of Excellence' –which could be born from centres of expertise[18].

STI policies described in the paragraphs above are based on the experience of developed countries which have maintained a long-term commitment to ensure funds for scientific research, set up favourable intellectual property laws, and facilitate the adoption and diffusion of modern biotechnologies (Niosi and Bas. 2004; Cockburn and Stern, 2010). Contrary to that, in some emerging and developing countries the formulation and implementation of STI policies are carried out by underdeveloped institutions, suffering from scarcity of resources, and weak capabilities (Niosi, 2010). However, some emerging and developing countries[19] have implemented STI policies for developing and using biotechnologies in different sectors, and they have paid special attention to the biopharmaceutical industry.

In sum, biotechnology enterprises require as a main input scientific knowledge; this fact has a direct implication for the science policy. Most of the new enterprises in biotechnology are small and their intellectual capital is their single value asset, thus this should be taken in account when designing intellectual property laws, which is an important part of the technology policy. As the small biotechnology enterprises evolve they need to collaborate with other organizations (e.g. VC, large firms). In this sense, innovation policies have to be in charge of creating those linkages. In addition, it is important to identify strategic sectors and define horizontal and vertical STI policies. Finally, evaluation and re-design of policies is important in order to improve results.

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[18] In Canada and the USA, education is a provincial or state responsibility, while centres of excellence are mostly national.

[19] Some countries have achieved successful biopharmaceutical products: Brazil, China, Cuba, India, Israel, Singapore, South Africa, South Korea (Nature Biotechnology, 2004)

CHAPTER V

SYSTEMS OF INNOVATION: THE CASE OF MEXICO

The concept of national systems of innovation (NSI) has been an important tool to identify the different agents that participate in the innovation process. Government intervention often supports knowledge flows and learning processes. However this is not an easy issue, especially in developing countries where centralization of decisions and problems of governance are common. The objective of this chapter is to mention the characteristics of the Mexican national system of innovation. In the first section of this chapter, the definition and characteristics of the NSI are presented. The second section illustrates the characteristics of the NSI in developing countries. Finally, in the third, the case of Mexico is portrayed.

5.1 Systems of innovation: national, regional and sectoral

The concept of national system of innovation appeared in the mid-1980s as a tool to design and implement industrial policies in Europe (Sharif, 2006). Since then, it has been used in both academia and policy-making fields (Sharif, 2006; Nelson, 2000) to analyze and assess the interaction between agents and public policies to support innovation. Consequently, the main objective of NSI, as analytical framework, is to identify the main institutions and agents involved in the innovation process as well as the interaction between those agents. Often these interactions are supported by public policies. The NSI has been defined in different ways, which stress different components of the concept. For example, one definition stresses the scope of the organizations involved in the NSI from exclusive R&D organizations to all social, political and economic aspects affecting scientific and technological knowledge and learning:

> "the narrow definition would include organization and institutions

> involving in searching and exploring –such as R&D departments, technological institutes and universities. The broad definition … includes all parts and aspects of the economic structure and the institutional set up affecting learning as well as searching and exploring (Lundvall, 1992: 12).

Another definition puts the emphasis in the broad scope of each component of the concept:

> "Innovation [is] the process by which firms master and get into practice product designs and manufacturing processes that are new to them, whether or not to the universe, or even to the nation...System [is a] set of institutions whose interactions determine the innovative performance... [N]ational. The concept may be too broad" (Nelson, 1993: 4-5)

Still, the following definition underlines the institutional aspects of the system:

> "[a] set of institutions that (jointly or individually) contribute to the development and diffusion of new technologies. These institutions provide a framework within which governments form and implement policies to influence the innovation process. As a such it is a system of interconnected institution to create, store, and transfer of knowledge, skills and artefacts which define new technologies." (Metcalfe, 1995, cited by Sharif, 2006: 745)

Although there are different NSI definitions, there are at least three main or basic elements for an innovation system to exist: firms, universities, and governments (including agencies and STI policies) (Nelson, 2000). The innovation system concept seems to be flexible: it can be adapted to the particular local conditions (social, political and economic), to the different levels of analysis (local, regional and national), and to the different economic activities (sector)[20] (Nelson, 2000; Sharif, 2006). The relevance of the NIS is that it allows governments to identify the basic elements and key linkages, and in terms of policy "it helps legitimize the importance of different aspects which are important but underestimated" (Sharif, 2006: 758).

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[20] For more about Regional innovations systems see, for example, Niosi et al (2005); Cooke (2002) and Sectoral innovation see Malerba (2004)

Do all countries have a NSI? It depends on the scope of the definition. On the one hand, the narrow definition of the NSI stress the generation of new technologies based on R&D institutions –which requires large investments in R&D capabilities, and generates new knowledge and learning; in this sense, not all countries have the capacities to establish these kind of institutions. On the other hand, the broad definition of the NSI, suggests that learning processes can take place in almost any circumstance. Given that innovation may be new for the country, for the industry or for the firm, therefore all countries have room for learning capacity (e.g. using foreign technology) (Shariff, 2006). The broad definition can be applied to emerging and developing countries, but the more restrictive definition put forward by Richard Nelson and others is more precise, and also has different policy implications than the larger one advanced by B.-A. Lundvall. It means that if government is willing to promote radical technological innovation then it has to consider the establishment of R&D organizations and STI policies aimed to foster scientific research and to promote business opportunities for new technologies.

What are the incentives to promote industrialization? According to Nelson (2000), countries differ basically by their resources endowments and size; for those reasons, governments have to make strategic choices about industries to foster. The NSI reflects "conscious decisions to develop and sustain economic strength in certain areas... build and shape comparative advantage" (Nelson, 2000: 16). Governments have to design and implement public policies targeting scientific and technological progress in line with macroeconomic policies (such as fiscal, monetary and trade policies) (Cimoli et al., 2009). In this sense, industrial policies are crucial to identify and shape the industries that will become the competitive advantages of a country.

Since the 1990s, the concept of regional systems of innovation (RSI) has gained relevance. This concept underlines regional characteristics; regions within countries also differ according to their resources endowment, and size (in terms of market size)

(Nelson 2000). The importance of regions resides in the close interaction between socio-economical agents (Cooke, 2002; Niosi et al., 2005)[21].

In early 2000s, the concept of sectoral system of innovation (SSI) appeared:

> "A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and an existing emergent and potential demand. The agents composing the sectoral system are organizations and individuals (e.g. consumers, entrepreneurs, scientists)...Agents are characterized by specific learning processes, competencies, beliefs, objectives, organizational structures and behaviours. They interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions (rules and regulations). Over time, a sectoral system undergoes processes of change and transformation through the co-evolution of its various elements." (Malerba, 2002: 250)

In brief, the building blocks of the sectoral systems are: knowledge and technology, actors and networks, and institutions (Malerba, 2002). The relevance of a SSI relies on interactions that take place within a sector: "it forms the locus of interaction of numerous networks generating particular kind of knowledge" (Edquist et al., 2004: 440). Knowledge, technologies, actors, institutions and interactions are specific to each sector and have implications for the development of those. Therefore, governments willing to support specific sectors have to identify the specific knowledge, agents and interaction related to the sectors.

Given that the creation of new technology requires large investments in terms of funds and human resources, in each country the concentration of those resources is often placed on few regions and in few technologies. The following section deals with the implications of NSI, RSI and SSI for developing countries.

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[21] The definition of this concept is presented on section 3.1 in the Chapter III.

5.2 Innovation systems in emerging and developing countries

As mention above, one of the main objectives of the system of innovation approach at any level (region, sector or nation) is to guide policy makers in the formulation and implementation of STI policies in a coherent way. The innovation systems literature emerged in the context of developed countries, which present historical conditions (e.g. institutions related to the system of governance and accountability) and resources (e.g. funds, human resources, state-of-the-art research institutes) that allow them to create and support technological innovations.

Since the 1990s, some authors have analyzed the environments and policies carried out by the governments of emerging and developing countries (e.g. Argentina, Brazil, Korea, Singapore, Taiwan and others, more recently China and India). The most salient characteristic of successful innovation systems in emerging countries is that most of them are focused on one or a few high technology sector(s)[22] (e.g. Korea on automobile and electronics, Singapore on micro-electronics and biopharmaceuticals, India on information technologies, Israel on software and biotechnology, Brazil on aircraft). High technologies involve science and technology inputs and sophisticated, complex manufacturing. In order to create these high-value products, governments have made large investments in qualified education and training, support high-tech enterprises, and build government agencies in order to coordinate the efforts. Governments in emerging countries have focused on few high tech sectors, and in most cases, the organizations (universities, enterprises and government agencies) related to these sectors are located in specific regions. As mention before (Chapter IV), the government efforts to encourage and support a variety of capabilities to generate and commercialize sophisticated products must be accumulated over time. Successful emerging countries have followed a pattern in the implementation of STI

[22] The exception is China, which seems to be pursuing a very broad spectrum of high-technology industries at the same time.

policies: i) support for the creation of technological capabilities (education and training); horizontal policies, ii) the prioritizing industrial sector (high-, medium-, and low- technologies); and establishing vertical policies.

5.3 National innovation system of Mexico

The aim of this section is to outline the characteristics of the national system of innovation (NSI) of Mexico. As mentioned above, the NSI concept involves three main elements: knowledge-creation institutions, enterprises and government agencies. In turn, each of these elements includes different agents and relations between them.

5.3.1 Economic performance

Although the process of industrialization in Mexico started in late1880s, the role of the government as designer of industrial policy started circa 1930 (Haber, 1989). Since then, different industrial policy approaches have been adopted (i.e. attraction of foreign investment, import substitution). Recently, the OECD carried out an assessment of the economic performance of Mexico. The document summarizes the results as follows:

> "Mexico's economic performance in terms of growth of GDP per capita has been respectable but still insufficient to close the gap vis-à-vis the most advanced OECD countries in terms of the population's living standards and overcoming widespread poverty. To shift the economy to a path of higher, sustainable growth, Mexico's economic policy needs to boost productivity growth. In the past, it has been sluggish. Given the salient role of innovation in driving the long-term productivity growth, the challenge is to encourage innovation throughout the Mexican economy. Achieving this goal will require significant, broad-based reform and dedicated efforts." (OECD, 2009a: 63).

5.3.2 Public policies and the formation of the NSI

Government plays a major role in the transformation of economies. In this sense, the

consolidation of a NSI depends on the evolutionary processes of public policies. Dutrénit et al. (2010) analyzed extensively the historical evolution of science, technology and innovation policies in Mexico. According to these authors the evolution of STI policies can be divided into four phases:

> Phase I 1935-1970: The foundation of the knowledge-creation institutions,
> Phase II 1970-1981: The creation of the CONACYT,
> Phase III 1982- late-1990s: Structural changes,
> Phase IV After 1999: Efforts to design innovation policies.

Phase I[23] is characterized by the establishment of universities[24], national research institutes, and university research centres. In this period, some domestic large enterprises established R&D facilities in different sectors such as cement, steel, chemistry, pharmaceuticals, glass, and brewing. These organizations shaped the scientific and technological activities in this phase. In addition, two developmental agencies were created: Nafin (a development bank) and Bancomext (a trade bank). These agencies sought to encourage technological activities. The main feature in Phase II was the creation of the National Council on Science and Technology of Mexico (CONACYT in Spanish). Since then, the mandate of this institution has been to design and implement science and technology policies according to the economic policy of the country. New organizations were created, such as research public centres, national research institutions, and new higher education institutions. In Phase III, incentive programs were implemented to improve the performance of the knowledge-creating institutions (e. g. the National System of Researchers, SNI in Spanish). However, the national government subsequently adopted neo-liberal

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[23] The description of the four phases of STI policies is based on Dutrénit et al. (2010) Ch. 3, pp. 142-152.

[24] The National Autonomous University of Mexico (UNAM in Spanish) was founded in 1910. The National Polytechnic Institute (IPN in Spanish) was creates in 1936 with the mandate to generate human resources to accomplish industrial and applied research for the economic development of the country (Dutrénit et al., 2010: 143).

policies that limited its intervention in the economy. Consequently, the national STI policies were almost entirely focused on the education system. In the 1990s, a variety of programs were created to encourage the development of technology and innovative capabilities by the private sector. These programs aimed to encourage R&D activities, technological upgrading, strengthen scientific and technological capabilities, and promote the university-industry partnerships as well as establish incubators for technology-based firms. Also, the government introduced some changes related to Intellectual Property Law. In Phase IV, the Law for the Promotion of Scientific Research and Technological Development (1999) was implemented. This set the basis for designing the scientific, technological and innovation policies in recent years.

After this process of creation and restructure of organizations, institutions and policies, the current Mexican NSI includes the following agents (Dutrénit et al., 2010: 63-92):

- Government organisms and institutions
  - National council of science and technology, CONACYT;
  - Scientific and technological consultative forum, FCCT;
  - National network of state councils and organizations for science and technology, RENACECYT;
  - Science and technology committees of the legislature
- Public research institutes
  - Public research centre-CONACYT (under the aegis of Conacyt);
  - Public research centres, PRC (run by different Ministries);
  - Research institutes and centres (administrated by HEIs).
- Mexican system of higher education institutions, HEI.
- Innovative enterprises in the private sector.
- Intermediate funding and coordinating institutions (such as foundations and

associations).

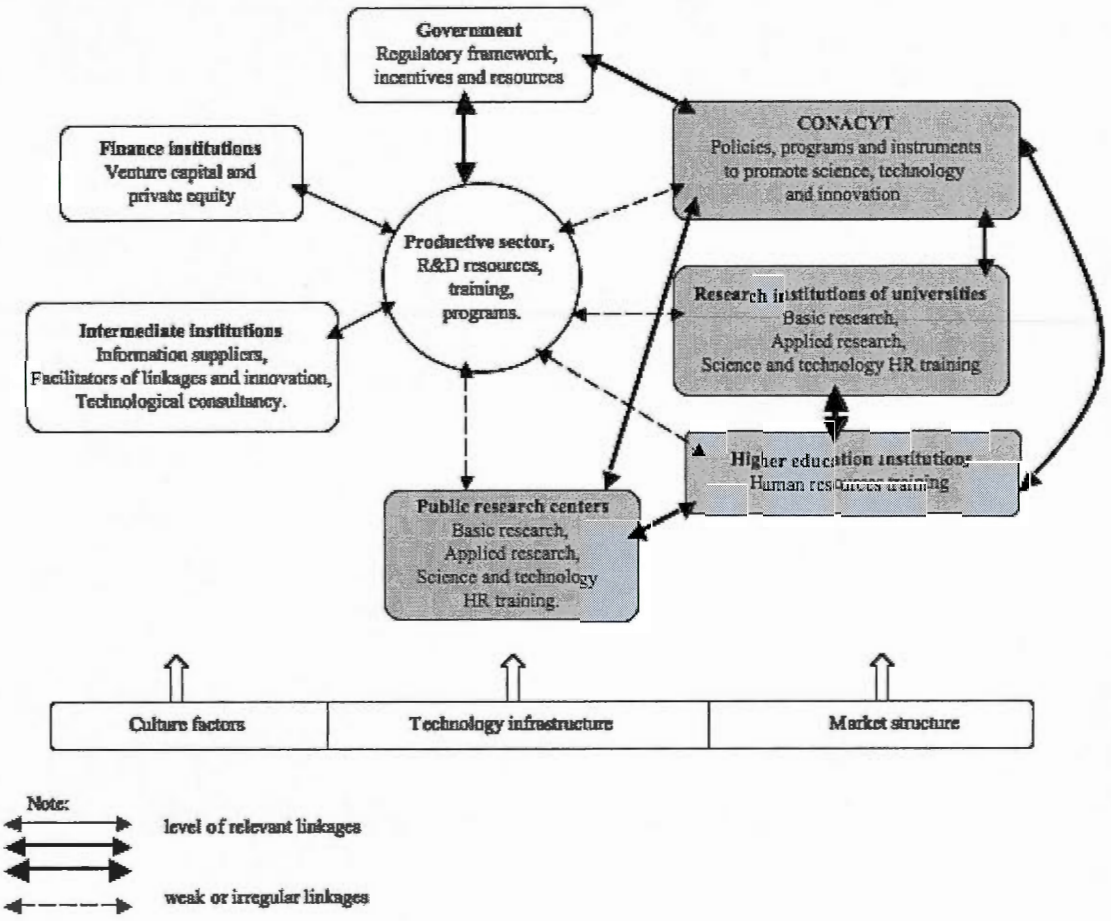
- At least part of the financial system.

The Mexican NSI includes a variety of organizations and institutions that have different interest; this circumstance affects interactions between agents. Dutrénit et al. (2010: 92-94) summarize the relationships between agents within the NSI as follows (see Figure 5.1):

> "The Mexican NSI has two main characteristics regarding interactions [between agents]. First, the productive sector acts almost as an isolated agent within the system. Although it maintains strong interactions with the government –which is mainly a result of macro-economic policy and some industrial incentives from government regulations— there is a clear lack of regular linkages with other economic and social agents ... there are not strong, dense and regular ties with intermediate and financial institutions. Neither are there strong ties to generate knowledge (HEI and PRC) ... The weakness of these linkages is a key factor to explain the slow development of national innovation capabilities. Second, most interactions take place between public institutions [CONACYT-public HEIs, CONACYT-PRC, and between public HEIs and PRC] ... This configuration has been built up over the years, from a STI [science, technology and innovation] policy based on a linear conception of the innovation process ... where production and transfer of knowledge from HEIs [universities] and PRC [public research centres] were at the centre of the system."

Figure 5.1

Interactions between agents of the Mexican NSI



Source: Dutrénit et al. (2010: 93).

Therefore, the Mexican NSI is unstructured based on the fact that: the private sector and the knowledge-creating organizations have different interests (Cimoli, 2000; Dutrénit et al, 2010). In order to improve this situation, in the last decade, the Mexican government has implemented some programs and policies to foster domestic technology development as well as emphasize research collaboration and promote its relevance for enterprises in order to accomplish successful innovative products

(OECD, 2009a). Some of the programs and policies are the following:

- Science and Technology Laws 1999 and 2002 (Leyes de Ciencia y Tecnología): they are se laws are focused on mechanisms to improve the interactions and coordination between agents

- Science and Technology Special Program 2002-2006 (Programa Especial para la Ciencia y la Tecnología, PECYT) the main objective of this program was to guide the design and implementation of public policy to improve the National System of Researchers (SNI).

- Science, Technology and Innovation Special Program 2007-2012 (Programa Especial en Ciencia, Tecnología e Innovación, PECITI) the objective of this program is to reinforce the PECYT 2002-2006.

Definition of priorities

One of the main objectives of the NSI is to identify the organizations and institutions that contribute to innovation. In the case of more sophisticated products (such as high tech products), the locus of innovation is located in networks of specialized inputs (Powell et al., 1996). In order to enable the interaction between different agents, some governments in industrialized countries have developed institutional frameworks and implemented a coherent package of STI policies. As mentioned in the Chapter 4, the design of STI policies takes in account priorities rooted in the national context (existing capabilities and political-socio-economical environments). However, the establishment of those priorities seems not to be an easy task, especially in a country where different groups of interest do not arrive to a consensus about the basic socioeconomic needs.

According to Dutrénit el al. (2010), the Mexican government has faced problems to

define the priority sectors that would guide the economic development of the country. Although the mandate of CONACYT is to design and implement the STI policies, this task has been limited by the "scientific elite, which has a strong influence on the establishment of priorities and the design of the STI policies" (Dutrénit et al., 2010: 153). In the last decade, some efforts have been made in order to define the strategic sectors of the country: for example, the PECYT 2001-2006 attempted, for the first time, to define the strategic sectors; however, that definition was in a broad way, without clear specifications of goals. The PECITI 2007-2012, after some prospective studies, defined eight strategic areas:

- Food and agro-industry
- Aeronautics
- Automobile and auto parts
- Electrics and electronics
- Pharmaceutical and health sciences
- Metallurgy
- Metal-mechanics and capital goods
- Chemical and petrochemical

As mentioned in the section 5.1, each sector requires a specific knowledge base and has different dynamics to generate and exploit business opportunities. Therefore: "one of the problems governments may face is the inability to understand the specificity of the sector, the technology or the institutional setting in which policy has to take place" (Edquist et al., 2004: 442).

5.3.3 Regional systems of innovation in Mexico

Empirical research has shown that enterprises, especially in high-tech sectors, tend to agglomerate in specific geographical areas, emphasizing the importance of regions in economic development. Therefore, regional innovation policies can be seen as a tool to reach national innovation (OECD, 2007). However, national policies play an important role in defining the macroeconomic environment and strategic sectors. In the case of Mexico, "the national policy framework does not sufficiently support clusters or regional innovation systems" (OECD, 2009b: 20). In Mexico there exist strong regional disparities that are reflected in economic performance, education and training, and poverty. These disparities are the result of a lack of coordination between the national and regional policies and other structural and administrative problems:

- The central government concentrates the basic tax responsibilities; states have few tax capabilities and suffer chronic financial deficits; they are thus unable to nurture by themselves any regional innovation system.

- The national policy framework does not support sufficiently cluster or regional innovation systems, it does not acknowledge the spatial dimension of the sectors being supported.

- High level of territorial concentration of innovation resources (funds, science and technology human resources, infrastructure) in the capital city.

- Lack of vertical coordination, low transparency.

- Lack of coordination between federal and state levels to formulate policies attracting FDI, and how this could be related and supported by science and technology policies.

- Lack of long-term strategy at national and sub-national level.

- There is not a clear policy to support the development of SMEs and indicators to track firm development over time. (OECD, 2009b: 21-22)

In recent years, the government of Mexico has implemented new programs in order to emphasize research collaboration and its relevance for enterprises in order to accomplish innovative products:

- Scholarships and the National System of Researchers.
- Tax credits (focused on SME, new technologies and improvement of competitiveness).
- CONACYT mixed funds, FOMIX (focused on science and technology promotion at sub-national levels).
- FORDECYT (this program complements FOMIX, "the fund has an innovative approach by targeting both geographic regions (neighbouring municipalities or stated) and thematic regions (group of municipalities or states that share a common problem) (OECD, 2009b).

However, the mechanisms to assess, monitor, and evaluate the science and technology capacities at sub-national level remain unclear: "there are no formal assessments of sub-national science, technology and innovation needs or mechanisms for recognizing the nature of science and technology expertise by region" (OECD, 2009b: 25).

In sum, the current Mexican context offers too few incentives to push private firms to conduct R&D activities –by their own or in collaboration- and innovate: there is a lack of financial support and efficient legal frameworks that can stimulate the flow of knowledge and learning; in terms of STI policies there are problems to define priorities (e.g. strategic sectors), and there is a lack of mechanisms to design,

implement and assess the pertinence and coordination of them.

Recently, in 2009, the S&T policy was modified, an Inter-sector Committee for Innovation was created to design and implement innovation policies[25]. This institutional body allows collaboration between government, enterprises and universities.

In sum, it seems that the Mexican institutional framework has generated some incentives to explore new technologies through scientific activities; however some obstacles persist and they hinder the collaboration between different agents. The efforts to foster scientific research are falling short in terms of the number of institutions dedicated to biotechnology research (see Chapter VIII) and the government investment in R&D activities. Table 5.1 shows the government investment in R&D activities with respect to the GDP in the period 1999-2008; Mexico not only has the lowest percentage among the OECD members, but also it has decreased to reach 0.37%, while other emerging countries like China, Brazil and India have a higher percentage than Mexico and also increased in the same period (OECD, 2010).

[25] Comité Intersectorial para la Innovación (CII) in Spanish. Information retrieved from http://www.economia.gob.mx/comunidad-negocios/innovacion/innovacion-comite (Accessed on 24 February 2012).

Table 5.1

Gross Expenditure on R&D activities as percentage of GDP

Country	1999 or first available year	2008 or latest available year
Selected OECD members		
Sweden	3.61	3.75
Japan	3.02	3.44
United States	2.64	2.77
Germany	2.40	2.53
United Kingdom	1.82	1.88
Canada	1.80	1.84
Italy	1.02	1.18
Mexico	**0.39**	**0.37**
Non-OECD members		
China	0.76	1.44
Brazil	1.02	1.13
India	0.77	0.88
South Africa	0.73	0.95

Source: Factbook OECD 2010 (information retrieved August 30, 2011).

In spite of a weak institutional framework and the absence of crucial actors for the adoption of biotechnologies, some firms are adopting, using, and developing biotechnologies in Mexico.

CHAPTER VI
THEORETICAL FRAMEWORK

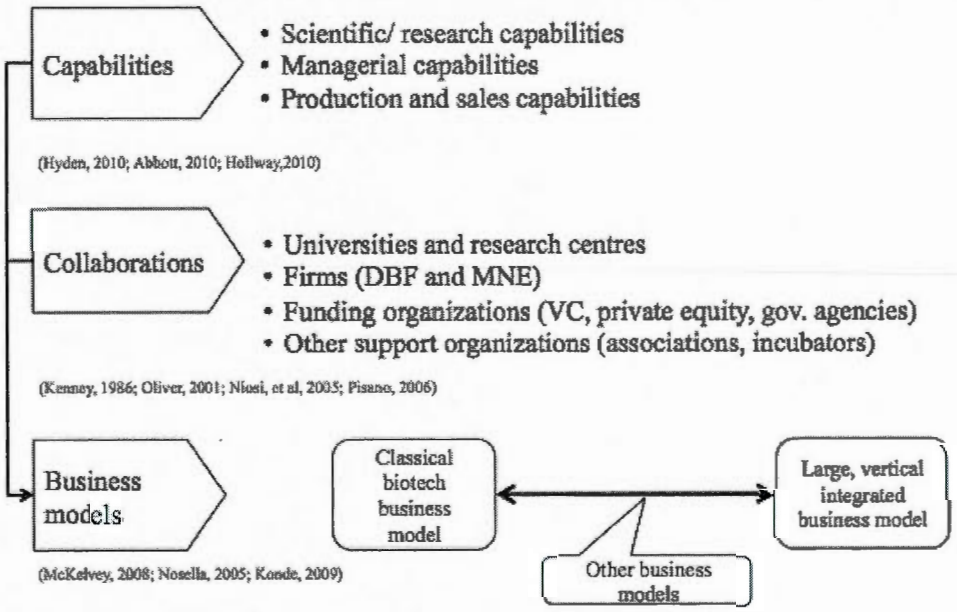
The objective of this chapter is to present the integration of the different concepts, reviewed in the previous chapters in order to analyze the theoretical question of this dissertation, which is to understand firms' adoption of generic high technologies that usually require complementary knowledge from other agents, in an institutional environment not well developed in terms of knowledge production, financing, and small government support.

The strategic management literature includes the concept of business models that is useful to analyze why and how agents create and capture economic value. The relevance of this concept relies in the fact that biotechnology enterprises are science-based businesses, which require a degree of scientific capabilities to create economic value. However, capturing economic value from science-based products is not evident. It depends on internal and external factors to the firm. Internal factors are related to the strategies, value chain/capabilities, partners/value networks, location and finance structure, while external factor are associated to scientific and technological progress, and changes in policies and consumer preferences. In order to identify the business models adopted by biotechnology enterprises in emerging countries I considered two main elements: capabilities and collaborations. Given the scientific knowledge base of biotechnologies and the variety of organizations that are involved in the creation of biotechnology products, the type of capabilities (scientific, production and commercialization) and collaborations define the biotechnology business models (Figure 6.1). The external factors, in turn, are related to the institutional environments in which the firm interacts. I use the term institutional environment to describe the policies and institutions that allow the scientific progress and the interaction between different actors to achieve the creation and

commercialization of biotechnology products.

Figure 6.1

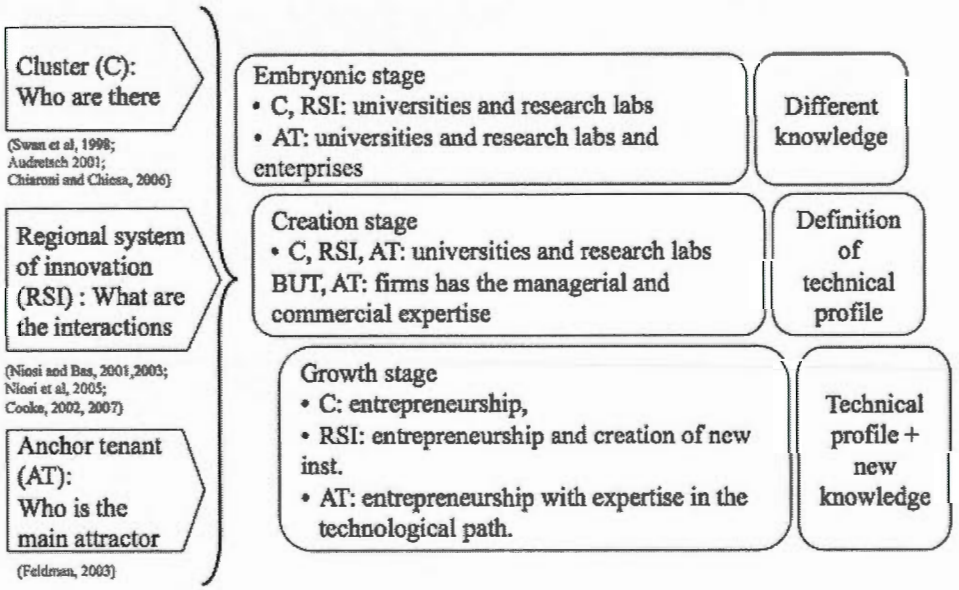
Components of business models in biotechnology



I used three concepts of the high technology agglomerations literature –clusters, regional system of innovation and anchor tenant- to analyze what kinds of organizations are present, what kinds of relationships are established and who is the main attractor in a biotechnology agglomeration in the different stages of its lifecycle. Scientific knowledge is a key input to develop biotechnology products. In this sense, universities and research centres and the heterogeneity or specificity of the scientific knowledge play an important role, as anchor tenants, to create new enterprises or attract other organizations. Also, the government support plays an important role to encourage entrepreneurship and attract experienced enterprises, which can contribute to the growth of the agglomeration (Figure 6.2).

Figure 6.2

Lifecycle stages of a biotechnology agglomeration



Finally, I used the STI policy literature to analyze and identify how governments could intervene for supporting the adoption of high technologies. In the case of biotechnologies, governments have to play an active role in the development of institutional environments, through the creation of organizations and implementation of STI policies, which allow the interaction between different actors and support the growth of enterprises (see Table 4.4, Chapter IV).

Table 6.1 integrates the different concepts used as theoretical framework in this dissertation. Column names show the lifecycle stages of a biotechnology agglomeration, while rows names show the relevant elements of a biotechnology agglomeration. Therefore, reading the table from left to right the integration of the concepts is as follows:

Emergent stage: Knowledge creating-organizations play an important role as anchor

tenants. Few scientists/entrepreneurs from these knowledge-creating organizations found small start-ups and they maintain informal collaboration with their colleagues to have access to the state-of-the-art knowledge and know-how. Maybe some angel capitals or venture capitalists are present in the region and they can provide financial support to the start-ups. Based on these characteristics these star-ups adopt BDF business model.

Transition stage: knowledge-creating organizations, still play the role of anchor tenant, and begin to define the technological profile of the agglomeration. More start-ups are founded and some alliances with other actors appear, for example, venture capitalists start to support new ventures. In addition, governments create organizations and design programs to support entrepreneurship. Biotechnology enterprises adopt DBF, product and platform business models.

Growth stage: the agglomeration has developed a specific scientific base and more start-ups are founded. Large firms –with production and commercialization capabilities- are attracted to the agglomeration, and may play the role of anchor tenants. There are dense collaborations between different organizations. Venture capitalists are more active and government implements programs to support firms' growth. Biotechnology enterprises adopt DBF, product and platform business models.

Sustain stage: the agglomeration maintains its scientific base, which attracts more firms. Collaborations are stable and venture capitalists are present in the location. Governments implement specific programs to attract new actors. Biotechnology enterprises adopt DBF, product and platform business models.

New opportunities: new knowledge is generated and collaborations with new actors are established. Government is active supporting the adoption of new technologies and the creation of new markets. New business models emerge.

Table 6.1

Integration: Agglomeration's concepts, government support and business models

	——— Time →				——— Time →
	Emergence	Transition	Growth	Sustain	New opportunities
Knowledge-creating organizations	Heterogeneity of knowledge **Anchor tenant**	Definition of technological profile **Anchor tenant**	Specific scientific base **Anchor tenant**	Specific scientific base **Anchor tenant**	Specific scientific base and new knowledge
Entrepreneurship and attraction of firms	Few start-ups (SME)	Δ SME	Δ SME Attraction of large firms **Anchor tenant**	Δ Firms Δ SME	Δ SME and attraction of firms
Collaborations	Informal	Few alliances	Dense interaction between enterprises and other agents	Stable interactions	New interaction with other agents
Funding	Maybe VC Angels and foundations	VC R&D taxes and subsidiaries	Maybe VC branch	Relocation of VC branches	
Government support/ institutional environment	Research funding	**RSI** -Dep. Econ. Dev. -Research hosp. -TTO and tech. parks -Support to start-ups	Programs to support firms' growth, important factor of attraction	Specific programs could attract new actors	Support to adopt new technologies and create new markets
Business models	DBF	BDF, PRODUCT, PLATFORM	DBF, PRODUCT, PLATFORM, FULL INTEGRATED		New business models

CHAPTER VII
HYPOTHESES AND METHODOLOGY

This chapter has two objectives: the first one is to recall the objective and questions of this research, and to present propositions and hypotheses. The second objective is to present the research design for this thesis.

7.1 Research objectives and questions

The general **objective** of this research is to understand firms' adoption of generic high technologies that usually require complementary knowledge from other agents, in an institutional environment not well developed in terms of knowledge production, financing and small government support. I propose to analyze this situation with the case of Mexico, which is an emerging country that recently has started to adopt biotechnologies, and three groups of research questions are presented:

- **Q1** What kinds of biotechnology users, actual or potential, exist in Mexico and what kinds of biotechnologies have been adopted? What business models are emerging in the Mexican-specific economic environment?

- **Q2** Given that high technologies tend to agglomerate, does Mexico have the potential to create and support a biotechnology cluster? What kinds of collaboration, if any, have emerged?

- **Q3** How public policy framework could be improved in an emerging economy such as Mexico in order to support the adoption and diffusion of high technologies, especially biotechnologies?

7.2 Hypotheses

In order to operationalize and contextualize these questions in a meaningful way, I present some propositions that take into account the context of emerging countries.

However this research has neither the time nor resources to analyze and test all of them, then I decided to enunciate these propositions as 'General hypotheses'. In addition, based on the literature review and research question, I propose some empirical hypotheses (H) that will be test for the case of Mexico.

7.2.1 Business models

In the strategic management literature, a business model is a planning tool for enterprises that includes two main processes: creating economic value and capturing that value (Magretta, 2002; Chesbrough, 2007). A business model also involves an ongoing process of evolution and adaptation (Shafer et al., 2005; Francis and Bessant, 2005; Chesbrough, 2007). Internal and external elements can influence the manner through which enterprises accomplish these processes (Onetti et al., 2010). The internal elements are those related to capabilities, while external elements are related to interaction with other organizations and institutions (Teece, 2010). In the technological change and evolutionary economics literatures, the enterprises' technological and managerial capabilities are crucial for the accomplishment of R&D and other innovative activities (Lall, 1992; Kim, 1997; Niosi and Bas, 2001). Also, collaboration agreements play an important role to complement firms' capabilities and knowledge, especially in enterprises using high technologies (Powell et al., 1996). In the particular case of biotechnology, R&D capabilities are crucial for the enterprise performance (Hayden, 2010; Abbott, 2010), besides technological capabilities (production activities) and managerial capabilities (organizational activities).

In the case of advanced OECD countries, biotechnology enterprises have developed business models closely related to scientific results. Therefore, discoveries in different disciplines have been associated with more complexity and diversity (McKelvey, 2004), generating opportunities for the creation of new products and

enterprises. In developed countries, two well-defined business models have emerged: the classical biotechnology model (based mainly on R&D activities) and the vertically integrated company business model (integrating the complete value chain, from R&D to commercialization) (McKelvey, 2008) or 'Genentech model'. As the use of biotechnologies has expanded, different business models have emerged depending of the socioeconomic conditions of each country (Fisken and Rutherford, 2002; Nosella et al., 2005; Konde, 2009). Emerging countries like China, India and Brazil have encouraged and supported the creation of biotechnology enterprises; they have attempted to reproduce biotechnology business models from developed countries, particularly the classical business model (based mainly on R&D activities). In other emerging and developing countries, relevant components that allow the adoption of the well-defined biotechnology business models are missing (such as R&D capabilities, collaborations and competitive markets), nevertheless, enterprises in these countries still have adopted modern biotechnologies and have created new products (Nature Biotechnology, 2010).

General Hypothesis 1: Given the scarcity of financial, human and technology resources and the lack of government vision to establish priorities. Therefore, a variety of business models, which differ from those of developed countries, are likely to arise in order to adopt modern biotechnologies in such conditions

General Hypothesis 1a: Even if the generation of biotechnologies has achieved limited success in emerging and developing countries, some of their applications have been used in production processes in those countries. Given that local firms are more concerned with biotechnology applications rather than biotechnology generation, they tend to pursue **"imitative innovation"** business models.

General Hypothesis 1b: Biotechnologies require a certain degree of capabilities and resources by the firm using them. Since the institutional infrastructure supporting

biotechnology is weak in some emerging and developing countries, firms have to rely to a great extent on their own expertise and resources.

General Hypothesis 2: Internal elements like strategy or financial structure are not the only ones that affect the generation of a business model; the environment in which enterprises perform also has an impact on the kind of business models these enterprises may adopt.

Q1. What kinds of biotechnology users, actual or potential, exist in Mexico and what kinds of biotechnologies have been adopted? What business models are emerging in the Mexican particular economic environment?

> **H1.** In an emergent stage of a biotech cluster within an emerging country with limited institutional support, the business models that are more likely to emerge are **more related to exploitation and imitation capabilities rather than exploration capabilities.**

7.2.2 Geographic agglomerations

High technology enterprises tend to agglomerate in specific geographic areas (Sexenian, 1994; Swann et al., 1998; Niosi et al., 2005), given the positive externalities they can obtain in specific areas, such as qualified human resources, specialized services, and access to funding (Braunerhjelm and Feldman, 2006). At least three concepts have been used to analyze the creation and evolution of agglomerations: cluster, regional system of innovation and anchor tenant. The Cluster literature has pointed out the participants of the agglomeration (Porter, 2000: 254, 2003; Braunerhjelm and Feldman, 2006). The Regional system of innovation has focused on the analysis of the interaction between the agglomeration actors (Cooke, 2004; Niosi et al., 2005). Finally, the anchor tenant concept stresses the role of main attractor(s) to the agglomeration (Agrawal and Cockbun, 2003). The creation of

agglomerations is caused by three different events: 1) relevant organizations are already in the geographic area, 2) changes in policies and laws push foundation of new enterprises, and 3) government mandate. Whatever the triggering event is, the development of high tech agglomerations depends upon the government intervention for building an environment that allows the creation, attraction, and design of new organizations and institutions (Cockburn and Stern, 2010; Feldman, 2003, Chiaroni and Chiesa, 2006).

Different scholars have used these concepts to analyze biotechnology agglomerations in developed countries. They have underlined the relevance of specific agents to adopt modern biotechnologies: universities, research centre, research laboratories in large enterprises (Swan et al., 1998; Audretsch 2001; Chiaroni and Chiesa, 2006; Niosi et al., 2005; Cooke, 2002, 2007; Feldman, 2003). Since the mid-1980s, some emerging countries, for instance China, India, and Singapore, have attempted to create biotechnology clusters imitating organizations and institutions of developed countries; however, the potential to create and maintain biotechnology agglomerations relies on the existence of resources, organizations, institutions and public policies, which sometimes are not available.

General Hypothesis 3: Even though some emerging and developing countries do have an important scientific base able to perform cutting-edge research in biotechnology, attempting to launch complex biotechnology-related products is rather difficult. This is because there is a lack of relevant agents that provide support for the commercial development of those products (e.g. research agencies with star scientists, experienced financial organizations, testing product organizations). For this reason, in **countries with an underdeveloped system of biotechnology support, the more likely efforts are to be found in low to medium complex biotechnologies**.

General Hypothesis 3a: Although in emerging countries firms rely to a great extent

on their own resources, modern/complex biotechnologies usually require a varied set of capabilities that **no single firm can master entirely**. Therefore, these firms need to look for some **collaboration** with external agents, at least to a certain degree. When they do not find a suitable partner in their home country they will try to find one abroad.

General Hypothesis 4: In countries with unstructured institutional environments, **there is no specific anchor tenant**. Knowledge-creating organizations and enterprises may adopt biotechnologies but their capabilities and their location are the result of historical events (almost no relation to biotechnology).

General Hypothesis 5: In environments where there is a lack of incentives to create new start-ups, the more likely source of **entrepreneurship is large companies,** which have the commercial, productive, and scientific capabilities to apply modern biotechnologies.

General Hypothesis 6: In the initial stage of a biotechnology agglomeration lifecycle, the support for scientific and technological capabilities is not enough to foster new businesses. Although these capabilities are relevant, the development of biotechnology agglomerations relies enormously on the financial system (venture capital, stock market, banks, government agencies) and on the organizations and institutions focused on supporting managerial and networking capabilities (technology transfer offices, government agencies, associations). Therefore, countries looking to foster biotechnology agglomerations **often put in place initiatives that facilitate technology transfer, and support different business models that are emerging from large enterprises and SMEs.**

General Hypothesis 7: As a result of policies aiming for advancing scientific knowledge related to biotechnology, research centres and laboratories have been created. Since the policy approach has been most often based on the linear model,

other types of institutions are not well developed or are even inexistent.

Q2: Given that high technology enterprises tend to agglomerate, does Mexico have the potential to create and support a biotechnology cluster? What kinds of collaboration, if any, have emerged?

> **H2:** In the emerging stage of a biotechnology agglomeration in emerging countries, with **weak financial support** for new ventures and a **poor entrepreneurship drive**, universities and research centres **partially act as anchor tenants** by means of project collaborations but not as spin-off generators, which may be accomplished in later stages.
>
> **H3:** Companies that have **developed scientific capabilities are more likely to establish collaborations** with national -and international- partners for exploration activities. **Universities and research centres** would be the more likely targets of collaboration for firms seeking to improve or complement/upgrade their capabilities.

7.2.3 STI policy

The role of government is to create and diffuse technological knowledge, stimulate learning processes, and create and maintain a coherent institutional system through public policies (Dalum et al., 1992; Niosi and Bellon, 1995; Carlsson, 2006; Cimoli et al., 2009; Cockburn and Stern, 2010). The dimensions that influence the design and implementation of public policies are: the kind of policies (e.g. science, technology and innovation), the scope (e.g. horizontal or vertical technology policies), the relationship with the environment (e.g. top-down and bottom-up), and the geographic scope (e.g. nation, region, sector) (Metcalfe, 1994; Dodgson and Bessant, 1996; Teubal, 1997; Tödtling and Trippl, 2005). Developed countries have implemented a variety of STI policies to provide both, incentives and support to the

creation and commercialization of new high technologies. In this sense, the following propositions are aimed to suggest a framework of STI public policies to encourage and support biotechnologies in emerging countries.

General Hypothesis 8: The **establishment of priorities** and the creation of institutions to generate business opportunities seem crucial steps to design and implement STI policies, and in turn, generate incentives to pursue business opportunities.

General Hypothesis 8a: Large, domestic companies are expected to acquire and imitate new technologies given their access to own financial, human and technological resources. In this sense, the eventual adoption and diffusion of high technologies will rely, at first, on the establishment of new **organizations and institutions that support the business models emerging from those large companies.**

General Hypothesis 8b: Given that the accomplishment of new biotechnology products require a collection of different capabilities, the generation of new biotechnology products rely on the **upgrading of institutional environments that foster, facilitate, and nurture the collaboration** among different organizations.

Q3. How could the Mexican public policy framework be improved in order to support the adoption and diffusion of biotechnologies?

> **H4:** Given the lack of VC and entrepreneurship, growth can be achieved by enhancing scientific capabilities in existing firms; which may be accomplished by government efforts like awareness campaigns (including promotion and funding), and strengthening the links between companies and knowledge-creating organizations by means of public policies.

7.3 Expected theoretical and conceptual contributions

Three bodies of literature are used to accomplish this research. The first one involves a managerial view of business that includes business model, capabilities, and collaboration through networks. These different views are closely related, and allow the understanding of the important role of creation and support of technological and managerial capabilities. In the case of biotechnology, the knowledge base and multidisciplinary nature make room for the 'participation' of different actors at different levels of aggregation (worldwide, national, and regional). In this sense, *my contribution resides in understanding the business models of firms using biotechnologies that evolve in emerging countries under conditions of meagre government support.*

The second body of literature involves regional agglomerations concepts –cluster, regional innovation system, and anchor tenant. These concepts focus on the forces that attract other organizations and suggest the characteristics of institutional environments that could support the growth of local firms and agglomeration. In the case of biotechnology, several authors have emphasized the role of organizations and institutions that allow knowledge exchange. In addition, some authors have analyzed the dynamics of creation and development of biotechnology agglomerations, especially in developed countries, but little has been said about the potential of emerging countries to create and develop biotechnology agglomerations, and especially how to generate these agglomerations. In this sense, the contribution to the agglomeration literature is to *understand how different organizations (enterprises and non-enterprises) interact in unstructured institutional environments of emerging countries, and how the creation and development of biotechnology agglomerations in those countries calls for the creation of institutions that support the emerging business models which are struggling to establish relationships/networking with other organizations to increase/complement their capabilities.*

Public policies aiming to support and improve STI activities are the third body of literature. Several authors have emphasized the role of government to create and support technology markets. In the case of biotechnology, empirical research in developed countries shows that government intervention in different ways (directly or indirectly) has been crucial to consolidate organizations related to biotechnologies (universities and research centres and enterprises). In the case of emerging and developing countries, the adoption and diffusion of new technologies face institutional obstacles and limited resources. In this sense, the contribution resides in *suggesting that in emerging countries the adoption and improvement of high technologies, such as biotechnologies, require an evolving institutional environment that allows the creation of ad hoc institutions for the emerging business models related to high technologies, and over time the adaptation of institutions fostering incremental innovation and eventually accomplish radical innovations.*

7.4 Research design

The objective and questions of this research deal with different bodies of knowledge and possess a multidisciplinary character. Strategic management, regional agglomeration and STI policies literatures are interweaved to explain the adoption of biotechnologies in Mexico. This research combines qualitative and quantitative methods to analyse the phenomenon.

7.5 Sample construction

At least two organizations are relevant for the adoption of biotechnologies: knowledge-creating organizations and enterprises (see Chapter II).

Given the scientific base and multidisciplinary nature of biotechnologies, crucial agents are knowledge-creating organizations such as universities, research centres and government research laboratories. These organizations are characterized by their

research capabilities reputation in terms of human resources and research lines. Therefore, the first step to define the sample was to identify Mexican universities and research centres carrying out biotechnology research. Mexico has a vast territory that encompasses 31 states and the Federal District (Mexico City). In all the states and Mexico City, there is at least one technical institute or university for training human resources in biotechnology at different levels (from technician to PhD level) (Secretaría de Economía, 2010). There are around 130 education and research organizations that have biotechnology programs; some of them conduct biotechnology research activities covering different degrees of complexity (Bolivar et al., 2003; Secretaría de Economía, 2010). Among these organizations, only 25 knowledge-creating organizations are the main scientific publishers in biotechnology applications (see Table 7.1).

Table 7.1

Number of biotechnology publications in Mexico, 1996-2008

Organizations	#Publications*	States
Universidad Nacional Autonóma de México-UNAM	818	Mexico City, Morelos, and other states
Instituto Politécnico Nacional-IPN	553	Mexico City, and other states
Universidad Autónoma Metropolitana-UAM	291	Mexico City
Research Centres of CONACYT	278	Mexico and other states
Instituto Mexicano de Seguro Social-IMSS	139	Mexico City, Morelos, and other states
Universidad Autónoma de Nuevo León	94	Nuevo León
Universidad de Guadalajara	72	Jalisco
Instituto Mexicano de Petróleo	70	Mexico City
International Maize and Wheat Improvement Centre-CIMMYT	64	State of Mexico
Universidad Autónoma del Estado de Morelos	51	Morelos
Universidad Autónoma del Estado de Coahuila	42	Coahuila
Universidad de Guanajuato	42	Guanajuato
Clínica Ruiz de Puebla	35	Puebla
Instituto National de Salud Pública	35	Morelos
Instituto Tecnológico de Veracruz	30	Veracruz
Instituto Tecnológico de Estudio Superiores de Monterrey-ITESM	28	Nuevo León and other states
Instituto Nal. Cardiología Ignacio Chavez	23	Mexico City
Universidad Autónoma de Baja California Sur	23	Baja California Sur
Universidad Autónoma de Yucatán	22	Yucatán
Universidad de Sonora	22	Sonora
Instituto Nacional de Ciencia Médicas y Nutrición Salvador Zubirán	21	Mexico City
Instituto Tecnológico de Celaya	21	Guanajuato
Universidad Autónoma de San Luis Potosí	19	San Luis Potosí
Universidad Veracruzana	18	Veracruz
Universidad Autónoma de Querétaro	15	Querétaro

*Data for 2008: January-September.

Source: Science-Metrix, as compiled for Canada Research Chair on the Management of Technology.

There are only five research organizations with more than 100 biotechnology publications in the period 1996-2008: UNAM (818), IPN (553), UAM (291), the

research centres of CONACYT (278), and IMSS (139)[26]. They are located mainly in the demographic and political centre of the country: for example UNAM, IPN, UAM and IMSS have their main campus and offices (headquarters) in Mexico City[27]; they perform research activities in different fields of biotechnology such as human and animal health, agriculture, food processing, and environment.

In addition to research organizations, enterprises are key agents to generate and capture economic value. I searched for information about Mexican biotechnology enterprises[28]. The identification of enterprises was based on an Internet search using key words (e.g. biotechnology firms in Mexico; biotech Mexico, Mexican biotech, in English and Spanish), and secondary sources (web sites of research centres and specialized literature). Also, I asked for a directory of biotechnology enterprises in Mexico to different organizations, such as the Mexican Association of Biotechnology and Bioengineering (Sociedad Mexicana de Biotecnología y Bioingienería), Ministry of Economy, and CONACYT. Unfortunately, none of these organizations had at that moment a biotechnology directory. Table 7.2 summarizes the results of my search for Mexican biotechnology enterprises.

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[26] The number of publications of each institution encompasses different campus or research centres. For example, the case of UNAM could include the publications of scientist attached to the Biotechnology Institute, the Centre for Genomic Science, the Faculty of Medicine, and the Faculty of Engineering.

[27] Other states relatively near to Mexico City host important research centres, for example, the Institute of Biotechnology-UNAM is located in Morelos, CINVESTAV-IPN is located in Guanajuato.

[28] As defined by the OECD, see footnote 6 in Chapter I.

Table 7.2

Distribution of biotechnology firms in Mexico

	State	Number of enterprises*
1	Mexico City	**19**
2	State of Mexico	**12**
3	Jalisco (Guadalajara)	5
4	Chihuahua	3
5	Morelos	3
6	Nuevo León (Monterrey)	**3**
7	Quereéaro	3
8	Sinaloa	3
9	Coahuila	2
10	Aguascalientes	1
11	Baja California Sur	1
12	Colima	1
13	Michoacán	1
14	Puebla	1
	Total	**58**
*Own search		

According to my search, 58 enterprises using biotechnologies are located in fourteen Mexican entities: Mexico City hosts nineteen enterprises, the State of Mexico hosts twelve enterprises and the other states host between one and five enterprises.

Here it is important to mention that in August 2010, after I conducted my fieldwork (September-October 2009), the Ministry of Economy published a study about the situation of biotechnology in Mexico. The document lists 306 biotechnology enterprises, however, the document also mentions that from these, only around 67 enterprises perform activities related to the development of biotechnologies (see Annex C). I compared my results with the list of the Ministry of Economy to validate my search: 50 of the enterprises I found on my own search match with the information of the biotechnology report.

Criteria of selection

Historically the main industrial and economic activities are located in three cities – Guadalajara (Jalisco), Monterrey (Nuevo León), and Mexico City- and part of the State of Mexico. *A priori* I expected that these states hosted consolidated research organizations and biotechnology enterprises.

- Knowledge-creating organization criterion: according to Table 7.1, organizations with more biotechnology publications are located in Mexico City and Morelos, followed by Nuevo León, Jalisco, State of Mexico and Guanajuato.

- Biotech enterprises criterion: according to the list of enterprises with biotech activities (Table 7.2 and Figure C.1 in Annex C), Mexico City and the State of Mexico host the large number of enterprises, followed by Jalisco, Morelos and Nuevo León.

Following these criteria (number of knowledge-creation organizations and biotechnology enterprises), I decided to consider three locations with quality research, number of firms and presence of linkages offices: Mexico City, Morelos and State of Mexico.

7.6 Data sources

Different techniques were used to collect data: questionnaires/interview and document review.

Questionnaires/Interviews

After identifying the sample of organizations using biotechnologies, (enterprises, universities and liaison offices) in the central area of Mexico, I contacted them by

phone. In this call I briefly presented myself, the intention of the research and why their participation could be useful. After this first communication, an invitation letter was sent, by postal mail and e-mail, to the contacts to formally ask them for their participation.

I asked for an interview to all enterprises in Mexico City, Morelos and State of Mexico (34 firms according to my own search) and also to the most salient research institutes in biotechnology within those locations. Finally, sixteen enterprises and four research organizations answered the main questionnaire and five technology transfer and liaison offices answered the second questionnaire. All data were collected in a face-to-face interview in their facilities. Table 7.3 presents a general description of the interviews carried out for this research. In addition, I met managers from other three enterprises (two multinational pharmaceuticals and one service enterprise) and one university, however, they did not accept to complete the questionnaire. The fieldwork was carried out from September 9th to October 7th, 2009.

Table 7.3

General descriptions of interviews carried out for this study

ID	Sector	Position	Location
Enterprises			
1	Human health	General Manager	Mexico City
2	Human health	Biotechnology Manager	State of Mexico
3	Human health	Biotechnology Research Manager	Mexico City
4	Agriculture	General Manager	Mexico City
5	Agriculture	Technical Manager	Mexico City
6	Agriculture	Chief of regulation and marketing	Mexico City
7	Agriculture	General Manager	State of Mexico
8	Agriculture	General Manager	State of Mexico
9	Agriculture	General Manager	State of Mexico
10	Agriculture	General Manager	State of Mexico
11	Food processing	Technology Development	State of Mexico
12	Food Processing	General Manager	State of Mexico
13	Food processing	General Manager	Mexico City
14	Environment	Technical Manager	Mexico City
15	Environment	Innovation and Technology development Manager	Mexico City
16	Environment	Manager of Quality Assurance and Monitoring	Morelos
University and research centres			
1	University	Technical Secretary of Technology Management and Technology Transfer	Morelos
2	Research Centre	Coordinator of Health Research	Morelos
3	University	Chief of the Biotechnology Department	Mexico City
4	Research Centre	Research Director	Mexico City
Technology transfer and liaison offices			
1	University	Chief of Technical Support	Mexico City
2	Federal government	Director of Entailment and Institutional Development	Mexico City
3	University	Coordinator of Academic Liaison	Mexico City
4	State government	Director	Morelos
5	University	Technical secretary of technology management and technology transfer	Morelos

The most important source was a questionnaire focused on information related to

enterprises and research centres: "Questionnaire about activities and characteristics of enterprises that use and develop biotechnologies in Mexico"[29] (Annex D). This questionnaire was inspired by the Statistics Canada biotechnology questionnaire, and is used in a larger project including Argentina, Brazil, Chile, China, India, Singapore and South Korea directed by Jorge Niosi and supported by FQRSC[30], as well as the Canada Research Chair on the Management of Technology directed by Dr Niosi. Another important source of information was a questionnaire for liaison offices of universities and government agencies: "Questionnaire for technology transfer and liaison offices related to biotechnological products and processes"[31] (Annex F).

The main questionnaire includes questions that were useful to answer the three groups of research questions. The group of research questions dealing with the characteristics and capabilities of Mexican biotechnology firms were answer by Question 1, which asks for biotechnologies in use and development, Questions 10 and 11 ask for biotechnology products and processes, Questions 2, 3 and 4 ask for capabilities, and Questions 21 and 22 ask for foreign trade. The group of research questions about agglomerations were answered by Questions 5, which asks for age, motives and advantages of the establishment, Questions 14 and 15 ask for collaborations. The group of questions about public policy were answered by Question 13, 16, 17, 19, and 20, which ask for issues about regulation law, IPR, funding and tax credits.

Technology transfer and liaison offices play an important role to support university-industry interactions. The second questionnaire includes questions about the services offered by the liaison and support agencies: Question 1 asks for age, Questions 2, 3

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[29] The Spanish version was titled "Cuestionario acerca de las actividades y characteristicas de las empresas que utilizan y desarrollan biotecnologías en Mexico".
[30] Fonds québécois de la recherche sur la societé et la culture (Quebec, Canada).
[31] The Spanish version was titled "Cuestionario para oficinas de vinculación universidad-empresa y transferencia tecnológica relacionados con productos y procesos biotecnológicos"

and 4 ask for motives of the establishment (mandate), Questions 5 and 6 ask for collaboration with other centres (in general and in biotechnologies), Questions 10-13 ask for services targeting biotech enterprises and the assessment of those services. Question 14 asks for results of the centre.

Document review

In order to validate the data collected, other sources of information were consulted (Yin, 1999; Patton, 2003). Quality research in biotechnology and potential commercialization are related with scientific publication and patents (Kaplan et al, 2004). In this sense, I used a journal database, compiled by Science-Metrix for the Canada Research Chair in Management of Technology that provides information about universities and PRC publications in biotechnologies fields during the period 1999-2008. In addition, I consulted the US Patent and Trademark Office (USPTO) that is one of the most important patent offices. In order to identify the patents related to biotechnologies I used the International Patents Codes (IPC) proposed by the OECD (Beuzekom and Arundel, 2009: 52):

- A01H 1/00
- A01H 4/00
- A61K 38/00
- A61K 39/00
- A61K 48/00
- C02F 3/34
- C07G 11/00
- C07G 13/00
- C07G 15/00
- C07K 4/00
- C07K 14/00
- C07K 16/00
- C07K 17/00
- C07K 19/00
- C12M
- C12N
- C12P
- C12Q
- C12S
- G01N 27/327
- G01N 33/53
- G01N 33/54
- G01N 33/55
- G01N 33/57
- G01N 33/68
- G01N 33/74
- G01N 33/76
- G01N 33/78
- G01N 33/88
- G01N 33/92

Other documents such as public official documents, consulting enterprises reports, and specialized literatures also were also used.

7.7 Data treatment

Three databases were created, one for each kind of participant: enterprises, research centres, and liaison and technology transfer offices. Given the small number of participants in each group, nonparametric tests –Spearman Rank-order correlation, Biserial correlation, and Chi-square with Yates correction for continuity statistics[32]- were used to test relationships between variables. The Table 7.4 presents how the research questions were addressed.

The answers of the main questionnaire were transformed in order to operationalize them. For example, in the case of number of employees, this variable was considered as an ordinal scale variable[33] given the big difference among the answers (from 3 to 900). I transformed this variable into a *rank order* variable (see process in Annex H). Other variables like import activities and collaborations were transformed into *continuous dichotomous* variables, whose values were YES and NO.

[32] The statistical softear to obtain this statistic was PSPP (a free program).

[33] "A *dichotomous* variable is a mesure of two conditions… A *continuos dichotomous* variable has some type of order to the two conditions… *Ordinal* scale data describe values that occur in some order. However, distance between any two ordinal values holds no particular meaning" (Corner ad Foreman, 2009: 3).

Table 7.4

Variables and sources of information

Research questions	Variables	Sources of information
1. What kind of biotechnology users, actual or potential, exist in Mexico, and what kinds of biotechnologies have been adopted? What business models are emerging in the Mexican-specific economic environment?	Type of biotechnology activities: kinds of biotechnologies used, purposes of using biotechnologies	Main questionnaire (Section 1)
	Type of capabilities: size, size biotechnology, export activities, kinds of biotechnologies adopted	Main questionnaire (Section 2, 3, 4)
	Complementary elements to define business models: collaborations, funding sources, and strategies	Main questionnaire (Section 5, 6, 7)
2. Given that high technologies tend to agglomerate, does Mexico have the potential to create and support a biotechnology cluster? What kinds of collaborations, if any, have emerged?	Research capabilities: number of knowledge-creating organizations, number of publications and patents.	Government documents, websites of universities, publication database, patents database
	Business opportunities: distribution of the potential enterprises in the different regions of the country	Government documents and specialized literature.
	Institutional environment: characteristics of liaison and technology transfer units, and complementary organizations Collaborations: kinds of relationships and motives for those collaborations	Second questionnaire and government documents. Main questionnaire (Section 3, 5)
3. How could the Mexican public policy framework be improved in order to support the adoption and diffusion of biotechnologies?	Design and implementation of STI policies in other emerging countries and Mexico	Specialized literature, government document, consulting reports.

PART II. EMPIRICAL EVIDENCE AND CONCLUSIONS

CHAPTER VIII
EMPIRICAL EVIDENCE

This chapter presents the analysis of the empirical results in order to answer the research questions related to business models and biotechnology regional agglomerations. The next chapter deals with the STI policies implemented in emerging countries and presents some lessons for Mexico.

8.1 Biotechnology enterprises and business models

Some emerging countries, like China, India and Brazil, have been encouraging the adoption of modern biotechnologies. These countries have attempted to imitate the experience of developed countries through the support of R&D activities and the creation of institutional frameworks that allow SME enterprises to commercialize biotechnology products (see Chapter IX for details). The most cited organizations in the adoption of biotechnologies are universities and research centres and DBFs. The business model that characterizes these DBFs is the classical biotechnology business model (see Chapter II): SME focused mainly on R&D activities, at least in the pharmaceutical sector. Emerging countries also have tried to generate and support DBFs that follow the classical business model[34]. However, SMEs are not the only ones adopting and developing biotechnologies. Traditional pharmaceutical companies in emerging countries are also adopting biotechnologies in order to remain in the market (Nature Biotechnology, 2010). Therefore, other kinds of business models are taking place in emerging countries.

Before analyzing the kinds of business models followed by the sample of enterprises interviewed in Mexico, it seems useful to identify the users of biotechnologies.

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[34] Nature Biotechnology published in 2010 special reports focused on biotechnology in China and India. These reports highlight the potential of the biotech enterprises to become part of the value chain.

Q1: What kinds of biotechnology users, actual or potential, exist in Mexico and what kinds of biotechnologies have been adopted? The main questionnaire gathers information about the kinds of biotechnologies used by the firms interviewed and their purposes (current production, product/process development and environment), as well as characteristics of the firms in terms of kinds of products, size, age and foreign trade.

Table 8.1

Biotechnologies and their uses by firms established in Mexico

Biotechnologies	Use				Production		Product/process development		Environmental reasons	
	YES	%	NO	%	YES	%	YES	%	YES	%
DNA codification	2	12.5	14	87.5	**2**	**100**	**2**	**100**	1	50
Proteins and molecules	3	18.8	13	81.3	**3**	**100**	**3**	**100**	0	0
Cell and tissue culture and eng.	6	37.5	10	62.5	5	83.3	5	83.3	0	0
Process biotechnologies	9	56.3	7	43.8	**9**	**100**	6	66.7	3	33.3
Sub-cell organisms	1	6.3	15	93.8	**1**	**100**	**1**	**100**	0	0
Bioinformatics	0	0	16	100	0	0	0	0	0	0
Nanobiotechnology	1	6.3	15	93.8	0	0	**1**	**100**	0	0
Environment biotech	3	18.8	13	81.3	2	66.7	2	66.7	0	0
Other (e.g. enzymes)	6	37.5	10	62.5	3	50	4	66.7	3	50
n=16										

Table 8.1 presents a summary of the kinds of biotechnologies adopted and the their purposes. Most of the enterprises interviewed have adopted and currently use biotechnologies related to process biotechnologies (56.3%), followed by cell and tissue culture and engineering (37.5%), proteins and molecules (18.8%), and

environmental biotechnologies (18.8%), while more complex biotechnologies such as DNA codification (12.5%) and nanobiotechnologies (6.3%) have been adopted by few firms; bioinformatics is not used by the interviewed enterprises. These results show that very few firms have adopted modern biotechnologies; low to medium complex biotechnologies are more prevalent.

Regarding the purpose of using biotechnologies, Table 8.1 shows that all firms use biotechnologies to aid their production and product development processes. In the case of bio-nanotechnology, only one firm is using it for product development. In this sense, in this sample no firm is dedicated to develop complex products based on modern biotechnology *per se*; rather, they use biotechnologies to improve production processes of products that are already in the market (e.g. like biogenerics medicines). In some cases, firms use biotechnologies for environmental reasons (e.g. water treatment (see Table 8.2).

Table 8.2

Biotechnology products and services

Sector	Products/services
Human health	Erythropoietin
	Recombinant anti-poison drugs
	Vaccines
Agriculture	Bio-fertilizers
	Bio-pesticides
	Bio-regulators
	Micro propagation
	Veterinary medicines
Food processing	Animal feed
	Diagnostic kits
	Microbial enzymes
Environment	Absorbent fiber for industrial substances
	Odor control and treatment
	Wastewater treatment

In order to characterize the users of biotechnologies in Mexico, the questionnaire asks about products in the market and development processes in different industries (e.g. diagnostics and therapeutics in human health; plant biotech and animal biotech; genetics and molecular modeling in bioinformatics; air, water, and soil in environment). According to that information, the interviewed firms produce goods and services that can be categorized into the following industries: agriculture, environment, food processing and human health.

Table 8.3

Characteristics of Mexican enterprises using biotechnologies

Sector	ID	Creation year or restructure	Number of years using biotech. (2009)	Number of employees (2008)	Export
Human Health	1	1999	NA	500	NO
	2	1970	**20**	**900**	**YES**
	3	1990	**19**	**108**	**YES**
Agriculture	**4**	1976	**33**	**94**	**YES**
	5	2004	5	16	NO
	6	2003	6	42	NO
	7	1995	12	3	NO
	8	1990	**15**	**110**	**YES**
	9	1992	**2**	**14**	**YES**
	10	1986	**23**	**34**	**YES**
Food processing	**11**	1974	**35**	**108**	**YES**
	12	1986	10	165	NO
	13	1998	10	18	NO
Environment	14	1995	**14**	**21**	**YES**
	15	1999	2	14	NO
	16	1996	13	33	NO

What business models are emerging in the Mexican-specific economic environment? Information in Table 8.3 summarizes the characteristics of the interviewed enterprises: age, years of experience using biotechnologies, and their

participation in foreign markets. Based on this information, two kinds of users were identified. The first one includes those enterprise currently using biotechnologies that were established since the 1970s (numbers 2, 3, 4, 10, and 11 in Table 8.3). Some of these enterprises have had products in the market for around 30 years and they also have used biotechnologies almost since then. In some cases, they have restructured their business organization (e.g. to change company mission and rename the company) and their production lines (e.g. to enter new markets or improve their processes). In addition, they have foreign trade activities. In these cases one can intuitively suggest that these kinds of firms have improved their biotechnology processes in order to maintain their position in the market. Also, the accumulation of capabilities has allowed these firms to adopt modern biotechnologies for improving production processes, and eventually to enter in new markets with new products. The second kind of users includes those enterprises which are relatively young –they were founded since the 1990s—, they are small and do not have activities in foreign markets (numbers 5, 6, 9 and 15 in Table 8.3). These enterprises have few years adopting biotechnologies; they seem to look for improving their processes and products in order to move their position in the local market.

Based on the information of Table 8.1 that contains current production, process and product development, and environment reasons, and Table 8.3 that summarizes information about age, number of years using biotechnologies, and foreign trade: ***the adoption of biotechnologies in Mexico seems to be carried out mainly by medium and large enterprises that are already in the market and look for improvements on their processes or lines of businesses.*** In addition, firms that have capabilities related to biotechnologies as well as production and commercialization capabilities in local and foreign markets are more able to adopt modern biotechnologies.

In order to test this proposition, I conducted non-parametric tests (see Annex H) to measure the relationship between 1) size and size of biotechnology, 2) size and years

using biotechnologies, and 3) years using biotechnologies and export activities. A Spearman rank-order correlation produced significant results (r_s=0.8640, p<0.05); it means that there are a strong relationship between the size and the size of biotechnology. This result suggests that according to the size of the firm (total number of employees), it has developed a capacity to have a number of employees dedicated to biotechnology activities –either full- or part-time. In addition, a biserial correlation produced significant results (r_b=0.4804, p<0.05) when measuring the relationship between firm size and the number of size biotechnology, which suggests that there is a strong relationship between these two variables. Regarding the relationship between years using biotechnologies and export activities, a biserial correlation also produced significant results (r_b=0.8358, p<0.01); these results suggest that there is a strong relationship between the firm's years using biotechnologies and its export activities.

Medium and large enterprises using biotechnologies have been in the market for more than 30 years and in some cases they have more than ten years using biotechnologies. This information confirms that large firms have developed scientific, managerial and commercialization capabilities that help them to adopt modern biotechnology. Most of these enterprises are not generating new products for the world; instead they are improving their processes and product lines to remain in the market. They have developed **"imitative business models".**

Other internal factors that affect the creation of business models, besides capabilities, are collaborations with other organizations, finance structure, location, and strategy and objective/mission (see Chapter II).

Regarding the funding sources, the interviewed enterprises have not received support from venture capitalists. Most of them have received funding support from family and friends. Two firms have received funding from government because they are

government-owned, one of them also receive funding from international institutions (e.g. World Health Organization). Other three firms mentioned they have obtained funding from government in addition to the family support. Only one firm mentioned to have private placement. This information confirms the limited financial support that biotechnology firms have. Commercial banks and public equity markets have a small participation in supporting innovative initiatives, especially of those coming from small and medium enterprises: "During the last ten years, the [VC] industry has predominately been governed by foreign investors who primarily focus on late-stage investments" (Charvel et al, 2006: 311). The venture capital industry in Mexico is in its infancy phase; private and institutional players do not have incentives to take high risks (Charvel et al, 2006; Lavca, 2010).

In order to analyze the strategies implemented by the enterprises in 2008, the questionnaire asks for two types of strategies: knowledge strategies and business strategies (Table 8.4). Regarding knowledge strategies, the enterprises mentioned they captured and used knowledge obtained from external sources, particularly from knowledge-creating organizations. In addition, all enterprises encouraged staff education. Although these enterprises encouraged the adoption of new knowledge and improvement of skills, they were not enthusiastic with the implementation of intellectual property. Most of the enterprises have several trademarks, however, few firms have patents, either granted or applications. Regarding the business strategies, most of the enterprises increased market penetration, began new R&D project, and expanded into foreign markets.

Table 8.4

Strategies implemented by Mexican biotechnology enterprises, 2008 (percentage)

Knowledge strategies	Agri.	Env.	Food proc.	Hum. health
Captured and used knowledge obtained from other industry sources	**29**	**100**	**100**	**100**
Captured and used knowledge obtained from knowledge-creating organizations	**71**	**100**	**100**	**100**
Development of new knowledge through collaborative agreements	57	50	33	100
Used and updated databases of scientific information	71	100	67	67
Developed firm policies and practices for IP protection	29	100	0	67
Developed or encouraged staff education/upgrading	**100**	**100**	**100**	**100**
Conducted an IP audit in all stages of development	14	0	0	33
Used IP to signal competency	43	100	67	100
Business strategies				
Increased firm size through acquisitions, merger or joint-ventures	29	50	0	33
Provide products and services to other firms	14	0	33	0
Increased market penetration (product trials/adapted products or processes)	**86**	**100**	**100**	33
Began new R&D project(s)	**86**	**100**	**67**	**100**
Expanded into foreign markets	**71**	**50**	**67**	**67**
Other (niche market)	0	0	33	0
n= Agriculture: 7; Environment: 2; Food processing: 3; Human health: 3; NA: 1.				

8.2 Potential biotechnology clusters in Mexico

High technology agglomerations require government intervention for creating organization and institutions that support their growth. Several countries have designed initiatives to create high technology agglomerations (e.g. regional clusters, industrial parks). Mexico is not an exception, and some initiatives have been presented to encourage the creation of agglomeration in different regions of the country. The PECITI 2008-2012 recognizes the importance of university-industry

collaborations; accordingly, some industrial parks have been proposed in different Mexican states, for example, Aguascalientes, Baja California, Chihuahua, Jalisco, Morelos, Nuevo León, State of Mexico, Sonora and Yucatán (PECITI, 2008). At least two technology parks have been designated to encourage university-industry collaborations for developing biotechnologies.

Table 8.5

Technology parks supporting biotechnologies in Mexico

Name of the park	Location	Supporting areas related to	Participants
Parque de Investigación e Innovación Tecnológica de Monterrey (PIIT)[a]	Monterrey, Nuevo León	Biotechnology, nanotechnology, mechatronics, ICT, and health	Private initiative, HEI, and research centres.
Parque Tecnológico Cuernavaca[b]	Cuernavaca, Morelos	Biotechnology, ICT, mechatronics, and health	Federal and State governments and HEI.

[a] Park of research and technology innovation of Monterrey, Nuevo León
[b] Technology Park Cuernavaca, Morelos

Source: PECITI (2008: 23)

Regarding the creation of biotechnology agglomerations, specific organization and institutions are needed to support their development (see Chapter III). Some scholars have mentioned that those organizations and institutions that support the adoption of biotechnologies in developed countries are difficult to find or create in emerging and developing countries. In this sense, this section deals with the analysis of the potential Mexico have for creating a regional biotechnology agglomeration.

8.2.1 Regional scientific capabilities

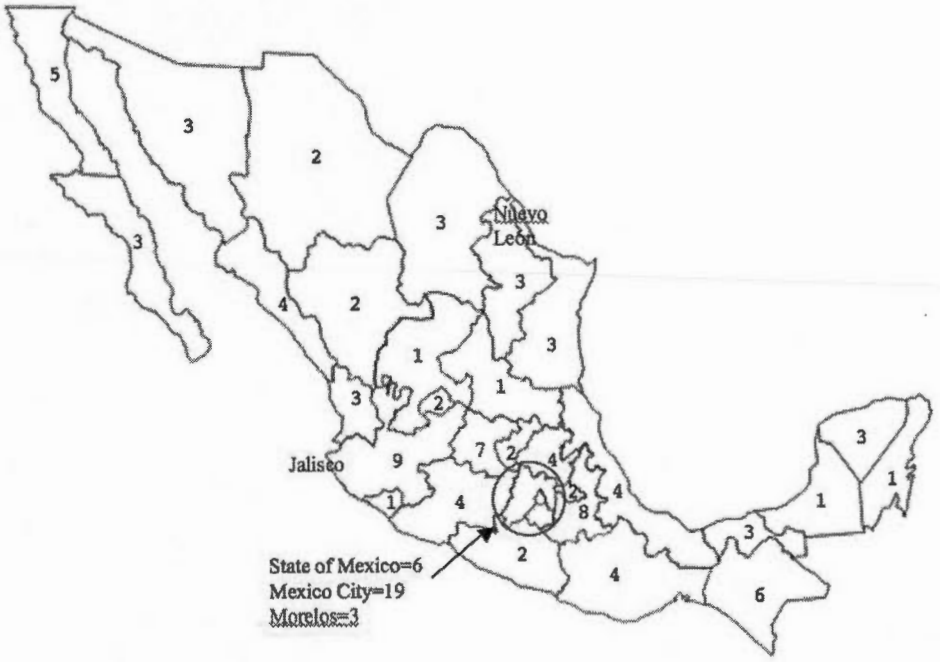
Q2: Given that high technologies tend to agglomerate, does Mexico have the potential to create and support a biotechnology cluster? The creation of scientific and technological capabilities relies strongly on institutional structures nurtured by

governments. As mentioned in Chapters II and III, high technologies enterprises tend to agglomerate in specific geographic areas. Biotechnology agglomerations rely on the existence of a variety of organizations that support the creation of capabilities in the area. The following paragraphs describe the organizations and institutions of different regions in Mexico.

Figure 8.1 shows the number of knowledge-creating organizations and research centres located in each Mexican state and the federal district (Mexico City). According to the Ministry of Economy, in 2008 Mexico had about 130 education and research organizations with programs related to biotechnologies, these include 48 master programs and 21 PhD programs dedicated to areas such as biochemistry, biology, bio-processing, pharmacology, genetics, and food processing (Secretaría de Economía, 2010: 251). These programs represent 8% of the total postgraduate programs in Mexico (ibid, p. 252). Among the universities and research centres in Mexico, only 25 have biotechnology publications in international journals (see Table 7.1 in Chapter VII) and only 10 organizations had more than 50 publications during the period 1996-2008 (see Table 8.6).

Figure 8.1

Number of universities and research centres with biotechnology activities in Mexico



Source: Own elaboration based on Secretaría de Economía (2010).

Table 8.6

Number of publications in different biotechnology areas, 1996-2008

Organizations	Total*	Human health	Agriculture	Other than human health and agriculture
Universidad Nacional Autonóma de México-UNAM	818	594	72	137
Instituto Politécnico Nacional-IPN	553	340	93	116
Universidad Autónoma Metropolitana-UAM	291	179	26	82
Research Centres of CONACYT	278	135	52	82
Institutio Mexicano de Seguro Social-IMSS	139	131	4	1
Universidad Autónoma de Nuevo León	94	61	14	17
Universidad de Guadalajara	72	50	10	11
Instituto Mexicano de Petróleo	70	27	1	40
International Maize and Wheat Improvement Centre-CIMMYT	64	12	47	5
Universidad Autónoma del Estado de Morelos	51	28	7	13

* Data for 2008: January-September

Source: Science-metrix as compiled for Canada Research Chair on the Management of Technology.

In addition to publications, the number of patents is a quality indicator of research. Table 8.7 shows that very few Mexican universities and research centres have registered scientific advances in the USPTO, the most dynamic patent office. These registrations started in the 1990s.

Table 8.7

Patents granted to Mexican universities by the USPTO, 1976-2010

Universities and research centres	Year 1st patent	Total biotechnology patents	State	Total patents
CINVESTAV - IPN	1990	6	Mexico City Guanajuato	17
Universidad Autónoma de Nuevo León	1998	3	Nuevo León	4
UNAM	1990	12	Mexico City Morelos	16
Escuela Nacional de Ciencias Biológicas - IPN	2004	1	Mexico City	3
ITESM	2008	1	Nuevo León	2

Source: Own elaboration based on USPTO, August 2010

According to the information of Figure 8.1 and Table 8.7, in spite of Mexico having some training and research organizations all over the country, there are few Mexican states with the potential to undertake cutting-edge biotechnology research. These locations host universities and research centres with research tradition: Mexico City, Morelos, State of Mexico, Jalisco and Nuevo León.

The central region of Mexico (Mexico City, Morelos and State of Mexico), particularly Mexico City, hosts the largest universities in the country, in terms of student population and research activities: UNAM, IPN and UAM. UNAM has faculties conducting biotechnology research in Mexico City (chemistry, sciences, medicine, bio-sciences, engineering) and Morelos (biotechnology and genomic sciences). IPN has also some schools and faculties related to biotechnology research, in Mexico City (biology sciences and biotechnology), Guanajuato (plant biotechnology and genomics), and Tlaxcala (applied biotechnology). UAM has

research activities in two campuses located in Mexico City (Iztapalapa and Xochimilco). These organizations have been actively involved in biotechnology research for more than 25 years, in the case of modern biotechnology (e.g. DNA coding, bioinformatics) for more than 10 years[35] (Table 8.8).

Table 8.8

Biotechnologies used in Mexican universities, 2008

Biotechnologies	University1	Research centre1	University2	Research centre2
Number of researchers	304	48	57	155
Number of biotechnology researchers	184	43	52	93
SNI researchers (percentage)	59	42	100	29
Biotechnology research activities				
DNA codification	YES	NO	YES	YES
Proteins and molecules	YES	NO	YES	YES
Cell and tissue culture and engineering	YES	NO	YES	YES
Process biotechnologies	YES	YES	YES	NO
Sub-cellular organisms	YES	NO	YES	YES
Bioinformatics	YES	NO	YES	YES
Nano-biotechnologies	YES	NO	YES	NO
Environment biotechnologies	YES	NO	YES	NO
Others	Genomics, Proteomics	Bioprospecting, Phytomedicines	Bio food	Genomics

Historically, scientific research has been concentrated in the centre of the country

[35] Information from interviews with universities

where the main campus of the three universities mentioned before are located. In an attempt to decentralize research activities, some of their faculties and institutions were relocated to other states. However, the concentration of research activities in the centre of the country remains solid; for example, in 2004 INMEGEN was created, a new research centre which aims to carry out genomics research. This centre is located in Mexico City too.

The state of Jalisco also has developed biotechnology research activities mainly in two organizations: the University of Guadalajara (UdeG) and the State of Jalisco's Research and Assistance in Technology and Design Centre (CIATEJ in Spanish). The UdeG carries out biotechnology research activities in the University Centre for biological and livestock sciences (CUCBA in Spanish), which host almost 70 researchers registered with the SNI[36] and the research lines include bioagriculture, phytopharmacology, inmunobiology, animal and vegetal genetics. Also, the UdeG has a partnership with the Civil Hospital of Guadalajara, the main research hospital of the region. Other important organization is the CIATEJ, a Conacyt-sponsored centre, which host more than 30 researchers register with the SNI[37] in areas like biotechnology, micropropagation and vegetal genetic improvement, microbial biotransformation, and quality of agrifood. In addition, some efforts have been made to promote and encourage the adoption of biotechnologies in the West region. For example, *Biocluster de Occident AC* is an association between research centres and government. The founders were the Institute of Higher Studies of West (ITESO in Spanish), Regional Chamber of Transformation Industry of Jalisco (CAREINTRA in Spanish), State of Jalisco Council for Science and Technology (COECYTJAL in Spanish), the government of the State of Jalisco, and Jalisco's major veterinary and

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[36] Information retrived from http://udg.mx/investigacion/directorio/centro/cucba (Accessed on 30 May 2012).

[37] Information retrived from http://www.ciatej.net.mx/index.php/investigacion/investigadores/?lang=es (Accessed on 30 May 2012).

pharmaceutical companies.[38]

The state of Nuevo León hosts the strongest research university in the Northeast of Mexico: UANL. This university carries out research activities in areas of biology, biotechnology and food sciences through the School of Biological Science, which hosts more than 60 researchers registered with the SNI[39]. A private university also is involved in the development and adoption of biotechnologies in the region: the ITESM' Biotechnology Centre. In addition, The State government in collaboration with the federal government and research universities have been active to generate economic development based on high technologies, including biotechnologies[40] and have promoted the capital city of the State, Monterrey, as the "International City of Knowledge".

In sum, there are few locations with biotechnology research capabilities: the centre of the country that includes Mexico City and Morelos, and potentially Jalisco and Nuevo León.

8.2.2 Technology transfer and liaison offices

Technology transfer and liaison offices also play an important role for incubation and licensing activities. Emerging countries supporting actively the adoption of biotechnologies have established incubators, technology parks, and technology transfer offices. In Mexico some universities and research centres have extension units –these units are in charge of the elaboration of research contracts, licensing and in some cases technology transfer agreements.

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[38] Information retrieved from http://www.bioclusteroccidente.com (Accessed on 01 June 2012).
[39] Information retrieved from http://www.fcb.uanl.mx/Investigaciones/Profesores_SNI/SNI%20Datos%20Recientes/SNI_Profesores_vigentes_del_2010.htm (Accessed on 01 June 2012).
[40] Information retrieved from http://www.mtycic.org:8080/node/174 (Accessed on 01 June 2012).

I interviewed five technology transfer and liaison offices related to biotechnologies located in Mexico City and Morelos. The general characteristics of these offices are presented in Table 8.9. According to this information, technology transfer and liaison offices depend on different institutions, such as universities, state government and federal government. These offices have assisted in the incubation and creation of spin-offs. Yet, there are other offices dedicated almost exclusively to assist research and technology contracts. Although the number of new enterprises is very low, these offices are enthusiastic about the creation of new enterprises; however, there are no well-defined mechanisms to follow-up the incubated enterprises after "graduation".[41]

Table 8.9

Incubation and liaison offices

ID	Year foundation	Depend of	Location	Incubation	Spin-offs
1	1987	University	Morelos	1	4
2	2007	State government	Morelos	2	0
3	Mid-1970	University	Mexico City	0	0
4	2004	Federal government	Mexico City	10	0
5	2004	University	Mexico City	5	1

Villasana (2011) analyzed the case of technology transfer offices of two important universities in Monterrey, Nuevo León: UANL and ITESM. She mentions that the creation of these offices was based on the State Development Plan and other programs aimed to support the foundation of new technology based enterprises. However, these technology transfer offices have had problems to develop relationships with private firms, and biotechnology researchers are poorly informed about the services of these organizations (Villasana, 2011: 50-51).

Based on the information gathered in the interviews and the analysis of Villasana

[41] Information from interviews with incubation and liaison offices

(2011), ***the creation of organizations in charge of technology transfer in Mexico is relatively young and undeveloped.*** In order to improve this situation, the government has promoted the creation of new organizations and institutions to encourage and assist technology transfer. In 2009, the modifications to the S&T Law established a new mechanism for technology transfer: Liaison and Knowledge Transfer Units (UVTC in Spanish). In fact, on December 2011 it was established the first UVTC, which involved two research centres and a government agency.[42]

8.2.3 Regional business opportunities

In 2002, Francisco Bolivar and colleagues conducted a study about biotechnology in Mexico. These authors identified industries where biotechnologies could be applied: agriculture, human and animal health, environment, aquaculture and livestock. In a recent study, the Ministry of Economy (2010) identified about 304 enterprises that potentially could become biotechnology users in different sectors: agriculture, food processing, environment, fermentation and biology products, livestock, pharmaceutics, and services. Figure 8.2 shows the distribution of these enterprises by sector: pharmaceutical (39.14%), agriculture (21.71%), and food processing (11.85%) are the sectors with a larger participation in Mexico.

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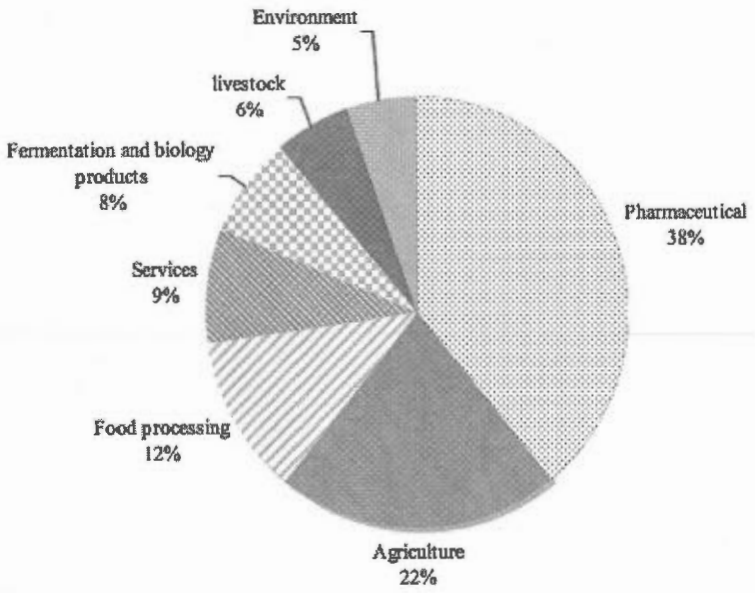
[42] Information retrieved from http://todos.cicese.mx/index.php?option=com_content&view=article&id=276:se-crea-la-primera-unidad-de-vinculacion-y-transferencia-del-conocimiento&catid=9:breviario&Itemid=100 (Accessed on 24 February 2012).

Figure 8.2

Distribution of potential biotechnology-using enterprises by sector in Mexico



Source: Own elaboration based on Secretaría de Economía (2010)

The Mexican states that host more potential users (enterprises) of biotechnologies are Mexico City (46.38%), the State of Mexico (13.16%), and Jalisco (12.5%) (see Annex C).

Considering the regional capabilities to develop scientific research, the activities of technology and liaison offices, business opportunities, there are few states that have the potential to create and support biotechnology agglomerations: 1) Mexico City and Morelos, 2) Jalisco, and 3) Nuevo León.

8.2.4 Collaborations in Mexico

What kinds of collaboration, if any, have emerged? As mentioned in Chapter III,

the adoption and development of biotechnologies requires the collaboration of different organizations. The collaboration between these agents often is coordinated and nurtured by a favourable institutional framework that promotes the incentives to push forward scientific advances related to biotechnologies, and the adoption and diffusion of those novelties. Therefore, when institutional frameworks are limited and without a long-term strategy, the collaboration between different agents faces several obstacles.

The institutional framework in which Mexican firms interact is unstructured, then *a priori* collaboration between different agents seems difficult to achieve. Nevertheless, Mexican firms using biotechnologies have started to establish some collaboration agreements. In order to clarify this point, the main questionnaire asks about collaboration with different organizations in Mexico and abroad, and the motives of those collaborations.

Figure 8.3

Percentage of collaborations

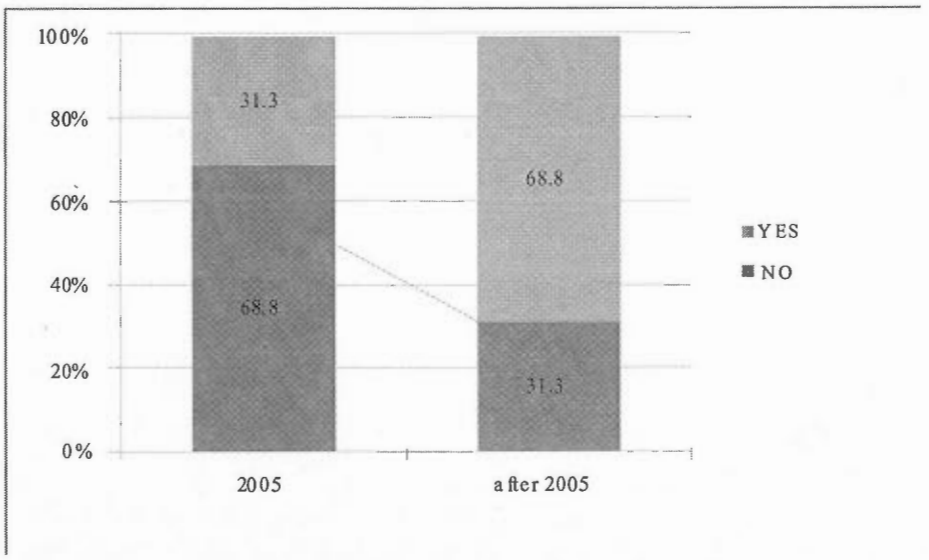


Figure 8.3 shows that in 2005, only 31.3% of the interviewed firms established

collaborations, after 2005, this percentage increases to 68.8%. Regarding the kinds of collaborations, Table 8.10 shows the different agents with whom these firms have established collaboration agreements, and the purposes of those collaborations.

Table 8.10

Collaboration between different agents and purposes of collaboration

Collaboration with	Reasons to collaborate	Agriculture	Environment	Food processing	Human health
Other biotech enterprise	To conduct R&D	YES			YES
	Access to others' patents				YES
	Access others' knowledge/skills				YES
	Access market	YES			
	Production/ manufacturing			YES	
Pharmaceutical enterprise	To conduct R&D				YES
Enterprise other than biotech or pharma	Production/ manufacturing				YES
	Access market				YES
Academic institutions/ Hospitals	**To conduct R&D**	YES	YES		YES
	Access to others' patents				YES
	Production/ manufacturing		YES	YES	YES
	Access IP				YES
	Access others' knowledge/skills	YES			YES
Government agencies or labs	To conduct R&D	YES	YES		
	Production/ manufacturing		YES		YES
	Access capital	YES			
	Access IP		YES		
	Access others' knowledge/skills	YES	YES		

Table 8.10 shows in general terms that the most active firms establishing collaboration agreements are those related to human health, followed by those in agriculture, environment, and finally food processing industries. In the case of firms in the human health industry, they collaborate with a variety of agents, such as other biotechnology firms, pharmaceutical companies and other kinds of enterprises, academic institutions, and government laboratories. The motives for these collaborations are related to the access to scientific advances and the adoption of new knowledge (e.g. to conduct R&D, access others' knowledge and skills, and access to IP). Collaboration with other companies aims to complement production and commercialization capabilities: production/manufacturing and access to markets. Firms in the agricultural sector collaborate with other biotechnology enterprises, academic institutions and government laboratories. The purposes of these collaborations are to conduct R&D, to access others' knowledge and skills, and to access IP. Here it is important to mention that other purposes such as 'Access to capital', 'Regulatory affairs', and 'Low expenses' did not appear as a factor to establish collaborations.

In addition to national collaborations, the interviewed firms also have established collaborations with organizations and institutions from other countries, which means that collaborations are not limited to local and national actors.

Table 8.11

Collaborations with organizations located in other countries

Country	Agents	Agriculture	Environment	Food processing	Human health
USA	Biotech enterprise			YES	YES
	Enterprise other than biotech or pharma				YES
	Universities/hospitals				YES
Europe	Biotech enterprise				YES
Other*	Biotech enterprise	YES			YES

*Confidential

Table 8.11 shows that the interviewed enterprises using biotechnologies in the human health sector are more dynamic in terms of collaboration with other countries, the motives for this collaboration are: to conduct R&D activities, regulatory affairs, production/manufacturing, and access to market. Most of these collaborations have been established with agents located in developed countries. **Access to capital, patents and other IP were not motives to collaborate with foreign agents.**

It seems that medium and large enterprises with higher technological and managerial capabilities are more active in the adoption of modern biotechnology and more able to establish collaboration agreements with international partners. In order to test this proposition, biserial tests were conducted to evaluate the relationship between 1) the firm size and biotechnology capabilities, 2) size biotechnology and international collaboration, and 3) firm size and international collaborations. The biserial correlations produce significant results for each pair of variables: size and external collaboration (r_b=0.4797, p<0.10), biotechnology size and external collaboration, (r_b=0.4423, p<0.010), and years using biotechnology and external collaboration

(r_b=0.4808, p<0.010) (see Annex H).

This pattern of collaboration confirms the need to seek complementary knowledge with other actors. Also, an important issue emerges. Even if the local institutional framework offers not well-coordinated support, firms try to use it no matter how limited it is, and when they need extra help they look for collaboration abroad. For this collaboration to take place Mexican firms need to have a certain absorptive capacity that is present in some large established companies but that is absent in small ones. Thus, the latter are at disadvantage because they are stuck with only the resources available from local institutions.

CHAPTER IX
STI POLICIES TO ADOPT BIOTECHNOLOGIES IN EMERGING COUNTRIES

Some emerging countries have implemented public policies in order to adopt biotechnologies. The objective of this chapter is two-fold: to describe the STI policies that were and have been implemented in three different emerging countries – China, India and Singapore, and to identify the pattern of STI policies implemented in those countries and propose policy recommendations to improve the adoption of modern biotechnologies in Mexico.

I selected these countries given the active involvement of their governments to adopt modern biotechnology and to support biotechnology agglomerations. China and India have been in the spotlight as new economic powers, while Singapore has been seen as an important player in the economy landscape. The governments of these countries have tried to generate economic growth through the promotion of high technology industries. Therefore, they have defined development strategies with long-term objectives; accordingly and have implemented a variety of STI policies.

9.1 China

Importance of technology and science

The particular characteristic of China is its transition from central planning (1949-1978) to a regulated market economy (since 1978). In the early 1950s, the government of China realized the importance of technology as the engine of economic growth. Consequently, the government designed programs that allow China to create and use knowledge as well as to develop capabilities in strategic industries: public policies were focused on the creation of research units and the development of

the Chinese research and production capabilities (Lui and White, 2001). In this period, different institutions were involved in creating technological capabilities, however, the State Planning Commission (SPC) was the most influential decision maker, with "ultimate control over economic plans, resource allocation and oversight" (Lui and White, 2001: 1097).

Later, during the late 1970s (the period of reforms), the Chinese government recognized the inefficiencies and lower effectiveness of a centrally planned economy in practice (Lui and White, 2001: 1098). Therefore, institutional changes were implemented to decentralize economic decision-making:

> "The aim has to shift from a government-led model of technical innovation principally centred around the programmes or plans prioritizing areas of R&D and given financial incentives, towards an enterprise-centred technology innovation system shifting away from public research institutes towards private enterprises as the centre of innovative activity" (Prevezer, 2008: 364).

Focus on biotechnology

Since 1985, the Chinese government has been promoting policies focused on the life sciences. The implementation of these policies can be divided into two phases:

- 1985-1995: creation of a favourable environment,
- After 1995: promotion of biotechnology business.

In the first phase (1985-1995), public policies were focused on the creation of a favourable environment: "strengthening infrastructure and creating funding programs that target R&D in particular technologies, biotechnologies among them" (Prevezer, 2008: 364). In addition, the government allowed the creation of spin-offs from research institutes, universities and large companies (Prevezer, 2008).

In 1986, the National High-Tech Research and Development Plan (the 863 Plan) targeted biotechnology as a strategic element for the industrial development:

- In 1988, the Torch program promoted the commercialization of key high-tech projects, including biotechnology;
- Key Laboratory Programs were established to fund R&D.

In the second phase (since mid-1990s), public policies have been more focused on promoting start-up companies, encouraging entrepreneurship, promote national and international collaborations, and modifying the patent law in order to promote the foundation of technology based start-ups (Konde et al. 2004: 41; Prevezer, 2008: 365):

- Incentives towards start-ups and helping entrepreneurs: these programs includes creating service centres, institutions for innovation funds, and building incubators;
- Development of human resources: in order to redefine the research and development strategy of research centres with biotechnology activities, more than 250 research institutions were privatized during 1998-1999, and other non-profit research institutions have been reorganized since 2000.
- Policies targeting "returnees" drawing back scientists from abroad: different programs have been established in order to create a research environment that attracts returnees;
- Location policies to stimulate the clustering of enterprises in science parks: since 1991, the Chinese government has established more than 53 science and technology parks in different locations. The most dynamic biotechnology locations are Shanghai, Beijing and Shenzhen;

- Policies focusing on establishing a venture capital industry: in 1996 the Chinese government promoted the creation of a venture capital industry, however, the incentives to develop this industry sector seem to be underdeveloped.

Different organizations have been involved in the promotion and coordination of the biotechnology policies, for example, government agencies including the Ministry of Science and Technology, the Ministry of Agriculture and the Ministry of Health among others; also, scientific organizations including the Chinese Academies of Sciences, the National Committee for Development and Technology and the National Research Institutions (Konde et al., 2004: 41).

As it has been shown, the Chinese government has been concerned with the technological development in both phases: central planning and reform. The main objective of these phases was and has been the creation of scientific and technological capabilities. As the Chinese government considered high-technologies industries in its economic development agenda, it started to formulate and implement STI policies focused on the development of capabilities for those technologies: promoting R&D activities, funding activities to accomplish innovation, and encouraging collaborations between different organizations (e.g. knowledge-creating organizations and enterprises). However, Lui and White (2001) and Prevezer (2008) emphasize the lack of coordination among public policies (e.g. incentives from central and local governments), and the "lack of interaction and networking both between public and private enterprises and between foreign and domestic firms" (Prevezer, 2008: 368). These circumstances have affected the adoption and diffusion of biotechnologies among the Chinese enterprises.

In sum, since the 1950s the Chinese government has implemented horizontal STI policies, which means that the government has invested resources in the creation of

capabilities in a variety of industries. As the country reached some industrial capabilities –specific knowledge and learning—, the government of China implemented vertical STI policies focused on high-technology industries. However, the demand and supply sides of technological and funding markets seem to be not well coordinated. According to Prevezer (2008), the main obstacles faced by small enterprises are the lack of funding and networking between different organizations that complement capabilities.

9.2 India

Policies to develop scientific and technological capabilities

Since the 1940s, the government of India has implemented public policies in order to reduce the technological dependence. Therefore, the government has implemented STI policies in order to develop own technologies. The evolution of technological and scientific capabilities can be divided into three phases (Chaturvedi, 2005):

- 1947-1970: creation of scientific and technological infrastructure,
- 1970-1990: creation of indigenous capacity,
- Since 1990: new economy reforms.

In the first phase (1947-1970), immediately after Independence, the Indian government implemented public policies focused on the creation of scientific and technological infrastructure in the country (Mani, 2004). In this phase, the government strongly supported the creation of knowledge-creation organizations. In 1958, the Scientific Policy Resolution was approved by the Indian Parliament to generate new capabilities: "Creating a base in science was seen as crucial for absorbing and eventually replacing the foreign technology as well as generating new capacities in technological innovation for the industrial development of the country."

(Krishna, 1996: 131). Consequently, the number of universities increased and major science agencies were established or expanded[43].

In the second phase (1970-1990), India announced its first Science and Technology Plan (1974-79). The main objective of this plan was to develop indigenous scientific and technological capacity to avoid technological dependence. In this sense, during the 1970s and 1980s, the policies on self-reliance and import substitution were strengthened through various mechanisms of economic protection and through restrictions on technology imports (Krishna, 1996: 132). In addition, the Indian Patents Act, 1970 was an important element to encourage the national industry: "product patents [were] not granted for pharmaceutical products, agro chemicals and food products. Therefore, Indian companies, especially in the pharmaceutical field, could do reverse engineering and develop more optimal processes for manufacturing known products." (Mani, 2004: 858).

In 1983, the Indian government announced the Technology Policy Statement (TPS) to increase technical competence and self-reliance especially in strategic areas. An outcome of the TPS was the Technology Information and Forecasting Assessment Council (TIFAC), created in 1988, whose main objectives have been technology forecasting and technology market surveys in order to promote specific home grown technologies with the industry (Mani, 2004).

In the third phase (after 1990), the TPS of 1983 has remained as a framework for the Indian technology policy. After 1990, the Council of Science and Industrial Research (CSIR) had to establish mechanisms to generate a percentage of its own budget. In order to do that, the agency has established research contracts and consultancy for non-government organizations (Mani 2004). In addition, in the mid-1990s, the Indian

[43] For example: the Department of Atomic Energy, the Council of Scientific and Industrial Research, the Defense Research and Development Organization, the Indian Space Research Organization, the Indian Council of Agriculture Research, and the Indian Council of Medical Research (Krishna, 1996).

government developed regulatory policies focused on the venture capital industry in the country: Securities and Exchange Board of India, SEBI (Venture Capital Funds) Regulations of 1996; Guidelines for Overseas Venture Capital Investments issued by the Ministry of Finance, 1995; and Central Board of Direct Tax Guidelines for Venture Capital Companies, 1995 (Mani, 2004).

In January 2003 the Prime Minister announced a new S&T policy, whose main objective is to raise India's overall research intensity. The policy has eleven different strategies and four new features:

- The recognition that although India has a large pool of scientists and engineers, their density is low,
- There is an explicit statement towards managing the brain drain from the country,
- An emphasis has been given to increased patenting both at home and abroad,
- There is an explicit articulation about the need to monitor the implementation of this policy (Mani, 2004: 860).

However, the financial resources dedicated to this new policy have fallen short to achieve the desired results (Mani, 2004).

Focus on biotechnology

According to Ramani (2002) the strategy of the Indian government to adapt and diffuse biotechnology can be divided into three phases:

- 1981-1986: the initiation
- 1986-1990: creation of scientific competences
- Since 1990: reaching out of the private sector

Since the early 1980s, the Indian government has established agencies focused on the development of biotechnologies. In 1982, the National Biotechnology Board (NBTB) was created. Later, in 1986 a separate government department replaced the NBTB, creating the Department of Biotechnology (DBT). This department is run by the Ministry of Science and Technology. Given that biotechnology, as a generic technology, requires the development of a variety of competencies in a variety of scientific disciplines, "[t]he establishment of the DBT served as a signal that the government considered biotechnology to be a priority area for development. It was welcome by academics, national laboratories as well as industrials" (Ramani, 2002: 5).

During the period 1986-1990, the Indian government supported the creation of scientific core competencies on biotechnology (Ramani, 2002: 5). In this sense, grants were given to universities, public research centres and teaching and research institutions partially supported by the government to undertake biotechnology projects. In addition, the DBT crated new research institutions focused on biotechnologies: the National Institute of Immunology, the Centre for Cellular and Molecular Biology, the National Facility for Animal Tissue and Cell Culture, and the International Centre for Genetic Engineering (in collaboration with United Nations Industrial Development Organization, UNIDO).

Besides scientific knowledge, government intervention is needed for the translation from scientific knowledge into commercial products. In this sense, after 1991, the Indian government has implemented new STI policies to consolidate the commercialization of biotechnology products (Konde, 2008: 48):

- The creation of technology parks with the support at central and state level: the objective of theses technology parks is to facilitate up-scaling, pilot-level production, and finally commercialization of indigenous biotechnology products.

- Industry promotion: some initiatives have been implemented to promote the creation of biotechnology enterprises, to monitor and nurture R&D in SME, and enabling public-private partnerships.

- Funding: the Indian government has promoted the creation of funds that allow biotechnology enterprises to grow.

- Academy-industry collaborations: although India has an important countrywide network of research institutions, there are some problems to establish linkages between research organizations and industry.

In sum, India has a long history designing and implementing public policies to create and develop scientific and technological capabilities; since the 1950s the Indian government has implemented horizontal STI policies. Once India developed some indigenous capabilities (mid-1980s), the government started to implement vertical STI policies in specific industries. Although India has achieved important results in the development and commercialization of high technology products, the consolidation of industries using biotechnologies have faced some troubles:

> "India has been successfully able to develop the nuclear bomb, satellites and supercomputers, because such projects involved a group of scientists who were given directives under a 'mission mode', i.e. under a cleared defined system of milestones targets and associated rewards. This route cannot be pursued in the integration of biotechnology ... [there is a] variety of techniques with multi-sectoral applications ... the Indian government [has] to consider more intervention in the creation of networks between Indian firms and between public laboratories and private firms themselves through national programs" (Ramani, 2002: 16).

Once again, managing the collaboration between different organizations seems to be a difficult process to achieve.

9.3 Singapore

Creating technological capabilities

Since the early 1960s, the Singaporean government has been engaged in the creation and development of technological capabilities: "The 1961-1964 Development Plan actively sought domestic industrialization, erecting trade barriers, providing tax incentives to foreign investors, and initiating a large infrastructure investment program" (Yong, 1992: 20).

After the late 1980s, the government of Singapore has established policies in order to encourage the adoption of biotechnologies. These policies support different organizations and institutions: supporting research, creating industrial parks, developing a venture capital industry, promoting star-up firms, and establishing a legal framework to encourage experimentation.

Focus on biotechnology

In 1988, the Economic Development Board (EDB) implemented the National Biotechnology Program. The objective of this program was to make Singapore 'the hub of commerce for the Asia-Pacific region'. The plan had five stages (Boisvert, 1998: 6):

- Promote biotechnological research in Singapore (five research institutions were founded);
- Construct an infrastructure that would simplify development of biotechnology;
- Train personnel;

- Develop economic measures, including tax incentives and approaching companies directly;
- Promote biotechnology to Singaporeans, particular with private investors.

In 1995, the Singaporean government designed the Biotechnology Cluster Plan. The main idea was "to integrate infrastructures and personnel to increase the competitiveness of biotechnology industry in the areas of R&D, bringing to market and services" (Boisvert, 1998: 7).

Focus on human health sector

Singaporean government has attempted to redefine the national institutional context in order to transform Singapore in the Asia's Hub for biomedical science with world-class capabilities across the entire value chain, from basic research to clinical trials, product/process development, full-scale manufacturing and healthcare delivery (Chaturvedy, 2005; Gin, 2007). In order to achieve this project, the Singaporean government created three agencies which are in charge of the implementation of the biomedical science initiatives: the functions of these agencies are to formulate the plans, to generate spin-offs and to support funding and academic research.

Education and Training: the National Biotechnology Program (NBP) is in charge of the training at all levels and the update of academic courses (Chaturvedy, 2005)

- Funding: different mechanisms have been implemented to encourage investments in biotechnology; these include a variety of tax exemptions, allowances and deduction/exemptions for venture capital investments, R&D activities and international consulting (Boisvert, 1998). Another source of funding is the Economic Development Board (EDB), which supports start-ups. Other programs followed by the Singapore government to promote equity investments in commercial projects in biomedical sciences are the attraction

of international companies and attraction of international venture capital (Chaturvedy, 2005)

- Legal framework: an important element in the development of biotechnology is intellectual property protection. In 1995 a new patent law was implemented: "The principal features of the new law cover a similar definition of protractible subject matter as that of the European Patent Convention. The law proposes that novelty will be assessed on a worldwide basis, with regard to both publication and use" (Chaturvedy, 2005: 117).

- Networks: the Singapore government has taken into account the collaboration required for the development of biotechnology, therefore, the initiatives "include arrangements like financial support; a clear strategy for supporting contract research organizations; open policy for imports of skilled manpower; promotion of close cooperation with firms; and arrangements for the emergence of public attitude" (Chaturvedy, 2005:109-110). The collaboration has to involve actors at national and international level (Chaturvedy, 2005).

The BIOPOLIS: In October 2003, Singapore made tangible the efforts to create a place that encompasses all the elements required to achieve biopharmaceutical products, a place in which all stages of the value chain are present –from scientific research to marketing and delivery. Biopolis "is an integrated R&D complex of two million square feet of space that houses Biomedical Research Council's five research institutes as well as R&D laboratories of numerous pharmaceutical and biotechnology companies" (Gin, 2007: 1134). With this science park, the Singapore government seeks to consolidate its position in pharmaceuticals and molecular biology research, and become a biomedical market at international level (Chaturvedy, 2005).

In sum, since the 1960s the Singaporean government has been focused in the creation

and development of technological capabilities. In the 1980s the Singaporean government started to implement vertical STI policies in order to encourage the creation and development of biotechnology capabilities in the human health sector.

9.4 STI policies in emerging countries

This section summarizes the STI policies implemented by the government of China, India and Singapore. These emerging countries have achieved successful results in the adoption of biotechnology, particularly in the biopharmaceutical sector, which has been one of the most dynamic sectors using modern biotechnologies.

According to the information presented in the previous section, a pattern in the evolution of the STI for increasing scientific and technological capabilities has been identified:

1. Creation of scientific and technological capabilities in different fields,
2. Focus on biotechnologies that could be applied in different sectors,
3. Focus on biotechnologies related to biopharmaceutical industry or human health.

Governments embracing economic growth through the development of high technology industries have implemented STI policies focused on the creation, development and support of scientific and technological capabilities. In order to achieve that, governments have created institutions with the mandate to design, implement, and evaluate STI policies and programs, in turn this activities allow the coordination between different programs and the establishment of a coherent pattern of policy choices.

According to the experience of the three countries, the first step was to make large

investments to modernize universities –for scientific research and training- and set R&D incentives, which underpinned a variety of capabilities used in different industries within the country. Once scientific and technological capabilities reached a point, in which the national government considered the country could face the challenge to create and develop high-technology industries, a combination of vertical-horizontal STI policies were implemented. Vertical STI policies are those policies focused on specific industries. Given that biotechnology is not an industry, but a group of techniques that can be applied to different industries, horizontal STI were implemented to develop scientific and technological capabilities in different biotechnology applications, for example, agriculture, human health, animal health, and environment. Finally, when national or regional governments considered they have acquired adequate capabilities, and at the same time a supporting institutional framework was built, they implemented vertical STI policies focused on one sector, for instance, biopharmaceuticals (in the three countries –China, India and Singapore). In addition, other institutions were created to collect, evaluate and diffuse relevant information for the development of biopharmaceutical industry.

The design and implementation of vertical STI policies vary among countries and regions. Regarding the characteristics proposed by Dodgson and Bessant (1996) to differentiate science, technology and innovation policies, some examples are mentioned here based on the experience of these three countries:

Science and technology policies

- Creation or revamping of national laboratories in specific biotechnology applications (e.g. agriculture, human health, environment)
- Support personnel training from technical to Ph.D. education.
- Improvements in scientific collaborations through research networks at

national and international level.

- Improvement of university-industry linkages and support of competitive R&D projects via mutual cooperation (e.g. projects must involve at least one university/research lab and one enterprise).
- Revision of intellectual property law as stimuli to create spin-offs, which means allowing academic researchers to generate and obtain economic value.
- In some countries, a program targeting returnees could help to recruit qualified scientific researchers trained abroad in the state-of-the-art biotechnologies.

Innovation policies

- Creation of organizations to support DBFs, including grants for entrepreneurs to register patents, build prototypes, and design business plans.
- Creation of organizations to facilitate the establishment of new DBFs and promote entrepreneurship (start-ups), including technological incubators and industrial parks.
- Foundation of agencies and programs to finance the entire process of innovation –from scientific research to the launching of DBFs, including a variety of tax incentives (e.g. R&D tax).
- Creation of a venture capital industry and attraction of foreign VC (allowances and deduction/exemptions for VC investments).
- Attraction of foreign investors and strategic partners (e.g. large pharmaceutical and chemistry companies) through tax incentives, international level of R&D infrastructure, and providing pre-seed funds to promote commercialization.

- International consulting
- Promotion to contract foreign skilled manpower.

The cases of these emerging countries (China, India and Singapore) show that the design and implementation of STI policies seem to imitate the experience of developed countries. However, given the different socio-economic conditions and institutional frameworks of each country, the intervention of the government and the results of STI policies vary. China has the potential to attract investments to different industries using biotechnologies given its potential market and commercial incentives. India has developed a strong scientific base and has re-converted traditional industries (e.g. chemical and pharmaceutical) into biotechnology users that are focused on export market. Singapore has focused its efforts on the most dynamic industry using biotechnologies: biopharmaceutical.

9.5 Mexico

As mentioned in Chapter V, since the 1970s, the Mexican government started to implement public policies to develop scientific and technological capabilities. In the last decade, the federal government has implemented public policies aimed to achieve innovation. However, these public policies have no clear priorities. In the Special Program on Science, Technology and Innovation (PECITI, 2007-2012), the Mexican government has attempted to define strategic industries in medium and high technologies.

Some Mexican research institutions and enterprises have adopted and developed modern biotechnologies (see Chapter VIII). The translation from scientific results into commercial biotechnology products has faced several institutional obstacles. The objective of this section is to show the public policies and programs that have been implemented in Mexico in order to improve the adoption and diffusion of

biotechnologies.

9.5.1 Science and technology policies

The National Program for Technological and Scientific Development 1984-1988 was the first program to establish explicit guidelines for biotechnology development related to national priorities such as food and health (Solleiro, 1995). In this period the specific research lines included development of biotechnologies like genetic engineering, tissue culture, and enzyme engineering, unicellular protein production. Also, some programs were implemented to encourage the adoption of biotechnologies (Solleiro, 1995: 31). The main result of these policies was the incorporation of biotechnology to the national research agenda and the strengthening of research capabilities (Solleiro, 1995; Corona, 2006), for example, the creation of the Institute of Biotechnology-UNAM and the CINVESTAV-IPN (Possani, 2003).

In the 1990s the role of the Mexican government was focused on supporting scientific development and leaving technological improvement to the private sector (Solleiro, 1995; Dutrénit et al., 2010). Therefore, in this period there was no specific policy focused on the adoption of biotechnology (Solleiro, 1995).

In the 2000s, the ST policies introduced biotechnology as strategic sector. The PECYT 2001-2006 recognizes the importance of biotechnology and proposes a National Program of Biotechnology and Genomics; however the Program did not define any budget for this purpose (PECYT, 2001: 155-177; Corona, 2006). The PECITI 2008-2012 and the National Development Plan (PND in Spanish) are in line regarding the importance of biotechnology (Table 9.1). However, the guidelines of PECITI are focused only on bio-safety and scientific research issues. There is no description about the mechanisms to translate research results into commercial products.

Table 9.1

Strategic areas for PND and ST policy

PND 2007-2012	PECITI 2008-2012	Strategic industries
-Health	**-Biotechnology**	**-Food and agro-industry**
-Education	-Medicine	-Aeronautics
-Food	-Energy	-Automobile and auto parts
-Environment and climate change	-Environment	-Electrics and electronics
-Energy	-Industrial technologies for manufacturing	**-Pharmaceutical and health sciences**
-Economic growth and sustainable development	-Materials	-Metallurgy
-Fight poverty	-Nanotechnology	-Metal-mechanics and capital goods
-Governance	-Information and communication technologies	-Chemical and petrochemical
-Population, equity and gender	-Applied mathematics and modeling	
-Infrastructure		
-Tourism		

Source: PECITI (2008: 48-49).

In the last decade, some efforts have been made to propose the guidelines to elaborate a national plan of biotechnology. Dr. Bolivar and colleagues (2003) and the Ministry of Economy (Secretaría de Economía, 2010) elaborated comprehensive analysis of the situation of biotechnology in Mexico: training and research activities; potential industrial uses, and described some successful cases. These analyses proposed some actions to adopt and diffuse biotechnologies in Mexico (see Table 9.2).

Table 9.2

Proposed actions to adopt and diffuse biotechnologies in Mexico

	2003	2010
Human resources		To form and train human resources, define new lines of research, and create new research centres
Infrastructure	To plan and optimize the research infrastructure	To improve the research infrastructure
Productive sector	To promote and foster the participation in the development of modern biotechnology industry	To form postgraduates that can be hired by the private sector
		To reward the creation of new process useful for the industry
		To develop incubators to exploit entrepreneurial ideas of young scientists
		To develop topic/sectoral clusters
		To create a fund for biotechnology activities
		To establish a biotechnology association
Regulatory framework	To develop and advance a regulatory framework	To create a regulatory framework that allow the access to GMOs
Social perception	To discuss and analyze issues related to biosecurity, bioethics and bioprospection.	
Uses of biotechnologies	To solve real problems	
National program		To promote and consolidate the adoption of biotechnology

Source: Own elaboration based on Bolivar et al., (2003) and Secretaría de Economía (2010).

The Ministry of Economy proposed also the creation of a National Program of Biotechnology (NPB), whose main objectives would be the coordination of the three key actors in the development of biotechnologies, academy, industry, and government, and to promote the development and consolidation of industries using these biotechnologies (Secretaría de Economía, 2010). In addition, the authors proposed the establishment of critical support organizations and linkages for a successful NPB: an association of biotechnology enterprises that promotes the development of biotechnology for the industry and the society, a fund to foster productive biotechnology, and a government agency that coordinated the resource management (Secretaría de Economía, 2010).

Regulatory frameworks

Since the mid-2000s, some regulatory laws have been enacted in order to promote scientific research and industrial use of biotechnologies. They include:

2005: Bio-safety Law for the use of Genetically Modified Organisms (LBMOGM in Spanish). The LBMOGM was elaborated by the Congress of the Union, after a discussion among different organizations and institutions involved with the development of biotechnology in Mexico, such as the AMC, UNAM, UAM, CINVESTAV among others and the Legislature, evaluating scientific evidence to define possible risks in order to generate an adequate and balanced regulatory framework for the use of GMOs (Bolivar, 2006: 8).

2005-2008: Bio-energy Laws. In Mexico there are three laws related with bio-energy:

- Law for the sustainable development of the sugar cane, 2005: the objectives of this law are to improve 1) the quality of the sugar cane, 2) its industrialization, and 3) the commercialization of the sugar cane products and by-products, such as ethanol.

- Law to promote and develop bioenergy, 2008: its objective is to promote the productions of inputs for bioenergetics, based on agricultural activities, forestry, algae, biotechnology and enzymatic processes, without jeopardizing the safety and sovereignty of the country.

- Law for the exploitation of renewable energies and for the funding of the energy transition, 2008.

In sum, since the 1970s the Mexican government has implemented S&T policies to improve the scientific and technological capabilities of the country, and recently some STI policies have been designed to encourage technological innovation. In the 1980s, the implementation of ST policies generated the basis of the country's research capabilities in biotechnology. After 2000, some regulations have been enacted to support the development of modern biotechnologies. In addition, some efforts have been made to propose the guidelines to crate a National Program of Biotechnology.

Mexico has two elements that policy makers have to consider when designing STI policies to promote the adoption and diffusion of biotechnologies: the Mexican population size and the accumulated experience in industrial activities. The constant growth of the Mexican population poses several challenges related to health, food, and environment. Mexico has an important market for biotechnology and biology products; for instance, the Mexican human health sector represents a market of 1000 USD millions.[44] According to the International service for the acquisitions of agri-biotech applications (ISAAA), with data for 2009, Mexico occupies the 15th place

[44] Mexico is among the eleven largest pharmaceutical markets worldwide, the seventh pharmaceutical emerging market, and the second market in Latin America, after Brazil (see, Carolyn Greton (Sept. 2011) and Kim Ribbink (Sept. 2011). Information retrieved from www.pharmavoice.com) (accessed on 23 September 2011).

among the countries that cultivated OGM (~100 000 ha.)[45]

9.6 Characteristics of biotechnology agglomerations in emerging countries

Table 9.3 summarizes the conceptual contributions of this research. Similar to Table 6.1 (Chapter VI), this table presents in the column names the stages of a biotechnology agglomeration. In the case of an emerging country with a limited government support, the 'previous conditions' are related to the capabilities developed previously to the adoption of modern biotechnologies. The 'emergence stage' or 'rejuvenation' represents the stage in which enterprises are more active in the adoption of biotechnologies and the government start to generate some programs to support the adoption and diffusion of biotechnologies.

The row names represent the relevant elements for the creation of a biotechnology agglomeration in an emerging country. At the emergence stage, knowledge-creation organizations play an important role to generate scientific research and train human resources. However, it is not clear that universities and PRC can play the role of anchor tenants. The lack of incentives to found science-based enterprises make unlikely that scientist working at those universities can establish biotechnology enterprises. In the case of entrepreneurship and attraction of other firms to the agglomerations, it is more likely to find medium and large enterprises in mature industries willing to adopt biotechnologies to improve their products and processes to remain in the market (i.e. rejuvenation) than new enterprises developing new biotechnology products to the world. These enterprises adopting biotechnologies implement **'imitation'** business models. Some scientists and non-scientists, however, can found small biotechnology enterprises. Some medium and large enterprises can establish formal collaborations with other agents like universities and other

[45] Information retrieved frowww.agrobiomexico.org.mx/documentos.htm (Accesed on 23 September 2011).

enterprises. In addition, the funding sources of biotechnology firms are most of the times family and friend; risk capitals (like VC and angels) are not present in the agglomeration. This situation is related to government support or institutional environment. In the emergence stage, government is trying to create organizations and design programs to encourage the adoption of modern biotechnologies and support the creation of new technology-based enterprises.

Table 9.3

Characteristics of biotechnology agglomerations in emerging countries

——— Time →

	Previous conditions	Emergence (Rejuvenation)
Knowledge-creating organizations	Support to new research centres	Heterogeneity of knowledge **Anchor tenant?**
Entrepreneurship and attraction of firms	In some sectors S&T capabilities	Medium and large firms **AT?** -Few R&D SME
Collaborations		-Informal collaborations **-Formal collaboration**
Funding		R&D tax credit/subsidies Private and family funds **NO VC**
Government support/ institutional environment		RSI 1st steps to improve the institutional environment -Dep. of economic development -Technology transfer offices and technology parks
Business models		IMITATIVE Few potential DBFs

CONCLUSIONS

This chapter presents the theoretical contributions of this thesis, its conclusions and implications for the STI policies for supporting the adoption and diffusion of biotechnologies in Mexico.

Back to the theory

Three different bodies of literature –strategic management, regional agglomerations and STI policies- were used to analyze how firms adopt generic technologies, such as biotechnologies, in institutional environments not well-developed such as Mexico. The following paragraphs summarize the theoretical value added of this thesis.

Business models

Business models are planning tools that involve the creation and capture of economic value (Magretta, 2002). External and internal elements affect the evolution and adaptation of business models. The external elements are related to the economic and institutional environments while the internal elements are tangible and intangible resources (Penrose 1959). In the last decade the concept of business model has been used extensively, however little theoretical research has been done to explain how the variety of elements influence the way in which the business model is designed (Onetti et al., 2010; Zott et al., 2011). Different authors have underlined the importance of strategy, financial structures, capabilities, collaborations, and location to formulate business models.

The resources view literature stresses the importance of internal resources as elements that distinguishes each firm (Penrose, 1959). The evolutionary economics view proposes that resources *per se* are not enough to generate competitive advantages. The repetition (through routines) and knowledge accumulation (Nelson and Winter, 1982) allows organizations to master specific activities, which are defined as

capabilities (Foss, 1996). According to these capabilities firms design their strategies to remain in the market (Nelson, 1991). In industries that rely strongly on scientific advances, firms often depend on collaborations with different organizations to obtain complementary capabilities and assets for creating and commercializing complex products and services (Powell et al., 1996).

Although biotechnologies can be applied to different industries, the pharmaceutical industry has been one of the most dynamic industry adopting modern biotechnologies (Pisano, 2006). Several authors have analyzed the biopharmaceutical sector in developed countries (Prevezer, 1997; Niosi, 2005; Cockburn and Stern, 2010). These studies have underlined that biotechnology firms in those countries have followed business models that are closely related to scientific research organizations. The founders of those firms are in most of the cases scientists who know the state-of-the-art of biotechnologies, have contacts with several funding organizations (private and state-owned) that support research activities and assist in the commercialization of biotechnology products. Based on these organizations and relationships, two well-defined business models have emerged: 1) classic biotechnology model and 2) large vertical integrated model (McKelvey, 2008). The first business model represents those biotechnology firms dedicated almost exclusively to R&D activities, while the second business model represents those firms that emerge from the classical model, and have integrated all the processes needed to create and commercialize biotechnology products (Pisano, 2006; McKelvey, 2008).

In this research, I have underlined the importance of three elements in the definition of business models in biotechnology enterprises: capabilities, collaborations, and institutional environment. Enterprises adopting biotechnologies in emerging countries face institutional obstacles and shortage of resources. Consequently, in emerging countries, other types of business models are appearing. For instance, I point out the existence of what I call an "**imitative business model**". Given the high risk involved

in the development of new biotechnology products, local enterprises seek at first, to adopt biotechnologies to imitate products that are already in the market. This imitation requires that local enterprises have some level of research, managerial and commercial capabilities to ensure the successful adoption of biotechnologies. In this sense, in emerging countries, medium and large enterprises with extensive experience seem to play **the role of entrepreneurs**. These firms have accumulated experience and resources that allow them to collaborate with other agents –at the national and international level. This collaboration is driven more by the urgency of large companies to remain in the market rather than by incentives generated by the institutional environment.

Geographical agglomerations

High technology enterprises tend to agglomerate in specific area or regions (Niosi, 2005). Biotechnology enterprises are not the exception, especially those involved in the human health sector. The reasons for these agglomerations are the positive externalities that enterprises can find in the region: qualified human resources, services, and funding (Prevezer, 1998; Niosi, 2005; Cockburn and Stern, 2010). Since the 1980s, several scholars have analyzed this phenomenon using different concepts. Three agglomeration concepts are relevant for this research: cluster, regional system of innovation, and anchor tenant. The concept of cluster identifies the actors within the agglomeration (Porter, 2000). The concept of RSI identifies the relationships between different actors in the region (Cooke and Morgan, 1998). Finally, the concept of anchor tenant identifies which organizations are the main attractors to the agglomeration (Agrawal and Cockburn, 2003; Feldman, 2003).

In the case of biotechnology, several authors have underlined the presence of different organizations and institutions that contribute to the creation and consolidation of biotechnology clusters in developed countries. These organizations

and institutions are: knowledge-creating organizations, DBFs, large firms, government agencies, government funds for scientific research, intellectual property laws, incentives to encourage entrepreneurship and attract venture capitalist, and collaborations between different actors. These organizations and institutions are different or non-existent in emerging countries, therefore, the dynamics of biotechnology agglomerations differ.

Some authors have mentioned that regional agglomerations follow a lifecycle that includes four stages: emergence, growth, sustainment and decline (Braunerhjelm and Feldman, 2006). Agglomerations following this lifecycle often rely only on one industry or similar industries. On the contrary, dynamics of agglomerations differ in the case several industries converge in the same geographic area: these agglomerations can rejuvenate due to the convergence of several high-technology industries (Menzel and Fornahl, 2009).

In the last two decades, emerging countries like China, India, and Brazil have implemented policies to create biotechnology agglomerations. These initiatives attempt to emulate prevalent conditions in developed countries (Prevezer, 2008). Therefore, these initiatives seek to create or attract all the actors involved in the creation and commercialization of biotechnology products. Some of the programs include the establishment of scientific and technological parks, and incubators. These initiatives require extensive government support, and most of the times the financial support falls short to accomplish the objectives. In addition, the periods of development of biotechnology products are long, especially in bio-pharmaceutics (12-15 years). Then, successful biotechnology agglomerations require large investments in infrastructure, creation of capabilities, and support for new enterprises with new biotechnology products. In this sense, agglomerations in emerging countries are not the same as those in developed countries.

I suggest that the rejuvenation in emerging countries is possible by the active participation not only of the government but the enterprises that aim at improving their products and processes to remain in the market. In this sense, entrepreneurship comes more from large, established enterprises –with products already in the market in sectors such as pharmaceutical, food processing, agriculture- rather than from biotechnology scientists working at universities and PRC. In addition, biotechnology agglomerations prosper in urban geographical areas, which host several industries – high-tech industries among them- and research universities. Often, such agents gather in these agglomerations for historical reasons even if most of the times these industries are not related with biotechnologies *per se*. Once interaction between enterprises and knowledge-creating organizations begin, probably universities will become anchor tenants for the creation of new biotechnology enterprises. In order to generate these DBFs, other organizations are needed to assist them.

However, in emerging countries like Mexico the creation of this kind of organization is hindered by the lack of institutional capabilities. In spite of this situation, medium and large enterprises that have accumulated research, managerial and commercial capabilities are able to establish collaboration agreements with national and international agents while SME, with less experience and resources, collaborate with national agents, mostly universities and PRC.

Public policy

The evolutionary economics approach suggests that the role of government is to create and diffuse technological knowledge, stimulate learning processes, and create and maintain a coherent institutional system through public policies (Dalum et al., 1992; Niosi and Bellon, 1995; Carlsson, 2006; Cimoli et al., 2009; Cockburn and Stern, 2010). The characteristics that influence the design and implementation of public policies are: the kind of policies (e.g. science, technology and innovation), the

scope (e.g. horizontal or vertical technology policies), the relationship with the environment (e.g. top-down and bottom-up), and the geographic scope (e.g. nation, region, sector) (Metcalfe, 1994; Dodgson and Bessant, 1996; Teubal, 1997; Tödtling and Trippl, 2005). Developed countries have implemented STI policies to encourage the creation and commercialization of new high technologies. Emerging countries, however, struggle to design and implement STI policies. According to the literature review, governments have to establish priorities in order to allocate resources effectively. In the case of biotechnologies, a first step is to establish the adoption of biotechnology as strategy for economic growth. Developed and emerging countries have established national programs of biotechnology to define the benefits of adopting biotechnology. Another important element is funding; biotechnologies require large investments, therefore, national resources should be allocated strategically in a few locations. Even in developed countries, there are few biotechnology agglomerations. Finally, governments may consider the attraction or creation of organizations and institutions needed to develop and commercialized biotechnology products.

Evidence from other emerging countries, where governments are willing to support the adoption of biotechnologies, shows that the process to create capabilities and institutional frameworks requires time and resources. Since the 1980s, the governments of the three countries presented in Chapter IX –China, India and Singapore- started to implement STI policies. However, in the cases of China and India the attempts to encourage the creation of organizations like DBF or technology parks, and new industries, for instance VC, have faced several obstacles. Also, collaboration between different organizations remains difficult to achieve.

It seems that a 'biotechnology plan' is an important step to define biotechnology as strategic generic technology for economic growth. However, at first, governments in emerging countries have to evaluate the creation of *ad hoc* institutions that assist the

emerging business models, and later, eventually, to create organizations and institutions to foster radical biotechnology innovations.

Implications for ST policy for adopting biotechnologies

Mexico could improve the adoption and diffusion of biotechnologies if the national government defines biotechnology as a strategic technology for economic growth, and establishes a National Program that sets the guidelines for the design and implementation of STI policies. In this sense, it seems crucial that the government evaluates the current situation of scientific biotechnology research and its real potential use by the industries that contribute to economic development. Once these elements are evaluated, government agencies could design programs that complement and enforce the lines suggested by the National Program of Biotechnology.

Another important element to be considered in the design of STI policies is regional agglomerations. The development of high technology agglomerations requires huge investments. Therefore, the Mexican government has to evaluate where the most salient research institutions already exist, and which kinds of enterprises are adopting modern biotechnologies in order to create appropriate organizations and institutions to foster innovation.

Finally, the collaboration and interaction of different organizations and institutions is crucial for the adoption of modern biotechnologies. Therefore STI policies for adopting biotechnologies have to emphasize the creation and implementation of mechanisms to encourage and facilitate networking. The examples of China and India show that establishing relationships between different organizations is not an easy task, even with the intervention of powerful and resourceful government agencies.

General conclusions

The general conclusion of this thesis is that business models appearing in emerging countries are different to those of developed countries.

Some emerging countries like Mexico, offer very few incentives to create DBF – SMEs dedicated mainly to R&D activities. Moreover, the opportunities for SMEs to become large enterprises based on the biotechnology products they have developed are almost non-existent (even in advanced countries). Therefore, large enterprises with experience, and managerial capabilities are more able to achieve the adoption of modern biotechnologies and the commercialization of biotechnology products.

There are some signs that allow thinking about a potential biotechnology agglomeration in the central region of Mexico (Mexico City and Morelos), which hosts high-level universities working on biotechnology research, and most of the SMEs and large enterprises that are adopting modern biotechnologies. There are other Mexican states that have also important research laboratories, but they do not have other organizations that can contribute for the creation of a biotechnology agglomeration. After the mid-2000s, SMEs and large enterprises started to establish collaboration agreements with agents, most of the times, located in the same region. Particularly, SMEs collaborate with national agents (most of the times knowledge creating organizations) while large enterprises have established collaborations with national and international partners.

Finally, government intervention seems mandatory to define and support the adoption of biotechnologies. The evidence of other emerging countries show that government should have a long-term vision that allows to devote resources to support knowledge creation, funding and improvement of institutional environments. However, the design and implementation of STI to adopt biotechnologies can be hindered by underdeveloped institutional capabilities. An emerging countries like Mexico, may seek to adopt a strategy for assisting the needs of business models that are appearing,

to learn and improve institutional capabilities.

Limitations and further research

The objective of this thesis was to analyze the adoption of a generic technology that can be applied to different industries, like biotechnology, in emerging countries. The main limitation was to identify biotechnology enterprises. In Mexico there is not an agency in charge of the collection of data of these enterprises and there are different sources with different information. As mentioned in Chapter VII, the report presented by the Ministry of Economy lists 306 biotechnology enterprises, which I preferred to mention them as "potential biotechnology-adopters", because it is not clear if they are actually using biotechnologies, particularly in the case of multinational companies (e.g. pharmaceuticals, grain-traders).

Another limitation, linked to the above issue, was the number and type of enterprises interviewed. Most of the enterprises were Mexican-owned. Thus, further research is needed to analyze other kinds of enterprises, for instance multinational corporations.

ANNEXES

ANNEX A

EMERGING COUNTRIES

There is not a clear definition of emerging countries. However, some authors have grouped emerging countries and coined terms like, BRIC (Brazil, Russia, India, and China), while a variety of agencies have proposed different lists of emerging countries that include: Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hong Kong, Hungary, India, Indonesia, Malaysia, Mexico, Morocco, Peru, Philippines, Poland, Saudi Arabia, Singapore, South Africa, South Korea, Russia, Taiwan, Thailand, and Turkey[46]. The table A.1 compares information about GDP, GDP per capita, and population of a list of developed countries and those that have been considered as emerging countries.

[46] For example, see S&P Global Broad Market Index Fact Sheet (Feb 15, 2011): https://www.sp-indexdata.com/idp/ViewPRCMethodologyHome.do?citiMethodology=citiGroupMethodology&indexId=2&prcId=0 (Accessed on 22 June 2011), see FTSE Country classification update (September 2010): http://www.ftse.com/Indices/Country_Classification/Downloads/Sept%202010/FTSE_Country_Classification_Sept_2010_Update.pdf (Accessed on 22 June 2011)

Table A.1

Leading and emerging economies

Country	GDP (PPP) USD billion (2010 est.)	GDP (PPP) per capita (2010 est.)	Population (July 2011 est.)
Leading economies			
USA	14,660	47,200	313,232,044
Japan	4,310	34,000	126,475,664
Germany	2,920	35,700	81,479,834
UK	2,173	34,800	62,689,362
Canada	1,359	39,100	34,030,589
Emerging economies			
China	10,090	7,600	1,336,718,015
India	4,060	3,500	1,189,172,906
Russia	2,223	15,900	138,739,892
Brazil	2,172	10,800	203,429,773
Mexico	1,567	13,900	113,724,226
South Korea	1,459	30,000	48,754,657
Indonesia	1,030	4,200	245,613,043
Turkey	961	12,300	78,785,548
Taiwan	822	35,700	23,071,779
Poland	721	18,800	38,441,588
Saudi Arabia	622	24,200	26,131,703
Argentina	596	14,700	41,769,726
Thailand	587	8,700	66,720,153
South Africa	524	10,700	49,004,031
Egypt	498	6,200	82,079,636
Colombia	435	9,800	44,725,543
Malaysia	414	14,700	28,728,607
Philippines	351	3,500	101,833,938
Hong Kong	326	45,900	7,122,508
Singapore	292	62,100	4,740,737
Peru	276	9,200	29,248,943
Czech Republic	261	25,600	10,190,213
Chile	258	15,400	16,888,760
Hungary	188	18,800	9,976,062
Morocco	151	4,800	31,968,361

Source: Central Intelligence Agency (2011)

ANNEX B

STRATEGIC MANAGEMENT

Strategy literature includes concepts and tools helping managers to deal with changes in markets (customer needs), institutional environments (regulations and policies) and technologies (information and communication technologies). For example, between the 1950's and the 1970's, strategy focus was on planning and managing portfolios of market-product to ensure long-term profitability (Ansoff, 1965; Andrews, 1971). In the 1980's, strategic though was focused on competition, how to find a competitive place in the market and within an industry to obtain superior profitability (Porter, 1980, 1985). Since the mid-1995, strategy authors have underlined the importance to react quickly to environment changes and maintain a competitive position (Brown and Eisenhardt, 1998). In the early 21th century, collaboration and rejuvenation of business models seem to be key elements to survive in a dynamic market place (Davenport et al., 2006; Johnson, 2010).

Table B.1

Technological revolutions and strategic management approaches

Technological revolution	New technologies and new or redefined industries	Strategic management approach	Dominant focus
From 1908 Age of oil, the automobile, and mass production	• Mass-produced automobiles • Cheap oil and oil fuels • Petrochemicals • Internal combustion engines • Home electrical appliances • Refrigerated and frozen food	**1950's-1960's** *Planning:* Business and budgetary planning	• Planning growth. • Capital and operational budgeting. • Financial control.
From 1971 Age of information and telecommunications	• Cheap microelectronics • Computers, software • Telecommunications • Control instrument • Computer-aided biotechnology and new materials	**1970's** *Balancing:* Optimizing corporate entities and functions.	• Balancing a portfolio of strategic business units/firms/products • Synergy of resources and functions.
		1980's *Positioning:* Industries, markets and firms adapting" and achieving unique "fit".	• Choosing industries and markets, and positioning within them • Adapting and fitting to the environment
		1990's *Resources and capabilities*: Resource-based view for competitive	• Sources of competitive advantage within the firm. • Responding to hyper-competition.
From 2003 Age of clean-tech and biotech	• Renewable energy • Energy storage technologies • Electric vehicles • Nano materials • Synthetic biology	**Early 21st century** *Organizational poise*: Value innovation through multiple business models.	• Innovations from collaborative business networks. • Portfolio of traditional and new business models • Corporate rejuvenation.

Source: Author, based on Davenport et al (2006: 170) and Johnson (2010: 96)

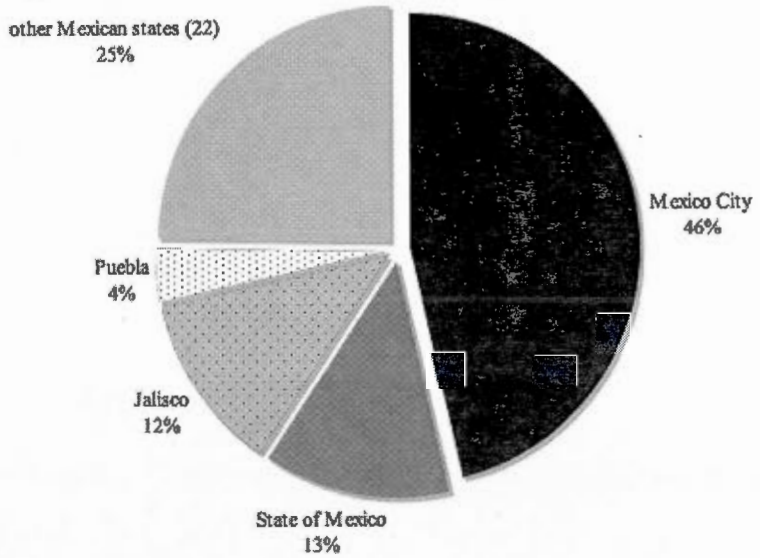
ANNEX C

BIOTECHNOLOGY ENTERPRISES IN MEXICO

In Augusts 2010 the Ministry of Economy (Secretaría de Economía) presented a study about the situation of biotechnology in Mexico. The Research Centre of Applied Biotechnology of the National Polytechnic Institute (CIBA-IPN in Spanish) was in charge to elaborate this study. This document list 306 'biotechnology' enterprises and includes national enterprises, subsidiaries of MNC, and state-owned enterprises. According to this study, these enterprises are located in 25 states and Mexico City (Figure C.1).

Figure C.1

Geographic distribution of potential biotechnology-using enterprises in Mexico (percentage)



Source: Own elaboration based on data from Secretaría de Economía (2010)

In this list the entities with more than 10 enterprises are: Mexico City (141), State of Mexico (40), Jalisco (37), and Puebla (11) (see Figure C.1 and Table C.1). Here it is important to mention that the some enterprises have commercial and distribution offices in Mexico City but their facilities for production and R&D could be located in other Mexican states. This fact may affect the number of enterprises.

Table C.1

Distribution of biotechnology firms in Mexico

	State	Number of enterprises
1	Aguascalientes	1
2	Baja California	2
3	Chiapas	2
4	Chihuahua	5
5	Coahuila	6
6	Durango	3
7	**State of Mexico**	**40**
8	Guanajuato	7
9	Hidalgo	2
10	**Jalisco**	**37**
11	**Mexico City**	**141**
12	Michoacán	5
13	Morelos	3
14	Nayarit	2
15	Nuevo León	9
16	Oaxaca	1
17	**Puebla**	**11**
18	Querétaro	4
19	Quintana Roo	1
20	San Luis Potosí	1
21	Sinaloa	5
22	Sonora	3
23	Tamaulipas	2
24	Tlaxcala	1
25	Veracruz	6
26	Zacatecas	1
	No defined	2
	Total	306

Source: Own elaboration based on data from Secretaría de Economía (2010)

These enterprises have activities in a variety of sectors. Table C.2 shows the number and percentage of enterprises according to the sector.

Table C.2

Number and percentage of (biotechnology) enterprises in different industries

Sector	Number	Percentage
Agriculture	66	22
Food Processing	36	12
Environment	16	5
Fermentation and biology products	23	8
Livestock	18	6
Pharmaceutical	119	39
Services	26	9
Total	304	100

Source: Own elaboration based on data from Secretaría de Economía (2010)

Here it is important to mention that not all these enterprises carry out biotechnology activities. For example, the study (Secretaría de Economía, 2010) lists 119 enterprises in the pharmaceutical sector: 28 multinational companies and 91 local companies. I searched on Internet if those multinational companies have biotechnology research activities. The results were that in some cases the MNEs mention that they have research activities, but they do not mention if these activities are related to biotechnologies. In the case of domestic enterprises, only a handful of them have biotechnology research activities.

Consequently, I searched for information of each enterprise on Internet, and when possible, obtain information about the products and technologies used. The objective of this search was to verify if the enterprises have scientific activities as we can find in biotechnology enterprises located in developed countries or other emerging countries like China and India.

ANNEX D

QUESTIONNAIRE FOR ENTERPRISES AND RESEARCH CENTRES

(ENGLISH)

UNIVERSITÉ DU QUÉBEC À MONTRÉAL
DEPARTMENT OF MANAGEMENT AND TECHNOLOGY

CANADA RESEARCH CHAIR ON THE MANAGEMENT OF TECHNOLOGY

RESEARCH TEAM:
Jorge Niosi, Ph.D. (professor and research director)
Julieta Flores Amador (Ph.D. student)

"QUESTIONNAIRE ABOUT THE ACTIVITIES AND CHARACTERISTICS OF ENTERPRISES USING AND DEVELOPING BIOTECHNOLOGIES IN MEXICO"

Statement of confidentiality

All responses to this questionnaire will be kept confidential and secure. They will be made available only to the research team, al of who will be bound by this statement of confidentiality. All reports arising from this research will refer to aggregate statistics and will not refer to any company by name, product or people.

I agree to abide by the above Statement of confidentiality _____
Interviewer signature on behalf of the entire research team

I have read and agree with the above Statement of confidentiality_____
Respondent signature on behalf of the company

Note. The interviewer is free to sign any non-disclosure agreement the respondent finds appropriate, and the signature of the interviewer on such as agreement will bind the entire research team to its terms and conditions.

Questionnaire

Name of person completing the questionnaire and title:

.....

Phone (s).....

E-mail (s).....

Fax (s) .....

Web address.....

Section 1: Biotechnologies in use (use the table provided)

This section measures the use of biotechnologies in your firm

Biotechnologies	Currently used	If currently used, you use them for			# years in use
		Product/process development	Current production	Environmental purposes	
DNA-The coding	Yes.... No....				
Proteins and molecules- The functional blocks	Yes.... No....				
Cell and tissue culture and engineering	Yes.... No....				
Process biotechnologies	Yes.... No....				
Sub-cellular organisms	Yes.... No....				
Other (i.e. bio-informatics)	Yes.... No....				
Nano-biotechnologies	Yes.... No....				
Environmental biotechnology	Yes.... No....				
Other (please specify)	Yes.... No....				

Section 2: Human resources in biotechnology

Number of biotechnology employees

2. a) How many employees did your firm employ in this country in 2008?.....
   b) How many employees had biotechnology-related responsibilities in 2008?.....
   c) Employees with full time biotechnology responsibilities in this site.....

Position	Number of full-time employees in biotechnology
Scientific Direction/Research	
Technicians	
Regulatory/Clinical Affairs	
Production	
Finance/Marketing/Business Development	
Administrative Management	
Other, please specify	
Total employees with full-time biotechnology responsibilities	

d) Employees with part-time biotechnology responsibilities

For each group listed below indicate how many are employees with part-time biotechnology responsibilities (less than 50% of their time spent on biotechnology-related activities)? If an employee fulfills more than one duty, report their primary responsibility. Count each person only once. Please report typical employment level for 2008 in full-time equivalents (FTE).

Position	Number of part-time employees
Scientific Direction/Research	
Technicians	
Regulatory/Clinical Affairs	
Production	
Finance/Marketing/Business Development	
Administrative Management	
Other, please specify	
Total employees with part-time biotechnology responsibilities	

e) Total Number of biotechnology employees.

Total employees with full-time and part-time biotechnology-related responsibilities

---

Recruiting and Staffing Practices

3. a) Does your firm have unfilled biotechnology-related positions?
No: Go to question 3 b)
Yes: In the table below indicate the number of unfilled positions by category:

Position	Number of unfilled positions
Scientific Direction/Research	
Technicians	
Regulatory/Clinical Affairs	
Production	
Finance/Marketing/Business Development	
Administrative Management	
Other, please specify	

b) Does your firm have a formal program to train and develop personnel for internal promotions to senior positions?
No
Yes

c) Did your firm attempt to recruit any biotechnology employees in 2008
No… ➔Go to question 4a
Yes…➔ Were you successful? No…➔ Go to question 3d
Yes…➔How many did you hire?

d) Did you attempt to hire biotechnology staff residing outside of this country in 2008?
No…
Yes…➔ In the table below indicate the number of biotechnology staff hired from each region.

Region	Repatriation	International hiring	Total
USA			
Canada			
Europe			
China			
India			
Asia (other than China or India)			
Other (please specify)			

Total employees hired abroad			

4. a) Did any biotechnology personnel leave the firm in 2008?
No… ➔Go to question 5
Yes…➔How many?

b) What % of those who left in 2008 was your firm's decision?.....

Section 3 - Firm history

5. a) What year was your company established? .....

b) What were the motives to establish the company in this location?
.....
.....
.....

c) what are the specific advantages that the company has in this location?

Advantages		YES	NO
Close to	Universities/research centres		
	Hospitals		
	Important suppliers		
	Important clients		
Access to specialized/qualified human resources			
Infrastructure (transport, communications)			
Access to financial support			
Government incentives	Policies		
	Funds		
Other (please specify)			

6. Is your firm a public firm?
No… ➔Go to question 8
Yes…➔ What year was the Initial public offering (IPO)?

7. a) Has your firm merged with another firm?
No… ➔Go to question 8
Yes…➔What year did the merger take place?

b) What was the reason for the merger?
.....

.....

8. a) Is your firm a domestically owned company?
No… ➔Go to question 10
Yes…➔

b) Does you firm have branches outside this country?
No…
Yes…➔Does your firm conduct R&D outside this country?
No… Yes…

9. Is you firm a spin-off? (A spin-off is defined as a new firm created to commercialize technology developed in universities, public laboratories or other firms?
No… ➔Go to question 10
Yes…➔Was your firm a spin-off from:

- University/hospital
- Another biotechnology company
- Non-biotechnology firm
- Government agency or laboratory
- Other, please specify

Section 4: Innovative biotechnology products

This section measures the development of new biotechnology products and processes by your firm.

10. a) Do you have products/processes on the market that require the use of biotechnology?
Yes… No…

b) Is your firm currently developing products that require the use of biotechnology?
Yes… No…

c) Is your firm currently developing processes that require the use of biotechnology?
Yes… No…

d) Do you consider biotechnology central to your firm's activities or strategies?
Yes… No…

11. a) In the table below, please indicate the number of biotechnology products or processes your firm currently has for each stage of development in the Human Health Sector. If it is "0" (zero) please indicate "0".

Biotechnology sector	Number of biotechnology products/processes by development stage					
	R&D	Pre-clinical trials	Clinical phase 1	Clinical phase 2	Clinical phase 3	Approved/ On market/ Production
Human health						
Diagnostics						
Therapeutics						
Drug delivery						

b) In the table below, for each sector listed please indicate the number of biotechnology products or processes your firm currently has for each stage of development. If it is "0" (zero) indicate "0".

Biotechnology sector	Number of biotechnology products/processes by development stage			
	R&D	Pre-clinical trials Field trials Pre-market	Regulatory phase Release assessment Final pre-market assessment	Approved/ On market/ Production
Agriculture biotechnology				
Plant biotechnology				
Animal biotechnology				
Non food agriculture for industrial uses				
Non food agriculture for medical uses				
Natural resources				
Energy				
Mining				
Forest products				
Environment				
Air				
Water				
Soil				
Aquaculture				
Fish health, genetics				
Bioinformatics				
Genomics and				

molecular modeling				
Gene therapy				
Food processing				
Bio processing				
Functional food/neutraceuticals				
Other (specify)				

Section 5: Biotechnology Products Regulations

12. a) In 2008, did you have biotechnology products/processes in any stage of R&D but not yet on the market?
No....➔Go to question 13
Yes...➔Go to question 12 b

b) Of the biotechnology products or processes your firm had in research and development stages (not yet on market) in 2008, how many require formal regulatory evaluation and/or approval by national regulatory authorities?
Number.....

c) In 2005, for your principal biotechnology product, what is the total duration of its regulatory process to date (in
months)?.....
d) What was your last year expenditure in
R&D?.....
e) What was your last year expenditure in
regulation?.....

13. Did you experience any problems in the regulatory process, such as:
Cost Yes..... No.....
Speed Yes..... No.....
Norms Yes..... No.....
Other Yes..... No.....

14. a) Did your firm contract out biotechnology related activities in 2008?

Organization	Number of contracts
University/hospital	
Government Lab	
Other biotechnology firm	
Other, please specify	
Total	

b) Did your firm provide contract services to other firms or organizations?
No…➔Go to question 15
Yes…➔For each type of contract please provide number and revenues

Organization	Number of contracts
Other biotechnology firm	
Pharmaceutical firm	
Form other than biotechnology or pharmaceutical	
Government Lab	
University/hospital	
Other, please specify	
Total	

Collaborative arrangements

Cooperative and collaborative arrangements involve the active participation in projects between your company and other companies or organizations in order to develop and/or continue work on new or significantly improved biotechnology processes, products and/or services. Pure contracting-out work is not regarded as collaboration.

15. a) Was your firm involved in biotechnology-related cooperative/collaborative arrangements with other companies or organizations in 2005? *(Please include both those inside and outside the country)*
No… ➔Go to question 16
Yes…➔Provide the number of arrangements by purpose and partner type

Arrangement purpose	Number of arrangements by partner type				
	Biotech firm	Pharma firm	Firm other than biotech or pharmaceutical	Academic institution/ hospital	Government lab or agency
To conduct R&D					
Regulatory affairs					
Access to others' patents					
Production/ Manufacturing					
Access markets					
Access Capital					

Access intellectual property					
Access others' knowledge/ skills					
Lower expenses					
Other, please specify					

b) In 2005, was your firm involved in biotechnology related cooperative/collaborative arrangements with other foreign companies or organizations *(located outside of the country)*?
No… ➔Go to question 16
Yes…➔In the table below, check collaboration/cooperation arrangements by each type and their
geographic location:

Partner type	USA	Europe	Canada	China	India	Other
Biotechnology firm						
Pharmaceutical firm						
Form other than biotechnology or pharmaceutical						
Government Lab						
University/hospital						
Other, please specify						

c) Rate the following purposes in your decision to form collaborative/cooperative arrangements with a foreign partner *(located abroad). Rank the three most important*

Arrangement purpose	Rank
To conduct R&D	
Regulatory affairs	
Access to others' patents	
Production/ Manufacturing	
Access markets	
Access Capital	
Access intellectual property	
Access others' knowledge/ skills	

Intellectual property

16 a) Does your firm have biotechnology related patents or pending patents?
No… ➔Go to question 16 d
Yes…➔How many? Indicate the distribution of biotechnology related patents and pending patents your firm has by Patent Office:

	Domestic	USPTO	European	Other
Existing patents				
Pending patents				
Expired patents				

16 b) Does your firm have biotechnology related trademarks?
No… ➔Go to question 17
Yes… ➔How many?

17. a) Did your firm assign or license biotechnology related intellectual property (IP) rights to another firm?
No… ➔Go to question 17 b
Yes… ➔For each type of IP instrument listed below, please indicate the number of IP rights granted by country.

IP instrument	Number domestic Firms	Number US firms	Number European firms	Number other firms
Licensing agreement				
Patent assignment				
Technology transfer agreement				
Other, please specify				

17 b) Did your firm acquire biotechnology related intellectual property rights from another firm?
No… ➔Go to question 18
Yes… ➔For each type of IP instrument listed below, please indicate the number of IP rights obtained by country.

IP instrument	Number domestic Firms	Number US firms	Number European firms	Number other firms
Licensing agreement				
Patent assignment				
Technology transfer agreement				
Other, please specify				

Section 6- Firm characteristics and financial profile

18. Please complete the following table. If information is not available please provide a carefully considered estimate in US$.

	2007	2008	2009 forecast
Total firm revenues (all sources)			
% revenues from biotechnology			
Total R&D spending			
% of R&D spending on biotechnology			

Financing activities

19. a) Did your firm attempt to raise capital for biotechnology related purposes in 2008?

No➔Why not?.....

.

Go to question 19e

Yes ➔Why did you attempt to raise capital? (Please check all responses that apply)

R&D Purposes
Production
Commercialize products
Clinical regulatory expenses

19 b) Were you successful in raising capital?

○ No➔ Go to question 19d

Yes➔ How much capital did you raise in 2008?

19 c) Did you reach your target?
No➔ Go to question 19 d
Yes➔ Go to question 19 e

19 d) What reasons did the lender/provider give in limiting the funds or refusing your request for capital?

.....
.....

19 e) What sources provided funding in the past?

Source	%
Domestic venture capital	
US venture capital	
European venture capital	
Venture capital from other countries	
Debt capital (i.e. banks)	
Angel investors/ family	
Government	
Private placement	
Initial private offering (IPO)	
Alliances	
Total	

20. Did your firm apply for tax credits for R&D?
No➔ Why not?
Yes

21. Did your firm export biotechnology products in 2008?
No➔ Go to question 22
Yes➔ Please check if exports to
US
Europe
Latin America
Japan
China
Other (please specify)

22. a) Did your firm import biotechnology products in 2008?

No➔ Go to question 23
Yes➔ Please check if imports from
US
Europe
Latin America
Japan
China
Other (please specify)

b) In 2008, what were the main intended end-uses of the biotech products imported by your firm? (Please indicate "yes" or "no")
End use
Resale as final product
Use as intermediary product or raw material in
- Seeding and planting
- Feed/food use
- Veterinary biologics
- Drug/pharmaceutical
- Other please specify

Section 7: Strategies used in 2008

23. Please indicate the significance of each of the following firm's strategies in the firm performance in 2008, by "yes" or "no".

Knowledge development strategies

	Yes	No
Captured and used knowledge obtained from other industry sources such as industry associations, competitors, clients and suppliers	☐	☐
Captured and used knowledge obtained from public research Institutions including universities and government laboratories	☐	☐
Developed new knowledge through collaborative agreements With other firms or organizations	☐	☐
Used and updated databases of scientific information	☐	☐
Developed firm policies and practices for IP protection	☐	☐

Developed or encouraged staff education /upgrading	☐	☐
Conducted an IP audit to ensure protection of products and processes at all stages of development	☐	☐
Used IP to signal competency	☐	☐
Business strategies		
Increased firm size through acquisition, merger or joint venture	☐	☐
Downsized operations of the firm	☐	☐
Provided products or services to other firms based on interim or incremental R&D discoveries to generate revenue flow	☐	☐
Entered product trials/adapted products or processes for increased market penetration	☐	☐
Began new research & development project	☐	☐
Expanded into foreign markets	☐	☐

Other, please specify.....

24. What are the plans for the company in the next five years?

.....

.....

.....

.....

.....

Thank you

ANNEX E

QUESTIONNAIRE FOR ENTERPRISES AND RESEARCH CENTRES

(SPANISH)

UNIVERSITÉ DU QUÉBEC À MONTRÉAL
DEPARTMENT OF MANAGEMENT AND TECHNOLOGY

CANADA RESEARCH CHAIR ON MANAGEMENT OF TECHNOLOGY

RESEARCH TEAM:
Jorge Niosi, Ph.D. (professor and research director)
Julieta Flores Amador (Ph.D. student)

"CUESTIONARIO ACERCA DE LAS ACTIVIDADES Y CARACTERÍSTICAS DE LAS EMPRESAS QUE UTILIZAN Y DESARROLLAN BIOTECNOLOGÍAS EN MÉXICO"

Cláusula de Confidencialidad

Todas las respuestas de este cuestionation setán manejadas de forma confidencial y segura sólo el quipo de investigación tendrá acceso a ellas, y se compromete a respetar esta cláusula de confidencialidad. Todos los reportes surgidos de este trabajo de investigación mostrarán estadísticas agregadas y no harán referencia a ninguna empresa por su nombre, productos o personas.

Me comprometo a respetar esta cláusula de confidencialidad_____
Firma del entrevistador en nombre de todo el equipo de investigación

He leído la cláusula de confidencialidad y estoy de acuerdo con ella_____
Firma del entrevistado en nombre de su empresa

Nota. El entrevistador tiene la facultad de firmar cualquier acuerdo de confidencialidad que el entrevistado juzgue pertinente, y la firma del entrevistador compromete a todo el equipo de investigación a respetar los términos y condiciones de dicho acuerdo.

Nombre de la persona que completa el cuestionario y su puesto

_____

Teléfono(s)_____

Correo(s) electrónico(s)_____

Fax_____

Sitio web_____

Sección 1: Biotecnologías en uso (use la siguiente tabla)

1. Esta sección mide el uso de biotecnologías en la empresa

Biotecnologías	Usadas actualmente	Si las usa actualmente, éstas son usadas para			Número de años en uso
		Desarrollo de Producto/proceso	Producción actual	Propósitos ambientales	
ADN- Codificación	Si.... No....				
Proteínas y moléculas- Los bloques funcionales	Si.... No....				
Cultivo celular / Cultivo e ingeniería de tejidos	Si.... No....				
Biotecnologías de procesos	Si.... No....				
Organismos Sub-celulares	Si.... No....				
Otros (ej.bio-informática)	Si.... No....				
Nanobiotecnologías	Si.... No....				
Biotecnología ambiental	Si.... No....				
Otro (por favor especifique)	Si.... No....				

Sección 2: Recursos humanos en biotecnología

2. Número de empleados en biotecnología

a) ¿Cuántos empleados laboraron en la empresa en el país en 2008?.....

b) ¿Cuántos empleados tuvieron responsabilidades relacionadas con biotecnología en 2008?.....

c) Empleados dedicados tiempo completo a responsabilidades en biotecnología en esta planta.....

Puesto	Número de empleados dedicados exclusivamente a actividades de biotecnología
Dirección científica/Investigación	
Técnicos	
Asuntos de regulación/clínicos	
Producción	
Finanzas/Mercadotecnia/Desarrollo de negocios	
Gestión Administrativa	
Otro, por favor especifique	
Total de empleados dedicados exclusivamente a responsabilidades de biotecnología	

d) Empleados dedicados tiempo parcial a responsabilidades en biotecnología

Para cada grupo enlistado abajo indique ¿cuántos empleados dedicados tiempo parcial tienen responsabilidades relacionadas con biotecnología (es decir, menos del 50% de su tiempo es dedicado a actividades relacionadas con biotecnología)? *Si un empleado cubre más de un deber, reporte su responsabilidad principal. Cuente cada persona solamente una vez.*

Puesto	Número de empleados dedicados tiempo parcial a actividades de biotecnología
Dirección científica/Investigación	
Técnicos	
Asuntos de regulación/clínicos	
Producción	
Finanzas/Mercadotecnia/Desarrollo de negocios	
Gestión Administrativa	
Otro, por favor especifique	
Total de empleados dedicados parcialmente a responsabilidades en biotecnología	

e) Número total de empleados en biotecnología.
Total de empleados de tiempo completo y tiempo parcial con responsabilidades relacionadas con biotecnología

---

3. Reclutamiento y prácticas de selección
a) ¿La empresa tiene vacante algún puesto relacionado con biotecnología?
No....➔Pase a la pregunta 3b)
Si.....➔ En la siguiente tabla indique el número de puestos libres de acuerdo a su categoria:

Puesto	Número de puestos vacantes
Dirección científica/Investigación	
Técnicos	
Asuntos de regulación/clínicos	
Producción	
Finanzas/Mercadotecnia/Desarrollo de negocios	
Gestión Administrativa	
Otro, por favor especifique	
Total de puestos vacantes	

b) ¿La empresa tiene un programa formal para capacitar y desarrollar al personal para promociones internas hacia altos puestos (senior)?
No...
Si....

c) ¿Su empresa intentó reclutar algún empledo en biotecnología en 2008?
No… ➔Pase a la pregunta 4a)
Si…..➔ ¿Tuvo éxito? No…➔ Pase a la pregunta 3d)
Si…..➔¿Cuántas personas contrató?.....

d) ¿Intentó contratar personal de biotecnología residiendo fuera de este país en 2008?
No…
Si…..➔ En la tabla siguiente indique el número de empleados en biotecnología contratados por cada región

Región	Repatriación	Contratación internacional	Total
Estados Unidos			
Canadá			
Europa			
China			
India			
Asia (otro además de China o India)			
Otro (por favor especifique)			
Total de empleados contratados del exterior			

4. a) ¿Alguien de su personal de biotecnología dejó la empresa en 2008?
No… ➔Pase a la pregunta 5
Si…..➔¿Cuántos?.....

b) ¿Qué porcentaje de aquellos que se fueron en 2008 se debió a la decisión de la empresa?.....

Sección 3 – Historia de la empresa

5.a) ¿En qué año fue establecida la compañía?.....
b) ¿Cuáles fueron los motivos para establecerse en esta localidad?.....
.....
c) ¿Cuáles son las ventajas específicas que tiene la empresa al ubicarse en esta localidad?

Ventajas		SI	NO
Cercanía con	Universidad/centros de investigación		
	Hospitales		
	Importantes proveedores		
	Importantes clientes		
Acceso a personal especilizado/calificado			
Infraestructura física (transporte, comunicaciones)			
Ventajas financieras			
Incentivos gubernamentales	Políticas		
	Fondos		
Otros (por favor especifique)			

6. ¿La empresa es una empresa pública?
No… ➔Pase a la pregunta 8a)
Si……➔ ¿En qué año fue la Oferta Pública de Venta (OPV)?.....

7. a) ¿Su empresa se ha fusionado con alguna otra empresa?
No… ➔Pase a la pregunta 8a)
Si.....➔¿En qué año tomó lugar la fusión?.....

b) ¿Cuáles fueron las razones de la fusion?.....
.....

8. a) ¿Es la empresa una compañía de capital nacional?
No… ➔Pase a la pregunta 10a)
Si.....➔

b) ¿La empresa tiene sucursales fuera del país?
No…
Si....➔¿La empresa realiza actividades de I+D fuera del país?
No… Si…

9. ¿La empresa es un spin-off (desprendimiento)? *(Un spin-off es definido como una nueva empresa creada para comercializar tecnología desarrollada en universidades, laboratorios públicos u otras empresas)*
No… ➔Pase a la pregunta 10a)
Si.....➔La empresa fue un spin-off de:

- Universidad/Hospital
- Otra compañía de biotecnología
- Empresa no biotecnológica
- Agencia o Laboratorio gubernamental

- Otro, por favor especifique

Sección 4: Productos biotecnológicos innovadores

Esta sección mide el desarrollo de nuevos productos y procesos biotecnológicos de la empresa.

10. a) ¿La empresa tiene productos/procesos en el mercado que requieren el uso de biotecnologías?
Si..... No...

b) ¿Actualmente la empresa está desarrollando productos que requieren el uso de biotecnologías?
Si..... No...

c) ¿Actualmente la empresa está desarrollando procesos que requieren el uso de biotecnologías?
Si..... No...

d) ¿Considera usted que la biotecnología es central para las actividades y estrategias de la empresa?
Si..... No...

11. a) En la tabla siguiente, por favor indique el número de productos o procesos que la empresa actualmente tiene para cada etapa de desarrollo en el sector de Salud Humana. Si éste es "0" (cero) por favor indique "0".

Sector de Biotecnología	Número de productos/procesos biotecnológicos por etapa de desarrollo					
	I+D	Ensayos Pre-clínicos	Fase clínica 1	Fase clínica 2	Fase clínica 3	Aprobado/ En mercado/ Producción
Salud Humana						
Diagnósticos						
Terapéuticos						
Administración de fármacos						

b) En la tabla siguiente, para cada sector enlistado, por favor indique el número de productos o procesos que la empresa actualmente tiene para cada etapa de desarrollo.

Si éste es "0" (cero), por favor indique "0".

Sector de Biotecnología	Número de productos/procesos biotecnológicos por etapa de desarrollo			
	I+D	Ensayos Pre-clínicos/ Ensayos de campo/ Pre-mercado	Fase reguladora/ Evaluación de lanzamiento/ Evaluación final de pre-mercado	Aprobado/ En mercado/ Producción
Biotecnología Agrícola				
Biotecnología de plantas				
Biotecnología animal				
Agricultura para uso industrial, no para alimento				
Agricultura para usos médicos, no para alimento				
Recursos Naturales				
Energía				
Minería				
Productos forestales				
Ambiente				
Aire				
Agua				
Suelo				
Acuacultura				
Salud de peces, genética				
Bioinformática				
Genómica y modelización molecular				
Terapia génica				
Procesamiento de alimentos				
Bioprocesos				
Alimentos funcionales/ nutracéuticos				
Otro (especifique)				

Sección 5: Regulaciones de productos biotecnológicos

12. a) En 2008, ¿la empresa tuvo productos/procesos biotecnológicos en alguna etapa de I+D, pero no aún en el mercado?
No....→Pase a la pregunta 13
Si.....→Pase a la pregunta 12b)

b) De los productos o procesos de biotecnología que la empresa tuvo en la etapa de I+D (no aún en el mercado) en 2008, ¿cuántos requerían la evaluación y/o la aprobación formal de autoridades reguladoras nacionales? Número.....

c) En 2005, para su principal producto biotecnológico, ¿cuál es la duración total de su proceso regulador hasta la fecha (en meses)?
.....
d) ¿Cuál fue el gasto de I+D en el año pasado?
.....
e) ¿Cuál fue el gasto en regulaciones del año pasado?
.....

13. La empresa ha experimentado algún problema en el proceso de regulación, tal como
Costo Si..... No.....
Tiempo Si..... No.....
Normas Si..... No.....
Otro Si..... No.....

14. a) ¿La empresa contrató actividades relacionadas con biotecnología en 2008?
No....→Pase a la pregunta 14b)
Si .....

Organización	Número de contratos
Universidad/Hospital	
Laboratorio gubernamental	
Otra empresa de biotecnología	
Otro, por favor especifique	
Total	

b) ¿La empresa fue contratada por otras empresas u organizaciones para proveer algún sevicio biotecnológico en 2008?
No...→Pase a la pregunta 15a)
Si....→Para cada tipo de contrato, por favor mencione el número e ingresos

Organización	Número de contratos	Ingresos
Otra empresa biotecnológica		
Empresa farmacéutica		
Otra empresa, no biotecnológica o farmacéutica		
Laboratorio gubernamental		
Universidad/hospital		
Otro, por favor especifique		
Total		

Acuerdos de colaboración

Acuerdos de Cooperación y Colaboración incluyen la participación activa en proyectos entre esta empresa y otras empresas u organzaciones para desarrollar y/o continuar trabajando sobre nuevos, o significativas mejoras a, procesos, productos o servicios biotecnológicos. Contratos que no incluyen el trabajo conjunto no son vistos como colaboración.

15. a) ¿La empresa tuvo acuerdos de cooperación/colaboración relacionados con biotecnología con otras compañías u organizaciones en 2005? (*Por favor mencione ambos, dentro y fuera del país*)
No… ➔Pase a la pregunta 16a)
Si…..➔Mencione el número de acuerdos por propósito y tipo de socio

Propósito del acuerdo	Número de acuerdos por tipo de socio				
	Empresa biotecno-lógica	Empresa farmacéutica	Otra empresa, no biotecnológica o farmacéutica	Institución académica/ hospital	Laboratorio o agencia guberna-mental
Para realizar I+D					
Asuntos regulatorios					
Acceso a las patentes de otros					
Producción/ Manufactura					
Acceso a mercados					
Acceso a capital					
Acceso a propiedad intelectual					
Acceso a conocimiento/ habilidades de otros					
Disminuir costos					
Otro, por favor especifique					

b) En 2005, la empresa tuvo acuerdos de cooperación/colaboracción relacionados con biotecnología con otras compañías u organizaciones extranjeras (*Localizadas fuera del país*)?
No... ➔Pase a la pregunta 16a)
Yes...➔En la tabla siguiente, marque los acuerdos de cooperación/colaboración por cada tipo y su localización geográfica:

Tipo de socio	E.U.	Europa	Canada	China	India	Otro
Empresa de Biotecnología						
Empresa Farmacéutica						
Otra Empresa, no biotecnológica o farmacéutica						
Laboratorio gubernamental						
Universidad/hospital						
Otro, por favor especifique						

d) Ordene los siguientes propósitos que influyeron su decisión para establecer acuerdos de cooperación/colaboración con socios extranjeros *(localizados en el extranjero)*. Ordene los tres más importantes

Propósitos del acuerdo	Orden
Para realizar I+D	
Asuntos regulatorios	
Acceso a patentes de otros	
Producción/ Manufactura	
Acceso a mercados	
Acceso a capital	
Acceso a propiedad intelectual	
Acceso al conocimiento/habilidades de otros	

Propiedad Intelectual
16. a) Su empresa tiene patentes o patentes pendientes relacionadas con biotecnología?
No... ➔Pase a la pregunta 16b)
Si .....➔¿Cuántas? .....

Indique la distribución de patentes o patentes pendientes relacionadas con biotecnología que su empresa tiene por Oficina de Patentes

	Nacional (IMPI)	USPTO	Europa	Otra
Patentes existentes				
Patentes pendientes				
Patentes expiradas				

16. b) La empresa tiene marcas registradas relacionadas con biotecnología?
No… ➔Pase a la pregunta 17a)
Si…… ➔¿Cuántas?.....

17. a) La empresa asignó o licenció derechos de propiedad intellectual (PI) a otra empresa?
No… ➔Pase a la pregunta 17b)
Si..... ➔Para cada tipo de instrumento de PI listado abajo, por favor indique el número de derechos de PI otorgados/asigandos por país.

Instrumento de PI	Número de empresas nacionales	Número de empresas en E.U.	Número de empresas en Europa	Número de otras empresas
Acuerdo de licenciamiento				
Cesión de patente				
Acuerdo de transferencia de tecnología				
Otro, por favor especifique				

17 b) La empresa adquirió derechos de PI de biotecnolgía de otra empresa?
No… ➔Pase a la pregunta 18
Si..... ➔Para cada tipo de instrumento de PI listado abajo, por favor indique el número de derechos de PI obtenidos por país.

Instrumento de IP	Número de empresas nacionales	Número de empresas en E.U.	Número de empresas en Europa	Número de otras empresas
Acuerdo de licenciamiento				
Cesión de patente				
Acuerdo de transferencia de tecnología				
Otro, por favor especifique				

Sección 6 - Características de la empresa y perfil de financiamiento

18. Por favor complete la siguiente tabla. Si la información no está disponible mencione un estimado considerado cuidadosamente en dólares americanos (USD).

	2007	2008	2009 pronóstico
Ingresos totales de la empresa (todas las fuentes)			
% de ingresos de biotecnología			
Gasto total en I+D			
% de gasto de I+D en biotecnología			

Actividades financieras

19. a) ¿La empresa intentó obtener capital para propósitos relacionados con biotecnología en 2008?

No➔¿Por qué no?.....

Pase a la pregunta 19e)

Si ➔¿Por qué intentó obtener el capital? (Por favor marque todas las opciones que apliquen)

- Propósitos de I+D
- Producción
- Comercialización de productos
- Gastos en regulaciones clínicas
- Otro

19 b) ¿Logró obtener el capital?

No..➔ Pase a la pregunta 19d)

Si... ➔ ¿Cuánto capital obtuvo en 2008?.....

19 c) ¿Se alcanzó el objetivo?

No..➔ Pase a la pregunta 19 d)

Si... ➔ Pase a la pregunta 19 e)

19 d) ¿Qué razones tuvo el prestamista/proveedor para limitar los fondos o rechazar la solicitud de capital?

.....

.....

19 e) ¿Cuáles fueron sus fuentes de financiamiento en el pasado?

Fuente	%
Capital de riesgo nacional	
Capital de riesgo de E.U.	
Capital de riesgo de Europa	
Capital de riesgo de otros países	
Capital de deuda (i.e. bancos)	
Inversionistas Angel/Familia/Amigos	
Gobierno	
Colocación privada	
Oferta Pública de Venta (OPV)	
Alianzas	
Total	

20. ¿La empresa postuló para la obtención de créditos fiscales para I+D?
No...➔ Por qué
no?.....
Si...

21. ¿La empresa exportó productos biotecnológicos en 2008?
No...➔ Pase a la pregunta 22a)
Si ....➔ Por favor marque si las exportaciones son dirigidas a

- E.U.
- Europa
- América Latina
- Japón
- China
- Otro (por favor especifique)

22. a) La empresa importó productos biotecnológicos en 2008?
No...➔ Pase a la pregunta 23
Si....➔ Por favor marque si las importaciones provienen de

- E.U.
- Europa
- América Latina
- Japón
- China
- Otro (por favor especifique)

b) En 2008, ¿cuáles fueron los principales usos finales de los productos

biotecnológicos que importó la empresa? (Por favor indique "si" o "no")

Uso Final	SI	NO
Reventa como producto final		
Uso como producto intermediario o material prima en		
Semillas y plantas		
Uso en alimentos/comida		
Veterinarios biológicos		
Medicinas/farmacéutica		
Otro, por favor especifique		

Sección 7: Estrategias usadas en 2008

23. Por favor indique la importancia de cada una de las siguientes estrategias en el desempeño de la empresa en 2008, diga "si" o "no".

	Si	No
Estrategias de desarrollo de conocimiento		
Utilizó conocimiento obtenido de otras fuentes industriales tales como asociaciones industriales, competidores, clientes y proveedores.	☐	☐
Utilizó conocimiento obtenido de instituciones públicas de investigación incluyendo universidades y laboratorios gubernamentales.	☐	☐
Desarrolló nuevo conocimiento a través de acuerdos de colaboración con otras empresas u organizaciones.	☐	☐
Usó y actualizó bases de datos de información científica.	☐	☐
Desarrolló políticas y practicas para la protección de la PI.	☐	☐
Desarrolló o incentivó la educación/actualización de los empleados.	☐	☐
Condujo una auditoria de PI para asegurar la protección de productos y procesos en todas las etapas de desarrollo.	☐	☐
Usó PI para mostrarse competente/crear una imagen competitiva	☐	☐

Estrategias de negocio

Incrementó el tamaño de la empresa a través de adquisiciones, fusiones, o joint ventures (alianza)	☐	☐
Contrajo operaciones de la empresa	☐	☐
Proveyó productos o servicios a otras empresas, los cuales estaban basados en descubrimientos incrementales de I+D, para generar flujo de ingresos	☐	☐
Introdujo ensayos de productos/ Adaptó productos o procesos para incrementar la penetración del mercado	☐	☐
Comenzó nuevos proyectos de I+D	☐	☐
Expansión hacia mercados extranjeros	☐	☐

Otro, por favor especifique.....

24. ¿Cuáles son los planes de la compañía para los próximos cinco años?

.....

.....

.....

.....

ANNEX F

QUESTIONNAIRE FOR TECHNOLOGY TRANSFER AND LIAISON OFFICES (ENGLISH)

UNIVERSITÉ DU QUÉBEC À MONTRÉAL
DEPARTMENT OF MANAGEMENT AND TECHNOLOGY

CANADA RESEARCH CHAIR ON THE MANAGEMENT OF TECHNOLOGY

RESEARCH TEAM:
Jorge Niosi, Ph.D. (professor and research director)
Julieta Flores Amador (Ph.D. student)

"QUESTIONNAIRE ABOUT TECHNOLOGY TRANSFER AND LIAISON OFFICES RELATED TO BIOTECHNOLOGY PRODUCTS AND PROCESSES"

Statement of confidentiality

All responses to this questionnaire will be kept confidential and secure. They will be made available only to the research team, al of who will be bound by this statement of confidentiality. All reports arising from this research will refer to aggregate statistics and will not refer to any company by name, product or people.

I agree to abide by the above Statement of confidentiality _____
Interviewer signature on behalf of the entire research team

I have read and agree with the above Statement of confidentiality_____
Respondent signature on behalf of the company

Note. The interviewer is free to sign any non-disclosure agreement the respondent finds appropriate, and the signature of the interviewer on such as agreement will bind the entire research team to its terms and conditions.

Name of the person completing the questionnaire and title

_____

Phone (s)_____ _____

E-mail (s)_____

Fax (s)_____

Web address_____

Section 1: History of the centre and human resources

1. What year was this centre established?.....

2. What were the motives to establish this centre?

.....

.....

3. What were the reasons to establish the centre in this location?.....

.....

4. Is this centre public or private?

- Private
- Public

Depending on:

- University
- Hospital
- Other organization (please specify)

5. In general, does the centre have agreements with other national and/or international centres of linkage or technology transfer?

No…

Yes….

In the case of biotechnologies, are there agreements with other centres? Types? Where?

National	North	Centre	South
Academy			
Technology transfer			

Incubation			

International	U.S.A	Canada	Europe	China	India	Other
Academy						
Technology transfer						
Incubation						

6. Is this centre collaborating with the following institutions? What is the impact of these collaborations in the performance of the centre?

- Mexican institute for the industrial property
- National council for science and technology (CONACYT in Spanish)
- Ministry of Economy
- Industrial associations
- Other (please specify)

Human resources

7. How many employees did the centre employ in 2008?.....
8. How many employees were dedicated **full time** to support services related to biotechnology? .....
9. How many employees were dedicated **partial time** to support services related to biotechnology?.....

Section 2: Support and services

10. Types of services that support enterprises using biotechnologies

SERVICES	YES	NO
Academy linkages (for basic research)		
Human resources formation (continuing education)		
Use of specialized equipment (for trials)		
Up-grading		
Incubation of enterprises		
Advice for launching new products		
Advice for regulatory/clinic affaires		
Advice for intellectual property		
Advice for get funding (public and private)		
Advice for the management of collaborations (e.g. alliances) with other enterprises or institutions		
Other (please specify)		

11. Please complete the following table. Mention the type and number of enterprises by sectors that have been supported by this centre, and the geographical location.

Biotechnology sectors		**Number of enterprises**	**Location**
Human health			
Diagnostics	Yes... No...		
Therapeutics	Yes... No...		
Drug delivery	Yes... No...		
Bio-agriculture			
Plant biotechnology	Yes... No...		
Animal biotechnology	Yes... No...		
Non food agriculture for industrial uses	Yes... No...		
Non food agriculture for medical uses	Yes... No...		
Natural resources			
Energy	Yes... No...		
Mining	Yes... No...		
Forest products	Yes... No...		
Environment			
Air	Yes... No...		
Water	Yes... No...		
Soil	Yes... No...		
Aquaculture			
Fish health, genetics	Yes... No...		
Bioinformatics			
Genomics and molecular modeling	Yes... No...		
Gene therapy	Yes... No...		
Food processing			
Bio processing	Yes... No...		
Functional food/nutraceuticals	Yes... No...		
Others (please specify)	Yes... No...		

12. Which means use this centre to make public its services (university-industry linkages or technology transfer)? How many times a year?

- None

- Information sessions
- Linkages congresses
- Personal invitation to potential enterprises
- Other (please specify)

13. Does the centre have a formal program to follow up the links that the centre has helped to make or companies that have been incubated?
No…
Yes…
How it works?
……
……

Section 3: Results

14. Results related to biotechnology in 2008

a) Number of publications (peer-review)……..
% publications of biotechnology in peer-review journals.....

b) Number of patents (or other intellectual property) given or filed……
Number of patents registered by this centre and then licensed, in what biotechnology sector?.....
……

How many patents are in the process to be licensed? in what biotechnology sector?
……

c) Number of demands solved by this centre.

Type of demand	Demands	Solved	Sector
To evaluate products			
To improve processes			
Other (please specify)			

d) Incubation of enterprises

How many enterprises were in incubation and in what biotechnology sector?
.....

How many enterprises are in process of incubation and in what biotechnology sector?
.....

e) Spin-off
Have this centre helped to the process of spin-offs?
No...
Yes...
What biotechnology sector?
.....

f) Economic results
Please complete the following table. If information is not available please provide a carefully considered estimate in USD.

	2007	2008	2009forecast
Licensing patents			
Assignment of patents			
Technology transfer			
Contracts			
Other (please specify)			
Total			

15. What are the plans for the centre in the next five years?.....
.....
.....
.....

ANNEX G

QUESTIONNAIRE FOR TECHNOLOGY TRANSFER AND LIAISON OFFICES (SPANISH)

UNIVERSITÉ DU QUÉBEC À MONTRÉAL
DEPARTMENT OF MANAGEMENT AND TECHNOLOGY

CANADA RESEARCH CHAIR ON MANAGEMENT OF TECHNOLOGY

RESEARCH TEAM:
Jorge Niosi, Ph.D. (professor and research director)
Julieta Flores Amador (Ph.D. student)

"CUESTIONARIO ACERCA DE LOS VÍNCULOS UNIVERSIDAD-EMPRESA Y OFICINAS DE TRANSFERENCIA TECNOLÓGICA RELACIONADOS CON PRODUCTOS Y PROCESOS BIOTECNOLÓGICOS"

Cláusula de Confidencialidad

Todas las respuestas de este cuestionation setán manejadas de forma confidencial y segura sólo el quipo de investigación tendrá acceso a ellas, y se compromete a respetar esta cláusula de confidencialidad. Todos los reportes surgidos de este trabajo de investigación mostrarán estadísticas agregadas y no harán referencia a ninguna empresa por su nombre, productos o personas.

Me comprometo a respetar esta cláusula de confidencialidad_____
Firma del entrevistador en nombre de todo el equipo de investigación

He leído la cláusula de confidencialidad y estoy de acuerdo con ella_____
Firma del entrevistado en nombre de su empresa

Nota. El entrevistador tiene la facultad de firmar cualquier acuerdo de confidencialidad que el entrevistado juzgue pertinente, y la firma del entrevistador compromete a todo el equipo de investigación a respetar los términos y condiciones de dicho acuerdo.

Nombre de la persona que completa el cuestionario y su puesto

_____

Teléfono(s)_____

Correo(s) electrónico(s)_____

Fax (s)_____

Sitio web_____

Sección 1: Historia del centro y recursos humanos

1. ¿En qué año fue establecido este centro de vinculación?.....

2. ¿Cuáles fueron los motivos para la fundación del centro?

.....

.....

3. ¿Cuáles fueron las razones para el establecimiento del centro en esta localidad?..

.....

4. ¿Este centro es público o privado?

- Privado
- Público

    Depende de:

    - Universidad
    - Hospital
    - Otra institución (por favor especifique)

5. En general, ¿el centro tiene acuerdos con otros centros de vinculación/transferencia tecnológica nacionales y/o extranjeros?

No…

Si….

En el caso de biotecnologías, ¿existen acuerdos de vinculación con otros centros? ¿de qué tipo y lugar geográfico?

Nacionales	**Norte**	**Centro**	**Sur**
Académico			
Transferencia tecnológica			
Incubación			

Extranjeros	E.U.	Canadá	Europa	China	India	Otro
Académico						
Transferencia tecnológica						
Incubación						

6. ¿Este centro mantiene cercanas relaciones con las siguientes instituciones? ¿Cuál es el impacto de esta cercanía en el desempeño del centro?

- Instituto Mexicano de Propiedad Industrial (IMPI)
- Consejo Nacional de Ciencia y Tecnología (CONACYT)
- Secretaría de Economía (SE)
- Cámaras industriales/empresas líderes
- Otras (por favor especifique)

Recursos Humanos

7. ¿Cuántas personas laboraron en el centro en 2008?.....

8. ¿Cuántas personas estuvieron dedicadas **tiempo completo** a labores de servicios y apoyos relacionados con biotecnologías?.....

9. ¿Cuántas personas estuvieron dedicadas **tiempo parcial** a labores de servicios y apoyos relacionados con biotecnologías?.....

Sección 2: Tipos de apoyos o servicios

10. ¿Cuáles son los servicios con lo que cuenta este centro y que están relacionados con el apoyo a empresas que usan biotecnologías?

SERVICIOS	SI	NO
Vinculación académica (para investigación básica)		
Formación de recursos humanos (actualización de personal)		
Uso de equipo especializado (pruebas o ensayos)		
Escalamiento		
Incubadora		
Asesoría para introducir productos en el mercado		
Asesoría en asuntos de regulación/clínicos		
Asesoría en el manejo de propiedad intelectual		
Asesoría para conseguir fondos públicos o privados		
Asesoría para gestión de colaboración (alianzas) con otras empresas o instituciones		

Otro (por favor especifique)		

11. En la tabla siguiente mencione el tipo y número de empresas por sector biotecnológico que son apoyadas por este centro, y estado en el que están establecidas

Sector de Biotecnología		**Número de empresas**	**Localidad**
Salud Humana			
Diagnósticos	Si... No...		
Terapéuticos	Si... No...		
Administración de fármacos	Si... No...		
Biotecnología Agrícola			
Biotecnología de plantas	Si... No...		
Biotecnología animal	Si... No...		
Agricultura para uso industrial, no para alimento	Si... No...		
Agricultura para usos médicos, no para alimento	Si... No...		
Recursos Naturales			
Energía	Si... No...		
Minería	Si... No...		
Productos forestales	Si... No...		
Ambiente			
Aire	Si... No...		
Agua	Si... No...		
Suelo	Si... No...		
Acuacultura			
Salud de peces, genética	Si... No...		
Bioinformática			
Genómica y modelización molecular	Si... No...		
Terapia génica	Si... No...		
Procesamiento de alimentos			
Bioprocesos	Si... No...		
Alimentos funcionales/ nutracéuticos	Si... No...		
Otro (por favor especifique)	Si... No...		

12. ¿Qué medios utiliza este centro para promover sus servicios (de vinculación universidad-empresa o transferencia tecnológica)? ¿Cuántas veces al año?

- Ninguna
- Sesiones informativas
- Congresos de vinculación
- Invitación personalizada a potenciales empresas
- Otra (por favor especifique)

13. ¿El centro tiene un programa formal de seguimiento a los vínculos que el centro ha ayudado a realizar o de las empresas que han sido incubadas?
No…
Si…
¿Cómo funciona?
……
……

Sección 3: Resultados del centro

14. ¿Cuáles fueron los resultados obtenidos en el 2008 relacionado con biotecnología?

a) Número de publicaciones con arbitraje (peer-review)……..
¿Qué porcentaje representan las publicaciones del área de biotecnología en revistas arbitradas?.....

b) Número de patentes (u otra propiedad intelectual) otorgadas o en espera……
¿Cuántas patentes registró el instituto/universidad/centro de investigación y fueron licenciadas por este centro y en qué sector de biotecnología?.....
……

¿Cuántas patentes están en trámite de ser licenciadas y en qué sector de biotecnología? …..
……

c) Número de solicitudes recibidas por empresas y resueltas por este centro. ¿En qué sector de biotecnología?

Tipo de solicitud	Recibidas	Resueltas	Sector

Para evaluar productos			
Para mejorar procesos			
Otro (por favor especifique)			

d) Empresas en incubación
¿Cuántas empresas estuvieron en incubación y en qué sector de biotecnología?
.....

¿Cuántas empresas siguen en proceso de incubación y en qué sector de biotecnología? .....

e) Spin-off
¿Se ha establecido alguna empresa (spin-off) basada en el conocimiento generado por la universidad/centro de investigación relacionado con este centro?
No...
Si...
¿En qué sector de biotecnología?
.....

f) Resultados económicos
Por favor llene la siguiente tabla. En caso de no tener el dato exacto por favor considere un estimado en dólares americanos (USD).

Fuente de ingresos	2007	2008	2009pronóstico
Licencia de patentes			
Cesión de patente			
Transferencia de tecnología			
Contratos			
Otro (por favor especifique)			
Total			

15. ¿Cuáles son los planes para los próximos cinco años de este centro?.....
.....
.....
.....
.....

ANNEX H

STATISTICAL TESTS

In order to test the correlations between different variables I used two nonparametric tests: Spearman correlation coefficient and biserial correlation coefficient. The Spearman correlation coefficient is a procedure to measure the relationship between two rank-order variables, while "the biserial correlation is a procedure to measure the relationship between a continuous dichotomous variable and an interval scale variable", both procedures can be applied to small samples (Corder and Foremar, 2009: 134).[47]

The formula to calculate the Spearman rank-order correlation coefficient with ties is:

$$r_s = \frac{(n^3 - n) - 6\sum D_i^2 - (T_x + T_y)/2}{\sqrt{(n^3 - n)^2 - (T_x + T_y)(n^3 - n) + T_x T_y}}$$

where n is the number of rank pairs and D_i is the difference between a ranked pair.

Also,

$$T_x = \sum_{i=1}^{g} (t_i^3 - t_i)$$

$$T_y = \sum_{i=1}^{g} (t_i^3 - t_i)$$

where g is the number of ties groups in that variable and t_i is the number of ties values in a tie group.

Corner and Foreman (2009) suggest to calculate the biserial correlation coefficient to

[47] These procedures are explained in detail in Corner and Foreman (2009) Chapter 7.

measure the relationship between a dichotomous continue variable and a rank order variable. The formula to calculate the biserial correlation coefficients is:

$$r_b = r_{pb}\frac{\sqrt{P_p P_q}}{y}$$

where

r_{pb} is the Spearman correlation coefficient with ties, and

$$y = \frac{1}{\sqrt{2\pi}}e^{-z^2/2}$$

where e is the natural log base and z is the z-score at the point dividing the proportion of the interval variable values associated with the dichotomous variable's first category (P_p) and the interval variable values associated with the dichotomous variable's second category (P_q).

In order to analyze the relationships between different variables, I ranked the values of the ordinal variables and dichotomous variables (see Table H.1) and calculated the coefficients (see Table H.2).

Table H.1

Ranked scores

Type of variable	Rank-order	Rank-order	Rank-order	Dicho cont	Rank-order	Dicho cont	Dicho cont	Dicho cont	Dicho cont	Dicho cont
ID	Size	Size biotech	Years biotech	Export	Nal collab (#)	Nal collab (dico)	External collab	Patents	Licensing _ out	Licensing _ in
1	15	15	6	4.5	12	11	14	12.5	7.5	5.5
2	10	12	15	12.5	3	3	6	4.5	7.5	13.5
3	4	4	3	4.5	7	11	6	4.5	7.5	13.5
4	2.5	5.5	1.5	4.5	13	11	6	12.5	7.5	5.5
5	11.5	13	12	12.5	16	11	14	12.5	7.5	5.5
6	6	5.5	11	12.5	7	11	6	12.5	7.5	13.5
7	9	9	4	4.5	7	11	6	4.5	7.5	13.5
8	1	2	8	4.5	14	11	14	12.5	7.5	5.5
9	11.5	8	16	12.5	10	11	14	12.5	7.5	5.5
10	13	7	10	12.5	3	3	6	4.5	15.5	5.5
11	2.5	2	1.5	12.5	10	11	6	12.5	7.5	5.5
12	14	14	6	4.5	3	3	6	4.5	7.5	5.5
13	5	2	6	4.5	3	3	6	4.5	7.5	5.5
14	8	11	14	12.5	10	11	6	4.5	7.5	5.5
15	16	16	13	12.5	15	11	14	12.5	15.5	13.5
16	7	10	9	4.5	3	3	6	4.5	7.5	13.5
Ties	12	30	30	1008	168	1440	1440	1008	2736	1200

Variables:

Size: total number of employees.

Size biotech: number of employees dedicated to biotechnology activities.

Years biotech: number of years using biotechnologies.

Export: having export activities.

National collaboration (#): number of national collaborations.

National collaboration (dicho): having national collaborations.

External collaborations: having international collaborations.

Patents: having patents.

Licensing_out: have assigned intellectual property

Licensing_in: have acquired intellectual property

Table H.2

Correlations

	Size biotech	Years biotech	Export	Nal collab (#)	Nal collab (dico)	External collab	Patents	Licensing out	Licensing in
Size	r_s =0.8640[b/]	r_s=0.4804[a/]	r_b=0.3574	r_s =-0.0165	r_b =-0.2495	r_b =0.4797[a/]	r_b =-0.0681	r_b =0.7913[b/]	r_b =0.0358
Size biotech		r_s=0.4496[a/]	r_b =0.2217	r_s =0.1387	r_b =-0.0962	r_b =0.4423[a/]	r_b =-0.0341	r_b =0.3965	r_b =0.1975
Years biotech			r_b =0.8358[b/]	r_s =0.0407	r_b =-0.1346	r_b =0.4808[a/]	r_b =0.0341	r_b =0.3965	r_b =0.1436
Export					X^2= 1	X^2= 1	X^2= 0.62	X^2= 0.45	X^2= 1
Nal collab (#)									
Nal collab (dico)							X^2= 0.03[b/]	X^2= 1	X^2= 1
External collab							X^2= 0.03[b/]	X^2= 1	X^2= 0.68
Patents								X^2= 1	X^2= 1
Licensing _ out									
Licensing _ in									

[a/]$p \leq 0.10$, [b/]$p \leq 0.025$

r_s= Spearman rank-order with ties correlation n= 16

r_b= Biserial correlation fd= 14

X^2= Chi-square correlation

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