INNOVATION SYSTEMS AND TECHNOLOGY TRANSFER IN TRANSITIONAL ECONOMIES: A CASE STUDY OF MEXICO

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ABSTRACT

Knowledge creation processes and the innovation systems through which it is transferred for the benefit of society are the economic driver of industrial economies in the globalized era, yet developing countries seeking to move through the transition from developing to developed status are struggling . A variety of theories and a range of speculations have been offered as to why some nations are more innovative than others, however little of this literature examines the theoretical and practical applicability of innovation models based on industrial societies for developing nations. This thesis examines a selection of theoretical innovation system models, analyzes their roots and assesses their applicability to transition economies where various pieces of the system present structural differences relative to developed nations. This thesis uses Mexico as a case study.

In the fifteen years since the 1994-95 collapse of Mexico's financial sector and the resulting economic crisis, the Mexican economy has made impressive progress towards macro-economic consolidation and stability. The OECD (2004) observes that the inflation rate has fallen from around 50% during the economic collapse of 1995 to about 4% in 2006. GDP growth has averaged 3.2% in the period from 1994 to 2008 (compared to the OECD average of 2.7%). As a partner in the North American Free Trade Agreement, trade liberalization has allowed Mexico to consolidate its export base and to specialize in medium- and high-technology manufacturing. However, the industrial sector in Mexico still shows a slow pace in developing, adopting and investing in technology. The Mexican industrial sector is lead by multinational firms that have located in Mexico due to the cheap costs of labour, while most of the research and development performed by these firms takes place outside of Mexico.

Mexico’s policy for S&T seems to show a disconnection between the discourse and practice. Indicators show that Mexico considerably lags in S&T development. S&T development has not contributed to facilitating the country's positioning as one of the top ten most competitive nations in the world. Rather, technology transfer outcomes in the country, relative to other transitional economies, manifest an increasing deceleration in Mexico's S&T competitiveness. This thesis contrasts the innovation system in which technology transfer processes navigate in Mexico to the leading literature on theoretical models of innovation. This process facilitates identifying crucial barriers and challenges of the Mexican system of innovation that need to be addressed in order to achieve a level of S&T development that would contribute to facilitating Mexico's transition to a developed economy.

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If I have seen further,
it is by standing on the shoulders of giants.
~Isaac Newton~

DEDICATION PAGE

With infinite love I dedicate this dissertation to my incomparable family who believed in me through this seemingly endless process:

To my sister Zulamit, and my brother Carlos Eduardo, and to my nieces Paulina and Melissa for making my world be the best place – you truly are my inspiration!

To Jamie, my husband and best friend, for your love, your patience and your unconditional belief in my ability – I am so fortunate for having you!

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Y especialmente a mis abuelos, Don Fermín y Doña Concepción Pando, y a mi madre, Manuela Pando, que con sus ejemplos de vida y dedicación, me han enseñado que con entereza, honestidad, humildad, perseverancia y trabajo arduo se siembran raíces más fuertes y se crece más alto.

So much of what is best in us
is bound up in our love of family,
that it remains the measure of our stability
because it measures our sense of loyalty.
All other pacts of love or fear
derive from it and are modeled upon it.
~Haniel Long~

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AVANCE	Alto Valor Agregado de Negocios con Conocimiento y Empresarios
CGIAR	Consultative Group on International Agricultural Research
CONACyT	Consejo Nacional de Ciencia y Tecnología de México
EPO	European Patent Office
G5	Group of Five (Brazil, Mexico, India, China and South Africa)
G8	Group of Eight (France, United States of America, Great Britain, Germany, Japan, Italy, Canada, Russia)
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GERD	Gross Expenditure on R&D
HDI	Human Development Index
IES	Instituciones de Educación Superior
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IP	Intellectual Property
IPN	Instituto Politécnico Nacional
ITESM	Instituto Tecnológico y de Estudios Superiores de Monterrey
JPO	Japan Patent Office
NAFTA	North America Free Trade Agreement
OECD	Organisation for Economic Cooperation and Development
P3	Public private partnership
PECiTI	Plan Especial de Ciencia, Tecnología e Innovación
PECyT	Plan Especial de Ciencia y Tecnología
PPP	Purchasing power parity
PRI	Partido Revolucionario Institucional
R&D	Research and Development
S&T	Science and Technology
SEP	Secretaría de Educación Pública

SESIC	Subsecretaría de Educación Superior e Investigación Científica
SNI S	Sistema Nacional de Investigadores
TBP	Technological Balance of Payments
TT	Technology Transfer
TTO	Technology Transfer Office
UNAM	Universidad Nacional Autónoma de México
UNESCO	United Nations Educational, Scientific and Cultural Organization
USPTO	United States Patent and Trademark Office

Chapter One

Innovation and Technology Transfer as Drivers of Economic Growth

1.1 Introduction

Innovations in information technologies, genetics and communications are driving global economies at an unprecedented rate. The dispersion of these technologies has not been confined to industrialized nations, as was often the case with previous innovations; instead they have reached the four corners of the earth, albeit at different speeds and different rates of adoption. Taken in combination, these three innovations have precipitated the spread of knowledge in ways that could not have been fathomed a mere twenty years ago.

As industrialized countries have embraced knowledge as the driver of the 21st century economy, innovation and the resulting products continually change our world. Many countries in the developing world are moving along the economic transition to a knowledge economy, which will further increase the global rate of innovation and discovery, thereby driving the rate of change at an even more rapid pace.

The rapid advancement of the knowledge-based economy in Organisation for Economic Co-operation and Development (OECD) countries has been attributed to investments in science and technology (S&T), innovation policies and ultimately the mobilization of the results from such investments through technology transfer (TT) and the management of intellectual property (IP). However, the vast majority of the theoretical models for efficient IP and technology transfer regimes, as well as quantitative results, are predominantly based on results drawn from the successes of the national system of innovation in advanced countries, whose TT success have contributed to measure global economic growth on indicators of S&T nature. As countries transition from developing to developed status, a functional and well consolidated national system of innovation, one that facilitates efficient technology transfer activities, is one aspect that will play an important role in facilitating this transition. To date, the literature has been largely silent on contributing a model of innovation that would align to the developmental characteristics of transition economies.

1.2 Problem Statement

The Mexican economy has been slow to reach the stage whereby it can be considered to be in transition. The implementation of the North American Free Trade Agreement (NAFTA) on January 1, 1994 was one of the important early initiatives that precipitated the basic changes needed within the Mexican economy. The next important step in Mexico's economic transition came in 2000, with what many considered to be the first democratic election, which broke a nearly 72 year period of rule by a sole political party – the *Partido Revolucionario Institucional* (PRI) (Institutional Revolutionary Party), resulting in increased political and economic freedom. Over the past decade, the Mexican economy has undergone slow but steady reforms that are allowing Mexico to reap a greater level of benefits from the free-trade pact with Canada and the United States. While this transition has been impressive, one wonders whether the results could have been improved. Was the economic theory for investing in scientific research and development the appropriate theory for the Mexican education system? Was the industrial theory too advanced for direct application to the economic circumstances in Mexico? Was the institutional design in Mexico one that could readily uptake advanced economic developments and translate them into marketplace impacts?

1.3 Objective

In Mexico, S&T development has not contributed to facilitating the country's positioning as one of the top ten most competitive nations in the world. Rather, technology transfer outcomes in the country, relative to other transitional economies, manifest an increasing deceleration in Mexico's S&T competitiveness. An analysis of Mexico's S&T policy is required in order to understand possible structural failures within Mexico's system of S&T. This thesis compares knowledge-based economic theory , including that about innovation systems based on research experiences in OECD countries against the experience observed in Mexico since its inception as OECD member in 1994. This thesis aims at providing insight into whether OECD theories can be easily adopted by transitional economies or whether they will require restructuring prior to adoption.

1.4 Approach

This thesis explores the national system of innovation in Mexico by contrasting the innovation system in which technology transfer processes navigate, to the leading literature on theoretical models of technology transfer. This process will facilitate identifying crucial barriers and challenges of the Mexican system of innovation that will need to be addressed in order for S&T being a contributor in facilitating Mexico's transition to a developed economy.

1.5 Thesis Structure

The following chapter provides the pertinent information to this issue. Chapter 3 discusses the theoretical contributions to the topic and summarizes the major thoughts. Chapter 4 provides results of contrasting the current innovation model in Mexico, against the theoretical analysis, offering strategic implications and impact to Mexico. Chapter 5 offers concluding thoughts, presenting a summary of the results, limitations and extensions to future research.

Chapter Two

Background

The advent of the new Knowledge Economy has meant that governments have had to realize the importance of measuring the economic impacts of, and the social behaviors from, innovation. Given that innovation plays a paramount role in economic growth, quantitative measures and cross-country comparisons of innovation activities have become some of the most important benchmarks in evaluating a country's position relative to international indexes.

Globalization has acquired a very strong emotive force. Some regard it as a beneficial opportunity to achieve international competitiveness and also as an inevitable and irreversible process; others attach to it a fear of inequity between nations as well as a threat to employment and sovereignty (Stiglitz 2006, 2002; Wolf, 2004). Critics perceive globalization as detrimental to living standards and social progress (IMF, 2000). Globalization indeed represents risks and challenges but it also represents opportunities for developing and transitional economies.

The concept of globalization originated at the close of the 19^{th} century, but was largely a corporate strategy. The inventiveness and cooperation among nations during, and following, the Second World War, set the stage for the enhancement of the concept. However, it was during the late 1980s and early part of the 1990s that the term became commonly used and applied. It is globalization that describes the processes of international cooperation and relations around the world, as well as determining the level of international competitiveness that countries enjoy (Mokyr, 1992).

Within national boundaries, each country's main objectives are – or should be – to provide for the needs of its citizens. Needs such as education, health, food, shelter, safety, communications and other benefits are the main objectives of democratic governments. Over the past 40 years, countries have been confronted with challenges regarding the ability to manage social change, such as controlling the knowledge base, energy sources and strengthening financial infrastructures (Phillips, 2007).

Decades of economic and fiscal mismanagement by the Mexican government, which led to an unprecedented debt crisis in 1982, leaving the country in bankruptcy, was followed by the negotiations of the North American Free Trade Agreement (NAFTA) between Mexico, Canada and the United States. NAFTA came into effect in 1994. Its objective was to promote a partnership among the three countries by eventually removing trade and investment barriers. While the intent of NAFTA was to facilitate trade, in reality, by the end of 1994 the Mexican economic and financial systems were facing collapse. This collapse resulted in an exponential increase in interest rates, cancelling of domestic investment and individual savings, as well as a large fall in the stock market that left Mexico with a devastated economy. For Mexico, it was indeed the first crisis of globalization. Mexican newspapers and economic and political magazines blamed this economic 'suicide' on the excessive flow of private foreign capital accumulation, arguing that the federal government followed a neoclassic model of trade openness that only proved to be effective for those economies where the conditions for such policies were given, namely the industrial economies, where all the production factors where present and working in equilibrium. (Lustig, 1997; Moreno-Brid, 1999; Cimoli and Correa, 2002; Pacheco-Lopez and Thirlwall, 2004; Moritz 2008). In Mexico, the neoclassic model proved to have its limits. Mexico showed its incapability of achieving sustained growth, generating employment and raising life levels for the great majority of the population. It ended up deepening the problems in the business and finance sectors, causing an economic recession, concentrating income and deepening social problems. The Mexican crisis of 1995 was to many the manifestation of structural problems of the Mexican economy in the globalization era and many in Mexican society believed that globalization was the cause of the economic crisis. This sentiment is supported by evidence that Mexico has low levels of human capital, an unfriendly domestic business environment, a large informal labour market and widespread poverty. In reality, what failed was the model adopted by the government.

In 2000, Mexico completed its long anticipated transition into democracy. The federal election in 2000 ended a 72-year period of political authoritarianism. Since then, the country has experienced an increase in political freedom, its citizens have easier access to bank lending and social programs that make benefits tangible for an expanding middle class. Economic modernization appears to have cut the levels of extreme poverty.

The 2004 Economic Survey of Mexico released by the OECD in 2004, a decade after the economic crisis, highlights the actions taken and implemented by the government in the aftermath of the 1994-5 economic/fiscal crises, which resulted in the Mexican economy making impressive progress towards macro-economic consolidation and stability (Table 1). The survey concludes that the Mexican government managed to reduce inflation from more than 50% in 1995 to below 5% (2009 year estimated at 5.1%). The current account deficit, was reduced to close to 1% of GDP in 2004 from 11.1% in 1994 (Camacho-Gutierrez, 2009) and the management of public debt had also reduced vulnerability to interest and exchange rate shocks. In the context of trade liberalization, the survey concluded that Mexico had also managed to reverse the negative effects and, under NAFTA, the country consolidated its export base and its specialization evolved towards medium- and high-technology manufacturing (OECD, 2004). In spite of the perceived benefits, the Mexican government has been unsuccessful in achieving its promised 7% annual growth; instead, it has struggled to reach an average 2.9% growth rate since 2000 and labour productivity remains low and is decelerating. According to the OECD, Mexico has the lowest level of human capital among the member countries.

Table 1: Mexico's key socio-demographic facts (2009 unless otherwise indicated)

Territory	1 972 550 km2
Population	111 million
Pop. Density	55p/km2
GDP (PPP)	1.536 trillion
GDP/capita	$14,104
GDP real growth	-6.5 (2009) 1.3% (2008)
Human Development Index (2007)	.857(high)*
Average years of school	7.2 years
Labor Force (2005)	47 million
By sector: Agriculture	13%
Industry	23.4%
Services	62.9%
Unemployment	5.6 (2009); 4% (2008)
Underemployment	26%
Population below poverty line (2008)	
Food based	18%
Asset based	47%
Inflation	
1994	~6%
1995	~50%
2000	15%
2009	5.1%

*According to the United Nations Development Programme, Mexico's Human Development Index classifies the country as high development, ranked 53rd out of 182 countries. The HDI combines three indicators of life expectancy (Mexico ranked 43rd) educational attainment (Mexico ranked 58th in adult literacy rate and 56th in combined gross enrolment) and income (Mexico ranked 58th). The HDI is measured with a value between 0 and 1. Norway is ranked 1st with a value of .971 while Niger is ranked 182th with a value of .340; Canada is ranked 4th with a value of .966 while the US is ranked 13th, at .956 (UNDP, 2009).

The domestic industrial sector in Mexico shows to be dormant in developing, adapting, adopting and investing in technology; additionally, the external industrial sector, considered the strongest industrial sector in Mexico, is the 'maquiladora' industry, led by large multinational companies who have chosen Mexico as a production hub, attracted largely by the inexpensive labour costs. Unfortunately, the maquiladora industry is not a fundamental contributor to promoting and increasing the Mexican national innovation capacity as these companies perform most of their R&D activities in their country of origin or in a country where conditions for innovation are more competitive. This has resulted in a domestic industrial sector that is characterized by medium and small companies, lack in financial stability, extremely low levels of labour specialization and rudimentary means of production. At its peril, Mexican domestic industry ignores the need for incorporating high technology into their business operations. Similarly, a not-so-friendly political and economic environment, in terms of creating and consolidating businesses also plays a significant role in impeding innovative intentions. According to the OECD's Economic Survey of Mexico (2004), interest rates in the country averaged 9.7% for three-month short-term loans, however, access to bank financing and lending was not available for longer terms, in the period to 2003 analyzed by the survey. However, more recent OECD data shows that in 2008, long term interest rates in Mexico were 8.1% (OECD, 2010).

Another important consideration is the enormous gap that exists between government entities, the scientific community and business leaders and organizations. Although Mexico has an established network of R&D institutions and many of them have made efforts to bridge between academia and industry, there is still a general impression that not only the scientific and innovative capacity in the country are immature, but also that their contributions are incapable of providing tangible solutions and opportunities for the country’s well being. This situation ultimately results in researchers devoting their efforts mainly to publishing scientific papers. However, there is little evidence of any transfer of the knowledge generated through applied research projects with industry partners.

Government expenditure on R&D activities are also a concern. In the ten-year period to 2003, Mexico invested only 0.38% of GDP into R&D (GERD) infrastructure and programs; in 2006 only 0.36% of GDP was invested in R&D. This is far from the 2000 Presidential promise of investing at least 1% of GDP in R&D annually by 2006, as stated in the *Plan Nacional de Desarrollo* -Mexican National Development Plan 2001-2006, the baseline document to the *Plan Especial de Ciencia y Tecnología (PECyT)* -Mexican Special Program for Science and Technology 2001-2006. The PECyT also intended that the share of government investment in R&D would be 40% of GERD, while private investment would account for 60%. Such a goal assumed a sustained average growth rate of 5% annually in the PECyT period.

In order to continue providing context to Mexico's positioning within the global innovation environment, this section introduces cross-country comparisons for the G8 and G5 country blocks . The G8 involves the 8 major industrialized democracies in the world (firstly known as the G6, later joined by Canada to form the G7 and with the later addition of Russia in 1997 to form the G8). Mexico has framed its economic policies to become one of the top 10 most competitive nations in the world--the comparison to the G8 block highlights the disconnect between discourse and reality. Additionally, Mexico's economic agenda is closely tied to the NAFTA treaty on which the country partnered with the USA and Canada. The comparisons between Mexico's S&T performance and that of the G5 (Mexico, Brazil, China, India and South Africa) helps to shed light on Mexico's 'learner' achievements in the context of other transition countries.

Table 2 presents, comparisons amongst G8 and G5 countries[1] in relevant areas with regards to the strengthening of a S&T infrastructure. It shows that Mexico is positioned at the lowest level of each indicator; in fact, the OECD shows Mexico ranked last in terms of investment in R&D and other activities of S&T. A clear competitive disadvantage if the country wishes “to position itself as one of the ten most important economies in the world and among the twenty most advanced in science and technology” (CONACyT, 2001).

[1] In 2005 the heads of state form Mexico, Brazil, China, India and South Africa were invited to take part in an expanded dialogue at the Gleneagles Summit of the G8. The group of five nations have been since then known as the G5 and have been recognized by developed nations as the five emerging nations with the greatest influence in world initiatives. The G5 has since then consolidated its structure and acted as a cohesive economic block, with coordinated efforts to common issues. The G5 countries account for close to 45% of the world’s population and the block’s relevance in the world economy continues to grow (www.groupoffive.org)

Table 2: Gross Expenditure on R&D in G5 and G8 selected countries

Selected Countries		Gross Expenditure on R&D							
		Gross Expenditure			% Financed by Source		% Performed by		
G5	Year	Total (million current PPP)	% of GDP	Per mill pop.	Industry	Gov.	Industry	Gov.	Higher Educ.
Mexico	2005	5 919	0.46	57	46	45	49	22	27
Brazil*	2003	13 487	0.98	74	41	59	n.a	n.a	n.a
China	2007	102 331	1.46	77	70	24	72	19	8
India*	1998								
South Africa	2005	3 654	0.92	76	43	38	58	21	19
G8									
Canada**	2007	23 877	1.88	724	49	31	56	10	34
United States	2007	368 799	2.68	1 220	66	27	72	11	13
United Kingdom	2007	38 892	1.79	640	47	29	64	9	24
France**	2007	43 232	2.08	680	52	38	63	16	19
Germany	2007	71 860	2.54	873	68	27	70	14	16
Italy	2006	19 678	1.13	333	40	48	49	17	30
Japan	2007	147 800	3.44	1 156	77	16	78	8	13
Russia	2007	23 482	1.12	164	29	62	64	30	6
OECD Total	**2007**	**886 347**	**2.3**	**748**	**64**	**29**	**70**	**11**	**17**

Source: OECD Main Science and Technology Indicators volume 2009/1
*Source: UNESCO
** Canada data 2005; France 2006: OECD Total 2006

Research and development activities in Mexico are performed mainly by government sectors with no signs of technological or knowledge mobilization to the business, industries or private sectors. Additionally, to increase the scientific and technological capacity, Mexico would have to aggressively promote the incorporation of science to the labour market. The data in Table 3 shows that the ratio of researchers per thousand employed citizens is only 1.2; Mexico is far from being a scientific and technological society (Hernandez-Ramirez, 2002).

At the same time, Mexican researchers considerably lag in regards to the impact of their knowledge contributions in the global context. Table 4 presents scientific productivity of peer reviewed articles among G5 and G8 countries.

Table 3: R&D personnel per thousand employed in G5 and G8 countries

Selected Countries		Researchers in full time equivalency	
G5	Year	Total count	per thousand employment
Mexico	2005	48 401	1.2
Brazil*	2003	59 838	n.a
China	2007	1 423 381	1.8
India*	1998	117 528	n.a
South Africa	2005	17 303	1.4
G8			
Canada	2007	134 300	8.2 (2005)
United States	2007	1 425 550	9.7
United Kingdom	2007	175 476	5.6
France	2007	211 129	8.3 (2006)
Germany	2007	284 305	7.1
Italy	2006	88 430	3.6
Japan	2007	709 974	11.0
Russia	2007	469 076	6.6
OECD Total	**2007**	**3 997 466**	**7.4 (2006)**
Source: OECD Main Science and Technology Indicators volume 2009/1 *Source: UNESCO			

Table 4: S&T productivity by cited publications in G5 and G8 selected countries

Scientific Productivity in Peer Reviewed Publications						
	Publications 1997-2006		Citations		Publication per researchers (FTE)	
G5	Total country	% of world	Total 2002 - 2006	Impact Factor	Total researchers	Publication per researcher
Mexico	52 029	.68	87 291	2.88	48 401	1.1
Brazil	113 801	1.49	206 231	2.95	59 838	1.2
China	365 207	4.79	692 283	2.77	1 423 381	.26
India	185 228	2.43	256 450	2.40	117 528	1.6
South Africa	n.a	n.a	n.a	n.a	17 303	n.a
G8						
Canada	349 405	4.58	1 028 532	5.45	134 300	2.6
United States	2 561 910	33.59	8 937 644	6.67	1 425 550	1.8
United Kingdom	684 059	8.97	2 158 717	6.13	175 476	3.9
France	471 030	6.18	1 266 844	5.23	211 129	2.2
Germany	655 451	8.59	1 955 974	5.74	284 305	2.3
Italy	327 413	4.29	927 466	4.39	88 430	3.7
Japan	698 975	9.16	1 581 619	4.39	709 974	.98
Russia	n.a	n.a	n.a	n.a	469 076	n.a
World Total	7 627 577	N/A	N/A	N/A	N/A	N/A
Source: Institute for Scientific Information, 2007 cited by CONACyT (2007)						

While Mexico has the opportunity to increase interest in activities of S&T by promoting its importance among its young population, unless such activities also meet with a conducive structure to keep students in the classrooms, Mexico will continue to lose ground to a number of emerging nations. China, Brazil, India and South Africa have made impressive strides towards positioning themselves in the global S&T sphere, where historically they had not had an active role, as it is shown in Table 3, with the increase of scientific personnel in the selected countries, as well as in Table 4 showing the impact of their contributions to knowledge.

A dynamic business sector is key to improve the rate of innovation and the adoption of technologies into markets (OECD, 2010). As technological development occurs, commonly, new companies emerge ready to adapt such new technologies for financial gains. Table 5 shows the entry rate of new companies in the selected country blocks, relative to the total number of existing companies in 2007.

Table 5: A conducive business environment to incorporate R&D and innovation

Country	Entry Rates (number of new/all registered)		Days to start a business	
G5	**2000-07**	**2007**	**2004**	**2010**
Mexico	n.a	7	58	13
Brazil	n.a	n.a	152	120
China	n.a	n.a	48	37
India*	4.3	3	89	30
South Africa*	6.3	7	38	22
G8				
Canada	6.8	8	3	5
United States	12.7	13	6	6
United Kingdom	16.3	18	13	13
France	9.6	11	41	7
Germany	15	12	45	18
Italy	13.5	12	23	10
Japan	4	4	31	23
Russia	13.5	15	44	30
OECD Total	**n.a**	**n.a**	**32.7**	**13**

* India 2001-06; SA 2002-05;US 2003-05;France 2000-06; Germany 2002-05;Japan 2002-05
Source: OECD 2010 Measuring Innovation: A New Perspective

The data shows that the most innovative countries in the G8 have increased the rate of new companies created in 2007, relative to their seven year average. France, for example, registered

11% new companies in 2007, while in the period from 2000-2006 the rate was 9.6% average; Canada 8% new companies in 2007, compared to 6.8% average in the period from 2000-2007 and the UK 18% compared to 16.3 % average in the same period. Mexico's entry rate in 2007 was 7% new companies. While no data is available to compare with the period of time prior to 2007, and despite the fact that Mexico, has also decreased its number of days required to start a business, as have all other G8 countries (except for Canada where the number of days to start a business increased from 3 in 2004 to 5 in 2010), Mexico ranks among the three most restrictive countries in the OECD members, in terms of barriers to entrepreneurship. In a scale of 0 to 6, from lesser to most, Mexico's index is 2.27, just below the most restrictive country, Turkey with 2.41, while the least restrictive is the UK with a 0.81 index (OECD, 2010).

With regards to financial support to entrepreneurship and incorporation of R&D in the business sector, Table 6 shows the tax benefit granted to companies investing in R&D, as well as long term interest rates in the selected G5 and G8 countries.

Table 6: Fiscal support to R&D in the business sector

Country	**Tax Subsidy (per US$ 1 R&D) 2008**		**Long term interest rate**	
G5	**SME**	**Large corp.**	**1990**	**2008**
Mexico	-0.012	-0.012	n.a	8.1
Brazil	0.254	0.254	n.a	n.a
China	0.138	0.138	n.a	n.a
India	0.269	0.269	n.a	n.a
South Africa			16.2	9.1
G8				
Canada	0.326	0.180	10.7	3.6
United States	0.066	0.066	8.6	3.7
United Kingdom	0.179	0.105	11.8	4.6
France	0.125	0.125	9.9	4.2
Germany	-0.020	-0.020	8.7	4
Italy	0.117	0.117	n.a	4.7
Japan	0.159	0.116	7	1.5
Russia	-0.012	-0.012	n.a	8.1
OECD Total	**N/A**	**N/A**		
Source: OECD 2009 Science Technology and Industry Scorecard (OECD, 2009b) OECD 2010 Measuring Innovation: A New Perspective				

In 2004 the OECD recognized that Mexico implemented the most aggressive fiscal stimulus package for businesses investing in R&D activities, however, data to 2008 shows that the overall tax benefit in Mexico results in -0.012; this indicator means that for each US $1 invested into R&D by a company in Mexico it results in -0.012 units of tax relief, irrespective of the firm's size (OECD, 2009a). Surprisingly, companies in Mexico are not motivated to invest in R&D, and if considering that interest rates to finance business activities at a long term in Mexico, was 8.1% in 2008, R&D for the private sectors seems a rather expensive alternative.

Table 7: Scientific productivity by patent applications in G5 and G8 selected countries

Country	**# triadic patents (2007)**	**Total Patents Applied in the Country (2004)**			**Ratios****		
G5	Total	Total	Residents	Non-residents	Dependency	Auto sufficiency	Inventiveness Coefficient
Mexico	15 (2002)20	13 194	565	12 629	22.35	.04	.05
Brazil	38 (2002)	18 692	3 892	14 800	3.80	.21	.60
China	144 (2002) 591	n.a	n.a	n.a	n.a	n.a	n.a
India	78 (2002)	n.a	n.a	n.a	n.a	n.a	n.a
South Africa	38 (2002)	n.a	n.a	n.a	n.a	n.a	n.a
G8							
Canada	706	37 227*	3 929*	33 298*	8.47	.11	1.63
United States	15 923	356 943	189 536	167 407	.88	.53	6.38
United Kingdom	1 645	29 954	19 178	10 776	.56	.64	3.22
France	2 468	17 290	14 230	3 060	.22	.82	2.35
Germany	6 146	59 234	48 448	10 786	.22	.82	5.87
Italy	756	n.a	n.a	n.a	n.a	n.a	n.a
Japan	14 605	423 081	368 416	54 665	.87	.87	28.80
Russia	66	n.a	n.a	n.a	n.a	n.a	n.a
OECD Total	49 974	N/A	N/A	N/A	N/A	N/A	N/A

n.a = not available; N/A =not applicable; * =data for 2003
**Dependency ratio= patent applications by non-residents/residents; Auto sufficiency ratio= patent applications by residents/total country; Inventiveness coefficient= patent applications by resident/10,000 population
Source: OECD Main S&T Indicators 2007 and 2009
Source: IMPI, WIPO, CONACyT 2007

The transfer of technologies represented by the mobilization from basic research inputs into outcomes in the form of patents is one of the important indicators among OECD countries as it measures the dynamism of the innovation system in a country, as well as its readiness to apply protection mechanism for competitive advantage among other countries. To investigate Mexico’s potential to become a key player in the knowledge economy under the premise that countries should look for endogenous innovation in order to achieve high levels of international competitiveness, as well as better economic performance as new growth theory posits, the data presented in Table 7 shows important disadvantages for Mexico. Data from countries such as India, China, Brazil, and in most recent years, South Africa, shows that while Mexico continues to struggle to stimulate its domestic scientific capacity; other emerging economies are successfully evolving towards international standards. From the G5 group comparison, the rate of growth in terms of triadic patent families[2], show that Mexico is ranked last relative to the rest of the G5 countries. The large majority of patent applications in Mexico is made by non-residents, a manifestation of the lack of dynamism in the interaction between R&D and the business sectors. This has a two-fold effect. On one hand the absence of any significant intellectual property limits the potential to generate resources to further basic research activities. On the other hand, the high degree of dependency of the S&T system in Mexico on external resources limits choices in moving forward. As Table 7 shows, Mexico's patent ratios compared to those of its G5 and G8 counterparts are worrisome; for each patent application filed in Mexico by a Mexican resident, 22.35 applications are filed in the country by non-Mexicans. At the same time, the auto-sufficiency ratio of Mexican residents' applications, relative to the total patent applications in the country is even lower, at 0.04 and the measure of inventiveness of the Mexican population, is only 0.05 patents filed by Mexican residents per 10,000 of population.

[2] Triadic patent families, defined by the OECD, groups together patents taken in the 'triad region" (Europe, North America and Asia) to protect inventions. It refers to patents taken at the European Patent Office (EPO), the Japan Patent Office (JPO), and the US Patent and Trademarks Office (USPTO) that share one or more priority claims. These patent families are thought to be of high and competitive economic value and are among the most used indicators to measure a country's technological dynamism, as the methodology used to define such families, removes the "home advantage" bias of counting only patents applied for at the domestic office in the country of analysis.

Another measure of the dynamism of domestic technology transfer activities is offered by the Technology Balance of Payments (TBP), which analyzes all the activities related to the international commercialization of goods of S&T. The OECD (2009) defines this as:

> the technology balance of payments (TBP) registers the commercial transactions related to international technology and know-how transfers. It consists of money paid or received for the use of patents, licenses, know-how, trademarks, patterns, designs, technical services (including technical assistance) and for industrial research and development (R&D) carried out abroad, etc. The coverage may vary from country to country and the TBP data should be considered as only partial measures of international technology flows.

Table 8 shows comparative data for G5 and G8 countries; once again, not only does Mexico face important and urgent challenges within its national boundaries to realize technological advantages, as presented by the information about patents in Table 6, but internationally as well.

Table 8: Technology balance of payment for selected G5 and G8 countries

Technological Balance of Payments (million USD)				
G5	Year	Receipts	Payments	Coverage ratio
Mexico	2005	180	2 094	.09
Brazil	n.a	n.a	n.a	n.a
China	n.a	n.a	n.a	n.a
India	n.a	n.a	n.a	n.a
South Africa	2006	46	1 279	.03
G8				
Canada	2006	2 514	1 358	1.9
United States	2007	85 919	48 957	1.8
United Kingdom	2007	34 622	17 816	1.9
France	2003	5 188	3 234	1.6
Germany	2007	42 739	38 350	1.1
Italy	2007	5737	4 619	1.2
Japan	2007	21 080	6 034	3.5
Russia	2006	529	1 138	0.5
Source: OECD Main S&T Indicators, 2007; OECD Main Economic Indicators per country, 2007.				

The country's Technology Balance of Payments depicts a grim perspective and confirms the information offered above; Mexico is an importer of technologies, rather than being an important supplier of them. The Mexican TBP is $US-1,913 million with a coverage ratio of 0.09. In short, Mexico depends almost in its entirety on imported technologies to address technological needs in the country, which seriously limits its growth options and potential to gain from innovation.

Chapter Three
Analytical Framework

As the global economy evolved from the agricultural and industrial revolutions in the mid 18th century to the mid and late 19th, when rates of growth among nations rose exponentially, development history reflects that a paradigm shift took place, introducing knowledge as a key factor of production, resulting in what is now widely recognized to be next knowledge revolution of the late 19th and early 20th centuries (for example, Phillips (2007), Friedman (2004), Oliver (2003) and Robbins-Roth (2000) offer that biotechnology is called the next technological revolution, as cited below). Knowledge and innovation began to complement other means of production, transcending limits of contemporary production possibilities, by incorporating technological products in the market place, permitting faster rates of growth and competitive gains in global markets. Similarly, contributions from the literature offered new ways to explain and study the knowledge contributions to economic growth, as well as its multi dimensional and multidisciplinary breadth.

The theory section of this thesis focuses in a selected set of models developed to illustrate the type of frameworks that have been proposed to explain how knowledge and innovation get transferred through different channels and actors, ultimately resulting in commercializable technology outputs. The goal is to isolate, technology transfer mechanisms. The foundation from this analytical framework and the selection of theories, builds on Schumpeterian theory. Schumpeter (1939) is widely acknowledged as one of the first scholars to introduce theories of entrepreneurship and innovation. He proposed that innovation processes and technological advancement within nations was the result of the 'wild spirits'. He attributed the term wild souls or wild spirits to the entrepreneurs and categorized them as the individuals and companies who had the vision, resources and capacity to invest in R&D.

3.1 Theory

Over the past fifty years, globally competitive countries have shifted from industrial economies to knowledge-based economies. Historically, growth theorists have focused on land, labor and capital as key assets for competitiveness and growth. Currently, regardless of the perspective from which it is studied, economic competitiveness and growth depends on the consolidation and management of intellectual capital, the capacity to further knowledge and to foster an innovative society (Solleiro and Castañon, 2002; Drucker and Goldstein 2007; Scott 1993). Theoretical models of growth often did not explicitly engage education and the obvious knowledge fostered by it that accrues for technological change and development (Easterlin, 1981). New Growth Theory which emerged in the 1980's, posits an endogenous innovation system is the key factor for development and growth, rather than knowledge and innovation being an independent, exogenous or residual form of investment.

The evolution of growth theory grounded in the Schumpeterian school of innovation driven by entrepreneurship in the late 1930s, ranges from Solow in the 1950s and 1960s to the 1990s with contributions from Lucas (1988), Romer (1990; 1994), Grossman and Helpman (1991;1994), and Aghion and Howitt (1998), has helped establish endogenous innovation and technological change as factors for sustained increase in development, measured by input per worker. The system is fundamentally driven by factors of human knowledge and activities such as R&D.

Knowledge and technological innovation are key pillars for economic development and growth (Grossman and Helpman, 1991). Ultimately, innovation is much more than invention. Innovation most frequently occurs within systems whose aim is to transform inventions into socially-valued products, and where success is measured by the ease of which inventions are adopted and adapted by society (Phillips, 2005 and 2007). Innovation is characterized by the fact that society always reshapes what it uses; in turn, the ability to renew innovation is dependent on understanding the changing context in which successive innovation occurs. Innovation is thus a creative activity that takes place within an organizational and a social context and has organizational and social consequences. In essence, innovation is the entire process that results in an invention being commercialized (Phillips, 2007).

Innovation drives technological change. The pace of change that characterizes the convergence of new technologies that underlie globalization is very rapid. Technology has been defined as "... information that is put into use to accomplish some task (p.6)" (Feldman and Stewart, 2007). Technology extends human potential by allowing people to achieve things that they could not have previously done. To understand technology, we must understand the relationship between the material world and the human world, between things and people (Misa, 1992). New studies in technology theory suggest that the social component has to be closely linked with its economic impact. Technological change is not simply invention and innovation; it also implies the manner in which knowledge gets applied and how it helps to satisfy needs. The entire process has a fundamental social characteristic. In the modern technological system, this argument has perhaps more weight due to the increased impact that technology is causing directly in society, creating by consequence a greater impact and relevance to the importance of appropriate innovation policy.

The spread of computing power to every corner of the developed world, the advent of new biotechnologies and the emergence of new materials and handling systems have the potential to change the way people live and work. Among the diverse fields in technology, biotechnology – which is the manipulation of living organisms (genetic resources) to obtain a vast array of agricultural, medical, industrial and environmental products and services – represents a transformative technology that has been called the next technological revolution (Phillips, 2007; Friedman, 2004; Oliver, 2003; Robbins-Roth, 2000). Yet, doing the science well is a necessary but not a sufficient condition for firms, the industrial sector and nation-wide economic development that can flow from technological innovation. Instead, mechanisms must be in place to encourage the value-added potential of the science: so-called *technology transfer mechanisms* (Nonaka, 1995). These mechanisms have been identified to include stable and predictable macroeconomic, commercial and social policies as well as regulatory rules and laws for product approvals and intellectual property protection.

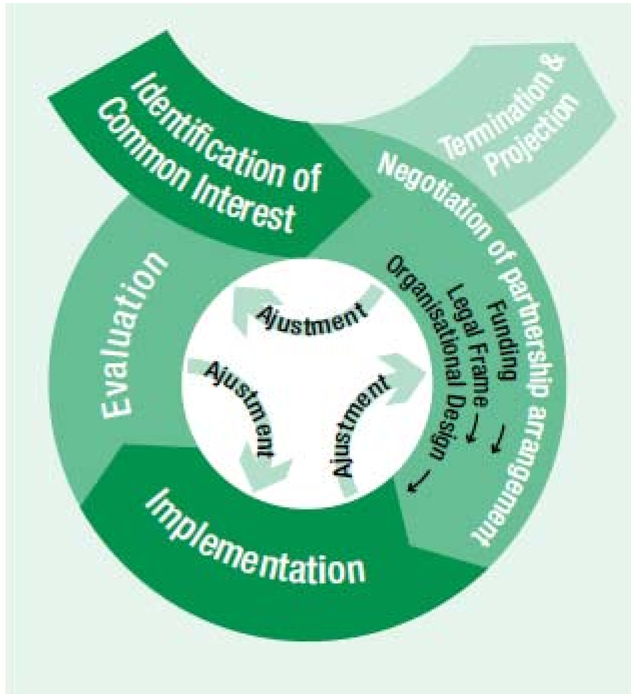
The present knowledge-based economy is characterized by knowledge playing the primary role to generate wealth. The challenge within the context of this new economic era is to efficiently extract, manage and translate knowledge for the benefit of the society as a whole. Technology transfer has been defined as "... the application of information into use where transfer is essentially the communication of information or technology (p.6)." (Feldman and Stewart, 2007). Technology transfer is influenced by national systems of innovation. The actors that contribute to consolidating innovation systems do so within localized structures that draw on international standards, generating productivity and growth, thereby offering a competitive advantage among nations.

Technology transfer has long-been an important issue, with the initial focus on the transfer of technologies for local use, but over time the focus shifted to technology transfer from the industrial world to the developing world. This was lead by the efforts undertaken as part of the 'Green Revolution' (Paarlberg, *et al.*, 2004). Like many streams of literature, over time the literature has diverged as the focus expanded. This is certainly applicable to the literature pertaining to technology transfer. One field of literature that developed focused on the relationship between innovation and the transfer of the resulting technologies.

In an article that assesses some of the public-private partnerships (P3s) undertaken by various centers of the Consultative Group on International Agricultural Research (CGIAR), Spielman and von Grebmer (2006) identify that 95% of the expenditure on agricultural research in developing nations in the mid-1990s was done by public institutions. In 1995, an estimated US$12.1B was spent on agriculture research in developing nations, with the objectives of enhancing crop yields, improving sustainable use of natural resources and the accumulation of capital for resource-poor, small landholding farmers. Their survey of 42 stakeholders involved with CGIAR public-private partnership initiatives found that the primary barrier for these initiatives was mutually negative perceptions of both partners, while the second major barrier was identified as fundamentally different incentive structures. One of the main reasons for the mistrust from the CGIAR stakeholders was the use of non-disclosure agreements, which ran counter to the cultural concept of sharing among the public sector researchers.

In a report undertaken through the International Food Policy Research Institute (IFPRI), Hartwich, *et al*., (2007) provide five general phases of public-private partnerships (Figure 1). The rationale for the establishment of these phases is based upon an analysis of 125 P3s drawn from twelve Latin American countries. The first phase is the identification of a common interest, where the potential partners assess themselves, but also the market, the value chain and the potential sources of financing. The second phase is negotiating the partnership contract, including financing and organizational design, where the main focus is on IP, but also includes the protocols for decision-making, information exchange and evaluation. The third phase is operating the partnership itself, which is quite straightforward in that this phase ensures that the partnership remains focused on the strategic plan. The fourth phase, evaluating the partnership, is defined as assessing the short- and long-term results, the functioning of the partnership and the evolution of the partnership. The fifth phase, deciding to terminate or continue the partnership, depends in part on the initial rational for establishing the P3, so it may terminate once specific milestones are achieved or continue to operate should a solid rationale exist.

Figure 1: IFPRI public-private partnership model



Source: Hartwich, *et al*., (2007).

While there is a plethora of literature on the interactions between the innovators and the commercializers of innovation (i.e. Rogers, 1962; Krattinger et al., 2007), Gilpin (2001) offers political economy framing to provide insight into the new market realities of globalization. He postulates that "although the end of the Cold War provided the necessary political condition for the creation of a truly global economy, it is economic, political, and technological developments that have been the driving force behind economic globalization." (Gilpin 2001, 8). Further, Gilpin observes that economic growth is a sociopolitical system composed of powerful economic actors or institutions (such as giant firms, powerful labor unions, large agribusinesses) competing with one another to formulate government policies on taxes, tariffs, and other matters in ways that advance their own interest. This thesis uses this political economy disciplinary approach to examine aspects of the transfer of technology and knowledge between public institutions and commercial interests.

Phillips (2010) identifies four broad competing theories of R&D, innovation and growth (Table 9), positing that focusing on understanding the theoretical lenses offered by each of the competing theories – based on neo-classical trade, clusters, innovation systems and creative economies theories, should highlight the importance of policies related to people, place and processes, providing valuable information in articulating appropriate innovation policy strategies.

Table 9: Four models of innovation

Assumptions	**Neo-Classical Trade Theory**	**Clusters**	**Innovation Systems**	**Economies of Creativity**
People	Individual optimization drives innovation	Angels and venture capitalists generate demand pull system	Research stars at core of science and technological push system	Creative, talented people ('creatives') driven by mix of personal and commercial motive
Place	Heckscher-Ohlin theorem posits production locates where comparative advantages match comparative endowments	"Agglomeration" of firms and industries create economies of scale where interdependences are traded (e.g. thick labour market and dense forward and backward linkages).	Untraded interdependencies (mysteries in the air) are geographically sticky	Creatives live in cities endowed by technology, talent and tolerance
Processes	Relative prices (e.g. wages, exchange rates, inflation, interest rates) more important than organizational structures	Mode 1 style system, where MNEs and Universities, interact in hierarchical processes; both are posited to be anchors for clusters	Social networks drive innovation in mixture of Mode 1 and Mode 2 systems (e.g. Triple Helix; Regional Innovation Systems)	Creative people live in purpose-built, heterogeneous, Mode 2 style networks

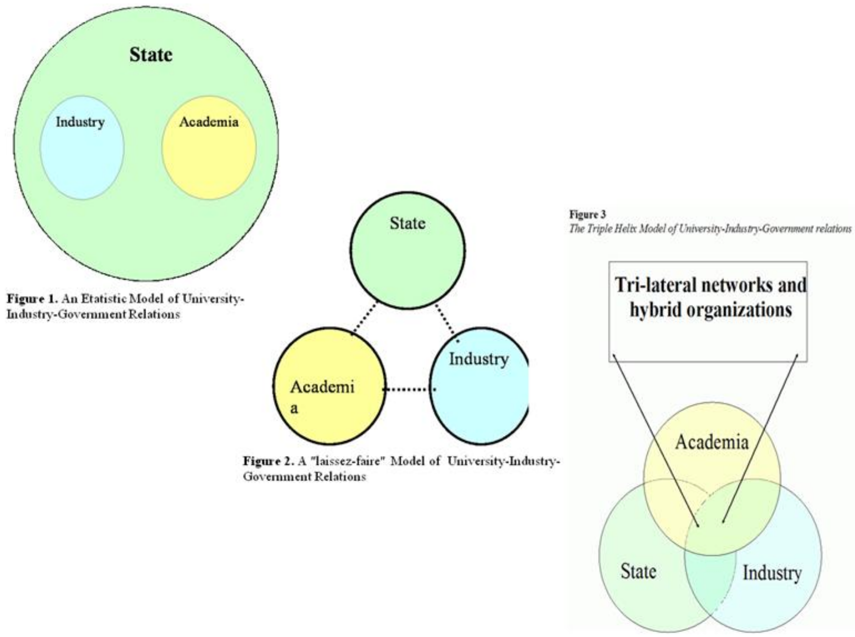
Source: Phillips, 2010.

Drawing on Phillips' four models of innovation, the theoretical analysis of this case study focuses on the insights provided by innovation systems theory, positing that Mexico needs to implement an innovation policy with immediate focus in strengthening its innovation system. Frameworks exist that attempt to conceptualize the innovation systems that are used, or have been used, to enable the transfer of public sector innovations.

One such framework is that offered by Etzkowitz and Leydesdorff (2000). The authors provide a Triple Helix model of innovation that examines the dynamics occurring between the public sector innovators of academia and government and industrial technology commercializers. Most discussions regarding the Triple Helix model of innovation analysis refer to the third version of this model, or Triple Helix III. The initial model, Triple Helix I, was very institutionalized and the relationships between academia, government and industry are largely controlled or directed by the state. The Triple Helix II relationship can be described as distinct innovation agendas with lines of communication between the three stakeholders that operated with high levels of mistrust and suspicion.

Triple Helix III is the model that most realistically represents the existing relationships in industrialized economies. In this model, distinct spheres represent academia, government and industry, but all three spheres overlap each other (Figure 2). The center of this model, where all three spheres overlap, is characterized by trilateral networks and hybrid organizations (Etzkowitz and Leydesdorff, 2000). Etzkowitz and Leydesdorff argue that the common objective of this model is "…to realize an innovative environment consisting of university spin-off firms, tri-lateral initiatives for knowledge-based economic development, and strategic alliances among firms (large and small, operating in different areas, and with different levels of technology), government laboratories, and academic research groups" (p. 112).

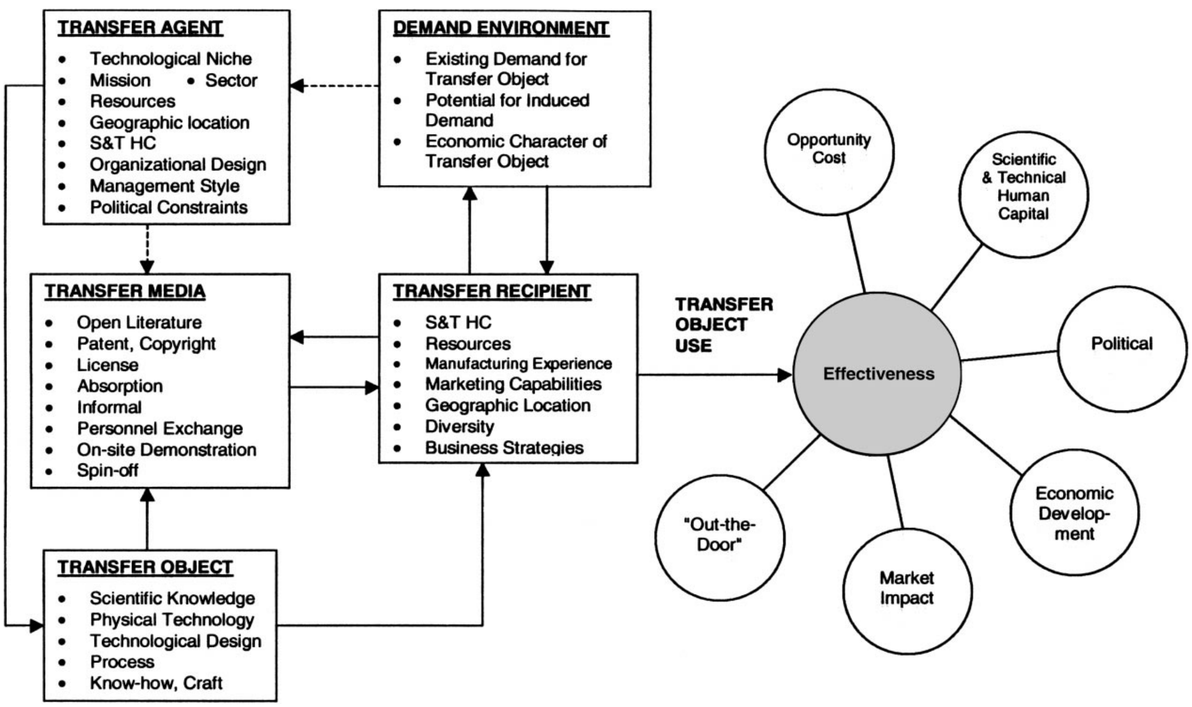
Figure 2: Triple Helix models of innovation



Source: Etzkowitz and Leydesdorff, 2000.

A second framework is the Contingent Effectiveness Model put forth by Bozeman (2000). Bozeman suggests that the various parties involved in technology transfer have diverse agendas and goals and that these are achieved to varying degrees of effectiveness. The Contingent Effectiveness Model (Figure 3) examines numerous factors within five identified parties involved in technology transfer from public institutions: transfer agents; transfer objects; transfer media; transfer recipients; and the demand environment. The transfer agent is the holder wishing to transfer a technology, such as a university. The transfer object is the particular innovative product or process to be transferred. The transfer media is the avenue chosen to commercialize the technology, such as starting a spin-off company or an exclusive license agreement. The transfer recipient is the party (usually a private firm, but not necessarily) that is interested in gaining access to, or purchasing, the innovative technology. The demand environment includes market and non-market factors that will impact the transfer process, such as price for the technology or the relationship to existing technologies. Bozeman argues that this model identifies "… that the impacts of technology transfer can be understood in terms of who is doing the transfer, how they are doing it, what is being transferred and to whom (p. 637)."

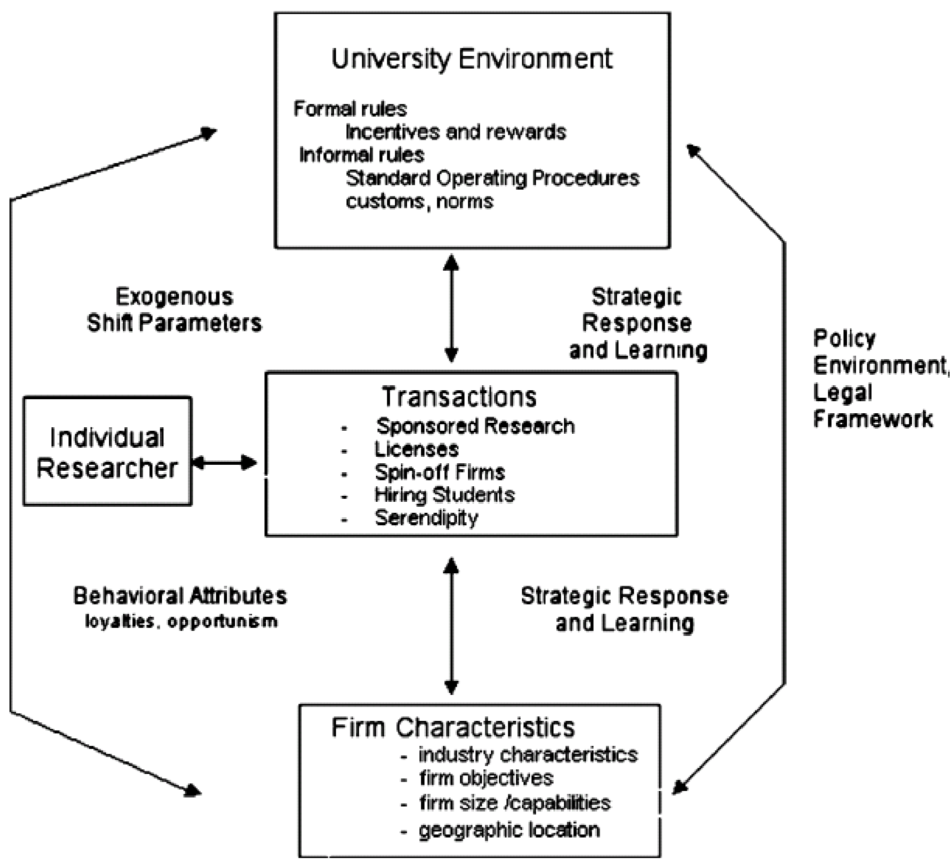
Figure 3: Contingent effectiveness model



Source: Bozeman, 2000.

A framework that focuses specifically on the transfer of university technologies is found in Bercovitz and Feldmann (2006). The authors argue that there are a variety of motivators and incentives within universities to transfer technology that is affected by economic, social and political influences. In examining the 'black-box' of university technology transfer, the focus is on "… factors that enhance or inhibit the creation and transfer of academic science" (p. 176). The University-Industry Relationship Schema (Figure 4) provides for an analysis of the dynamics that exists between the four crucial elements of university technology transfer: the individual researcher; the transfer mechanism; the firm characteristics; and the university environment. The dynamics that exist between the four principles of the schema are defined as exogenous shift parameters, behavioral attributes, strategic responses and policy/legal environments. Bercovitz and Feldmann argue that this framework highlights that "… legal, economic, and policy environments that comprise the system of innovation determine the rate and type of university knowledge production and thereby influence the rate of technology change (p. 186)".

Figure 4: University-industry relationship schema



Source: Bercovitz and Feldmann, 2006.

As Grossman and Helpman (1994) propose, economic policy makers face the difficult question of how to best promote rapid, sustainable economic growth in the face of depreciable stocks of irreproducible natural resources. Improvements in technology are the best chance to overcome the apparent limits of growth. Presently, innovation and technological improvements are the best choices for a country to increase its economic potential. One of the key factors for economies to truly take advantage of the benefits of globalization is to achieve a competitive level of technological development.

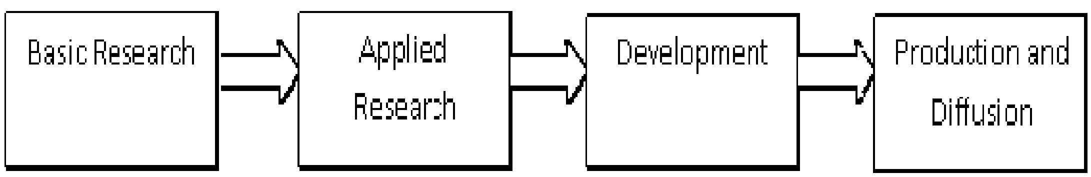
3.2 Linear and chain-link models of innovation

Due to the diversity of agents and processes that can be defined as part of innovations and the pieces that in one way or another intervene, the innovation process is complex. The simple linear model provided by basic research and applied research and development offers an interpretation of the innovation process. Over the past two decades, the model has evolved, moving from solely research and development, to include activities as broad as generation, modification and transfer of scientific knowledge and integrating technology knowledge, ultimately complementing and interrelating science and technology, and projecting this interrelation to a local, regional, national and international scope. As a condition for the advance of science, it must absorb the advances offered by technology; more than ever, scientific discoveries depend on the instruments provided by technology development, but more fundamentally in the facility that it provides to satisfy social needs and expanding competitiveness of production systems.

3.2.1 Linear model of innovation

Early efforts at providing understanding about the interactions of science and technology - in the form of R&D, with the economic environment in which they are performed, resulted in the definition of the linear model of innovation. Godin (2005) postulates that the linear model of innovation has been the preferred theoretical base for the justification of government support to R&D and for the development of S&T policy. Godin (2009) goes on to offer the following definition: "the linear model of innovation is a very popular 'theory' used until recently to explain technological innovation. It suggests that technological innovation starts with basic research, then moves on to applied research and then development. Once development is completed, the technology is produced on a large scale by industry, then diffuses through the economy" (p.6).

Figure 5: Illustration of the linear model of innovation

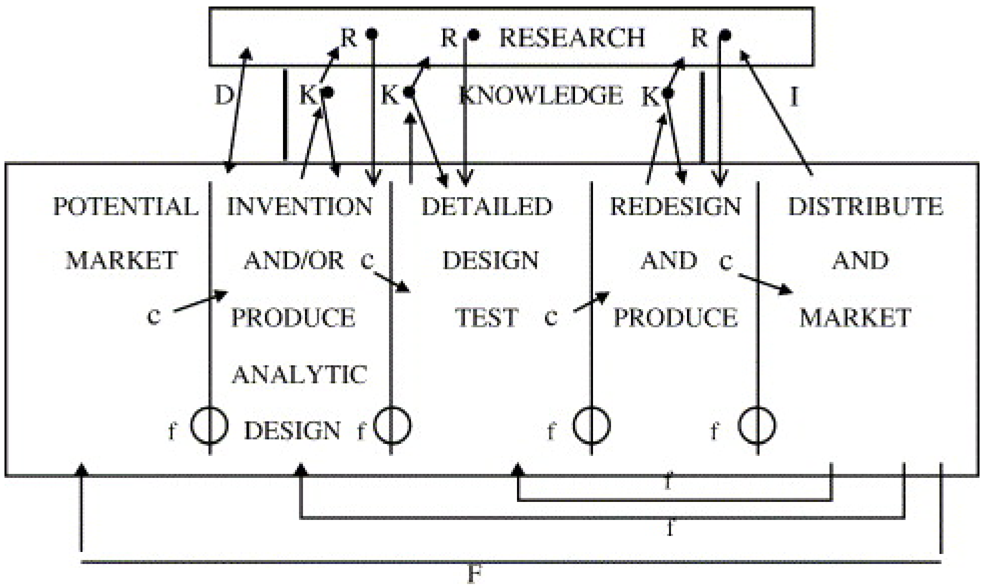


Source: adapted from Godin (2005).

3.2.2 Chain-link model of innovation

Wonglimpiyarat and Yuberik (2005) build on Rogers' (1962) innovation diffusion theory and compare the earlier linear models to the evolved chain-link models citing Kline and Rosenberg (1986) '…underlying the process of innovation is the strategic implication of successful innovation. The successful innovation needs an integration of in-house research activities, production activities, marketing, and inter-organizational relationships.' The work supports that innovation management and diffusion theories have evolved to chain-link models, factoring in concepts of technology push and demand pull to define the various actors and institutions that intervene at evolving stages of the innovation process.

Figure 6: Kline and Rosenberg (1986) chain-link model



Source: Wonglimpiyarat and Yuberik (2005).

Pretescu (2004) postulates that "according to Kline and Rosenberg (1986), the relationship between science, technology and the economy, society and markets is a more symbiotic or interdependent one than a simple linear relationship, stipulating that strong science leads to strong technology. Their chain-link model suggests a relationship of multiple feed-backs and cross influences between the elements, whereby: 1) Technological inventions facilitate advancements in science—understanding how and why inventions work; 2) Science facilitates new technological innovation/inventions--optimizing, improving and applying, and 3) Markets drive technological advancement and their application. Decisions on pursuing technological advancement are profit driven. These decisions may at times accelerate or impede the pursuit of the application of certain technologies into marketable products" (p14).

The models selected for this study, described earlier, are interpretations of the chain-link model, adapted to propose and illustrate the relational dependency of all the different actors in the systems as proposed by the theoretical purpose of each framework. Some of these models and theoretical contributions have increasingly being referenced by OECD measurements of impacts and development of technological capacities by member economies. It can be inferred that most developed economies have successfully adopted a type of chain-link model in which to base their innovation policies.

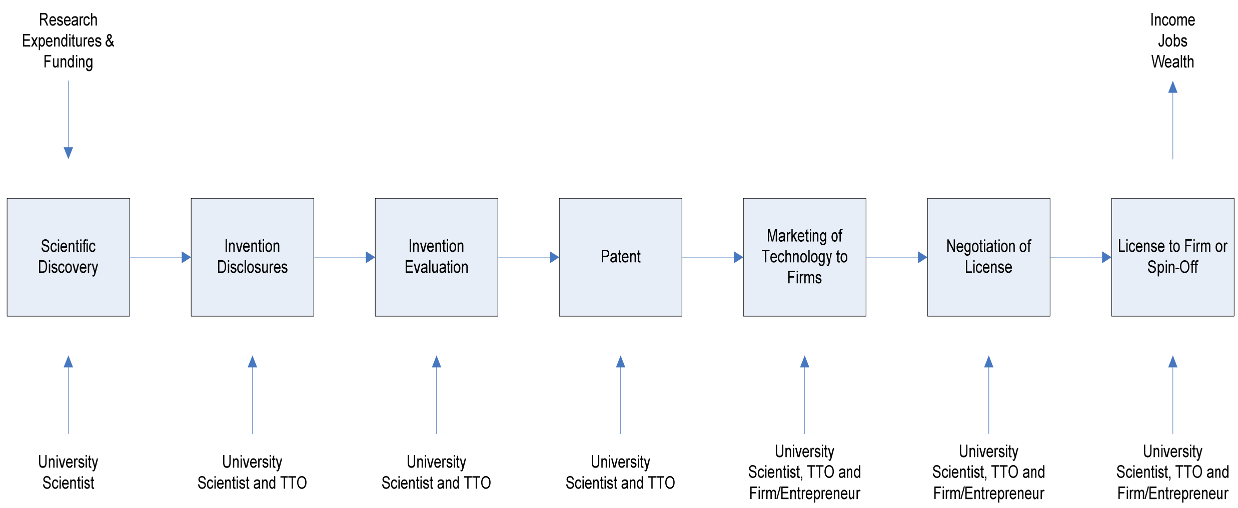
In the case of developing or transitional economies, given the relational complexity of the chain-link models, compared to the weaker interactions among institutions, seem to have less opportunity for success. The earlier and simpler concept of a linear model, finding R&D as its departing point, to then evolve toward developing an innovation system, seems as a most viable alternative for developing or transitional countries. As Schumpeter (1939) posed at the advent of the knowledge economy, a linear model can be seen as science push model in which efforts and outcomes of R&D activities are moved further into production.

3.3 Mexico's S&T capacity in the 21st century: The National System of Innovation

An *ex-post* analysis about the 1994-1995 technological competence in Mexico indicates that the model of an open economy has not functioned as an effective and efficient catalyst for processes of transfer and acquisition of technological capacities. This model of economic openness assumes a synergistic relationship among direct foreign investment, international markets and, on the other side, the technological capacity of the country. It is perceived that this relationship only occurs to economic leaders when certain conditions are given. As the technological capacity in Mexico was so obsolete and rudimentary (see Chapter Two), there is an obvious lack of balance among the factors. The natural reaction would be then to promote technological advancement and competitiveness to compete in global markets.

While an initial contrasting of the Mexican system of innovation to the frameworks observed here would suggest that the country seems to fit the Etzkowitz and Leydesdorff's Triple Helix I mode, given the strong state intervention in the system, further contrasting suggests that although the designing of an innovation system and policy in Mexico is intended to be more closely aligned with those of developed nations, the lack of dynamism in the relations among the system's players provides evidence that even an early stage chain-link model of innovation in Mexico is a premature alternative. From the various frameworks for technology transfer discussed in this chapter, the one that is most readily adaptable to Mexico's unique situation is that offered by Feldman and Stewart (2007). The earlier discussions of technology transfer models are based on assessments of technology transfer in industrialized economies and therefore, are too institutionally complex. Feldman and Stewart offer a form of a linear model, or a clear representation of a logical model of innovation, that illustrates a very basic, early stage planning/adoption of a process leading to obtaining clear understanding of the stages necessary to carry forward a scientific input to a commercializable or transferable outcome. This is supported by the linear model of innovation analysis in Godin (2005), which posits that a linear model is "... a thought figure that simplifies and affords administrators and agencies a sense of orientation when it comes to thinking about allocation of funding to R&D" (p.35). This model, given its simplicity, can be adapted to closely represent the present technology transfer situation in Mexico and can be built upon to provide the base for an innovation system with state sponsored R&D as the starting point in the development of a scientific infrastructure (Figure 7).

Figure 7: Linear model of how technology is transferred



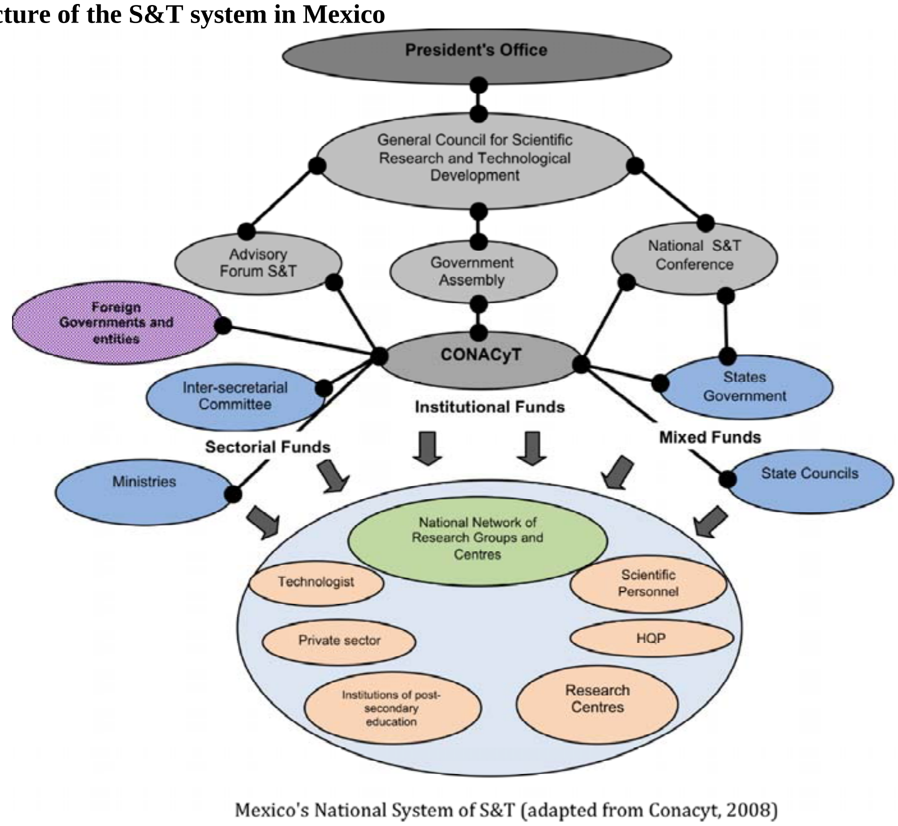
Source: Adapted from Feldman and Stewart (2007).

The technology transfer processes and the environment in which it exists are influenced by national systems of innovation and it is evident that they are extremely different in economies known for their innovative leadership and those with less developed characteristics, like Mexico (Moravcsik 1985, cited in Hill 1986). Recent analysis of the concept of national systems of innovation (NSI) focuses on how to measure performance or under performance in the technological capacities of countries. Much of this work is based on a clear-cut approach derived from 'wins' experienced by NSI in highly developed nations. But this approach does not fully accommodate the organizational and institutional structures among countries with greatly different context, especially in the case of developing countries. For example Balzat and

Hanusch (2004) conclude that the development stage and functioning of innovation systems in less developed countries give them a fragmented characteristic which makes the notion of a national system of innovation somewhat irrelevant. In advanced economies, the macroeconomic, commercial and industrial policies, as well as the regulatory system, are characterized by stability and integration, thus their national system of innovation can contribute greater functional cohesiveness. In Mexico, in spite of a fairly well consolidated set of institutions devoted to research and development, the innovation system is largely disarticulated (Solleiro, 2002). Government and its policies are in continuous opposition to the needs of the academic and scientific community and although changes have been proposed, and recently attempted, they have not yet shown major results that will open doors for complementary actions and feedback. It is also important to note that the country has problems organizing and coordinating the different levels of government, resulting in a lack of identification and focus on other social problems. Policies for health, education, wages, retirement and pension plans are extremely poor, causing an important shortage of human and physical capital. Mexico likely has to urgently address this situation, as it impedes human capital, which is the key determinant of productivity levels, and productivity growth in the long run (OECD, 2005).

Before moving forward with this analysis, it is important to offer a general overview of the organizational infrastructure of the main actors in the science and technology (S&T) panorama in Mexico (Figure 8).

Figure 8: Structure of the S&T system in Mexico



Source: Adapted from Conacyt 2008.

The Mexican S&T institutional structure is lead by the country's President, through the Ministry of Public Education (SEP). The SEP is the ministry whose budget ledger accounts for all of the funds allocated to S&T activities in the country. The S&T agenda in Mexico aims at coordinating and fostering scientific and technological development in Mexico. This agenda is monitored by a General Council, which streams down to three main groups of stakeholders as shown in Figure 8. Dependant of the SEP and the General Council and other 'high level' stake holders, the National Council for Science and Technology (CONACyT), formed in 1970, has the mandate to organize, coordinate and facilitate Mexico's S&T agenda. Its mission is to foster and strengthen technological development in the country by fostering scientific research, supporting technological development and modernization, establishing programs for the training of highly qualified human resources, as well as the communication and dissemination of S&T data and information (CONACyT, 2005).

While CONACyT provides one aspect of S&T leadership in Mexico, it is also surrounded by another layer of stakeholders who ultimately filter down decisions and operating policies to the S&T network level where the actual activities of S&T take place. This operating level is coordinated by CONACyT and it consists of the SEP-CONACyT Research and Development Centres in Mexico. These R&D centres are the main locations where most of Mexico's scientific research is performed. There are currently 26 R&D centers in Mexico, grouped in three main categories according to their area of specialization: Natural Sciences and Engineering Disciplines; Social Sciences and Humanities; and Technological Development. CONACyT is also responsible for the administration of the *Sistema Nacional de Investigadores* (SNI) (National System of Investigators), whose main objective is to provide support and incentives to researchers in the public, private and academic sectors, important stakeholders who are considered key actors in the S&T network. The goal is to stimulate the efficiency and quality of research productivity in Mexico, albeit, at various levels of coordination and functionality, which ultimately affects their impact in contributing to the shaping of the S&T policy in the country.

Parallel to the R&D activities performed at the SEP-CONACyT Centers, Mexican universities (public and private) also play an important role in the country's R&D activities. One must keep in mind that universities in Mexico are structured differently than the known structures in most developed nations. In Mexico, university education in private institutions is considered to have the highest quality. In fact, employers value significantly more a graduate from a private university than someone from a public institution as it is widely recognized that educational programs in public universities fall behind in terms of quality and ability to train highly qualified personnel. Further, R&D activities are not a fundamental mandate of the university later phase in Mexico. There is minimal funding in support of R&D efforts at Mexican public universities. The Sub-secretary of Higher Education and Scientific Research (SESIC), under the SEP, regulates and promotes research activities in universities and is responsible for budget allocations.

There are also other entities that integrate the S&T infrastructure in Mexico, such as state or provincial councils and agencies, as well as the commissions of S&T in the Mexican Congress and Senate, agencies that ultimately determine and move forward the S&T agenda in Mexico. Figure 8 shows the complexity and the 'top heavy' characteristic of the Mexican National System of Science and Technology. Although the formal structure appears to offer a very attractive potential for further analysis of the S&T agenda, the following section, concentrated on the National Network of R&D in the country, suggests that the level where scientific discoveries are created and moved forward through the innovation process (to yield desirable economic outcome) is somewhat disconnected from the formal superstructure.

Following the change in government in 2000, Mexico recognized that efforts to encourage scientific research and technological development in countries are directly aligned with the degree of economic performance. In 2001, the Mexican Law of Science and Technology, enacted a constitutional commitment from the Federal Government to prioritize and encourage S&T in the country. The instrument to set the framework into is the *Programa Especial de Ciencia y*

Tecnología 2001-2006 (PECyT) (Special Program of Science and Technology 2001-2006). Its mandate is to support a structural change in the National System of S&T.

From the same baseline law, an amendment of the Law of Science and Technology established the obligation of the public and private sectors, to invest at least the equivalent to one percent of the country's GDP into S&T activities. This new addition to the law is at the core of the PECyT, announced by the Council (CONACyT, 2001). The plan had three strategic objectives: 1) to establish a national policy in regards to S&T; 2) to increase the country's scientific and technologic capacities; and 3) to increase the competitiveness and innovativeness of the Mexican business sector.

The objective of the rest of this thesis is to contrast the effectiveness of the Mexican policy as intended by the objectives in the PECyT, in order to stimulate knowledge creation and growth relative to the country's reality and its capacity to achieve such objectives. The Feldman and Stewart logic model of technology transfer flow will be used to structure the analysis. Chapter 4 provides a detailed assessment of the crucial factors for assessing the success of the strategic objectives.

Chapter Four

Results

Feldman and Stewart (2007) posit that R&D and technology transfer refer to research activities undertaken primarily at universities, as these institutions are the main innovation contributors (or most commonly involved in innovative research activities) in most developed countries. As noted above, Mexico's S&T infrastructure has a distinctive characteristic in that it is mostly agglomerated into a hierarchy of R&D centres, dependant on, and reporting to, the central coordination of the SEP-CONACyT. There are also a number of public and private universities (e.g. the *Universidad Nacional Autónoma de México* (UNAM), the *Instituto Politécnico Nacional* (IPN), the *Instituto Tecnológico y de Estudios Superiores de Monterrey* (ITESM), and others) in Mexico that historically provided the base for the recent consolidation of the network of R&D centres; these institutions are known as IES (Higher Education Institutions). For the purpose of this study as well as for comparative purposes, 'university R&D' will be considered to be R&D activities in México, carried out by the SEP-CONACyT network and the IES.

The Mexican PECyT 2001-2006 contained three main strategic objectives that involved 14 strategies (Table 10). These 14 strategies, which are also among the 19 main actions identified by the Mexican National Development Plan 2001-2006, are the factors that should have helped Mexico "to position itself as one of the ten most important economies in the world and among the twenty most advanced in science and technology" (CONACyT, 2001).

Together with the launch of the PECyT, a number of policies were passed by the Mexican Congress with the intention of supporting the PECyT's framework. One of such policies, approved by Congress in late 2002 gave CONACyT absolute control over the delivery and management of the S&T agenda for all federal agencies, at the same time as the line of reporting was removed from the Ministry of Education directly to the president. This new acquired autonomy was supposed to give CONACyT freedom to focus specifically on applied research activities to link the country's scientific priorities to national problems and technological solutions of social value. As well, the Council was given authority to pursue the objectives and strategies in the PECyT by aligning priority areas among all federal agencies and fostering participation of all Mexican states.

Table 10: The Mexican PECyT's objectives and strategies

Fundamental blocks	*Strategic objectives*	*Strategies and action plan*
a) The National System of Science and Technology	1. Establishing a State policy in Science and Technology	1. Structure the National System of S&T 2. Revise CONACyT's legal framework to allow for changes in its mandate 3. Foster strategic areas of knowledge necessary for the advancement of the country 4. Decentralize the S&T activities 5. Encourage a culture of knowledge among Mexican society
b) National Scientific and Technological Capabilities	2. Increase the Country's Scientific and Technological Capacity	6. Increase the national budget for activities of S&T 7. Increase the country's base of highly qualified personnel in S&T 8. Foster basic and applied R&D 9. Broaden the S&T basic infrastructure including the various levels of education system 10. Strengthen international cooperation in S&T
c) Competitive and Innovative Business Sector	3. Increase the competitive and innovative level of the business sector	11. Encourage private sector investment in R&D 12. Promote technological development and R&D participation among companies 13. Promote the incorporation/hiring of scientific-technical personnel in companies 14. Strengthen the infrastructure aimed at supporting and fostering competitiveness and innovativeness among companies

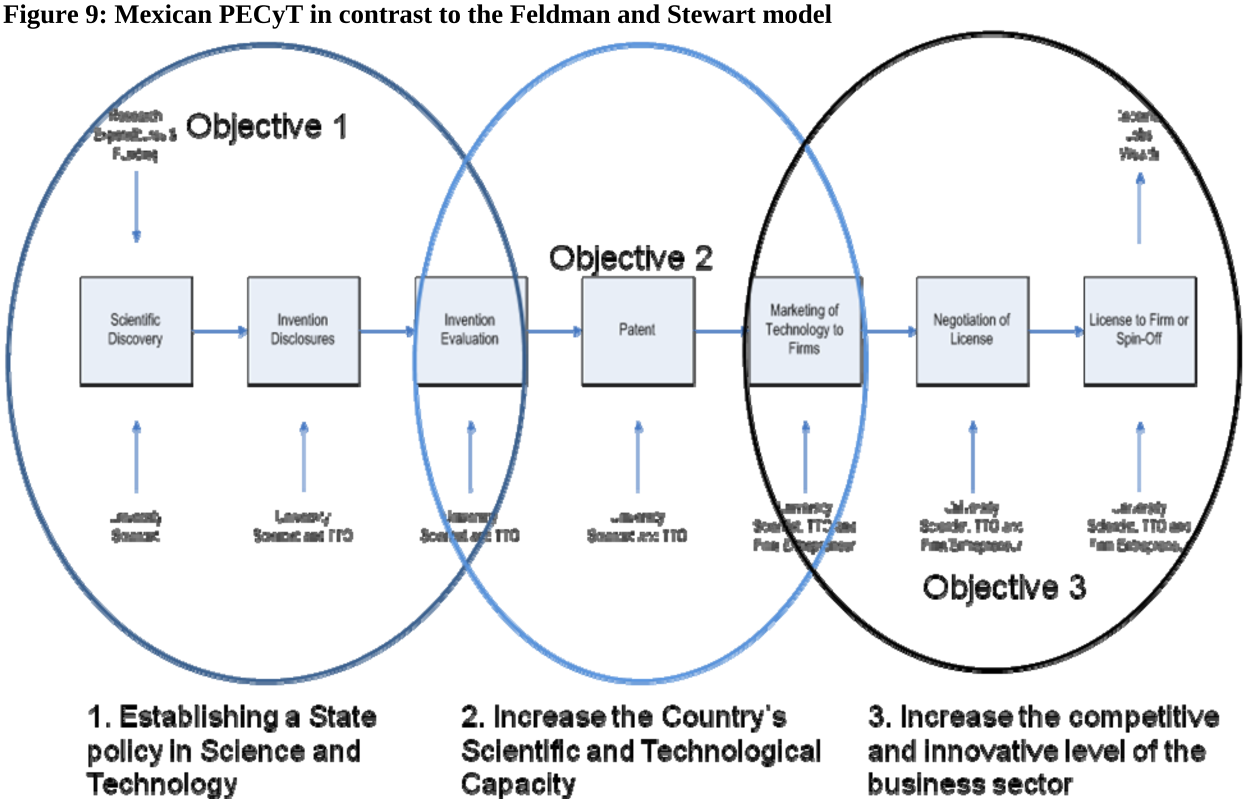
Source: Adapted from Conacyt 2001.

4.1 Mexican model of innovation: PECyT as a linear model

The Feldman and Stewart flow chart in Figure 7 assumes a parallel synchronized flow of knowledge throughout the chain of actors that transforms knowledge into public goods, benefiting society and improving quality of life along the way. Knowledge is, in part, derived from education (one of the core responsibilities of government) and an innovation intensive society depends upon an educated society. The Feldman and Stewart model starts with the existence of scientific discovery or knowledge, which is available to flow through the stages and actors it will encounter in its lifecycle. The push of scientific discovery is dependent upon the investment of resources into a synchronized, well-connected and communicated system of knowledge creation.

Comparing the Feldman and Stewart model with the Mexican PECyT strategy (Figure 9) reveals horizontal similarities, where the three main foundational blocks are identified as: 1) institutions; 2) resources and infrastructure; and 3) markets and adopters.

Figure 9: Mexican PECyT in contrast to the Feldman and Stewart model



As supported by the analytical framework in this thesis, the proposed linearity of selecting the Feldman and Stewart model (2007) allows separating parts of the S&T agenda focusing into pieces to provide an in depth analysis. The flow of knowledge through the model starts with R&D funding which coincides with the first objective of the PECyT. As referenced in the theoretical background, Schumpeter (1939) introduced ‘science push' as one departure point on which a system of innovation can be built. The first objective and foundational block proposed here will focus on determining if this primary departing point is present and sufficient in the Mexican PECyT. Only if it exists in Mexico, to continue with an analysis of the second objective, namely the intention to increase the country’s capacity with regards to S&T, and finally, to complement the system by focusing on increasing the competitiveness and innovativeness of the Mexican business sector, the second and third objectives of the PECyT.

4.2 Objective 1: Establishing a State policy in Science and Technology

In the PECyT of 2001-2006, the first objective and the relating five strategies recognize the need for a well-integrated S&T system.

Table 11: PECyT Objective 1: The National System of S&T

Strategic objective	*Strategies and action plan*
1) Establishing a State policy in Science and Technology	1. Structure the National System of S&T 2. Revise CONACyT’s legal framework to allow for changes in its mandate 3. Foster strategic areas of knowledge necessary for the advancement of the country 4. Decentralize the S&T activities 5. Encourage a culture of knowledge among Mexican society

Source: Adapted from CONACyT, 2001.

The objective and strategies are aimed at promoting and consolidating S&T policy by bringing together all the existing actors of a historically fragmented and disconnected S&T infrastructure into a cohesive legal framework. Prior to the PECyT, the activities of S&T were centralized by the state, so that different government sectors felt disconnected from the S&T agenda and therefore were less interested in adopting policy changes into their own objectives and mandates. Historically, this lack of identification and coordination among federal entities hindered the onward movement of the national agenda resulting in failed national S&T efforts. A decentralized approach to S&T would allow each government sector and regional entity the autonomy to adopt S&T strategies aimed at creating and strengthening sectorial and regionalized technological capacities, which together would create a synergistic force that would translate into national competitiveness. While the activities of S&T are decentralized, the national strategic focus would be consistent with the critical areas for the country's development. If effective, these measures would assist in promoting S&T alternatives to the most needed areas of development in the country, by encouraging the Mexican society to be more receptive to the acceptance and implementation of scientific knowledge.

The existence of a cohesive S&T development system is a necessary foundation for competitive performance relative to international standards. In Mexico, there are too many layers of bureaucracy involved and directly governing the flow of resources and communication in regards to the S&T agenda. As presented above, the main knowledge generators are the SEP-CONACyT centres and a limited number of autonomous universities and specialized institutes (which receive funding from the Council). Prior to the inception of the PECyT and the amendments to the S&T law that followed to support the plan activities, CONACyT only received and administered about 13% of the government expenditure on R&D (CONACyT, 2007). This dramatically limited its capacity to foster, improve and position the country's R&D activities at internationally competitive levels, thereby hindering its scientific capacity for generating knowledge. With the inception of the PECyT, CONACyT acquired complete control of the country’s national agenda for S&T, implementing programs and supporting systems. This provides it with the opportunity to align the national priority areas with those of the states and to receive, allocate and monitor funding to R&D activities as identified in the strategies to the first objective of the PECyT. However, in the period covered by the program, the country failed to deliver on the objective. No changes have resulted that would indicate that Mexico has moved forward to consolidating its S&T system. Although it was recognized by OECD that Mexico had made impressive steps toward reviewing its innovation policy and aligning it with international standards (OECD, 2004), data published by the organization in the years following the launch of the program, confirm the inability of the country to reach its objective. It seems as though CONACyT did not respond well to its new mandate of being responsible for the S&T agenda. The Council did not find the right mechanism to foster participation from the states and no immediate actions were followed to address areas of priority for the country, or implement programs to encourage and motivate the scientific personnel in working together towards addressing such needs. Similarly, no educational initiatives and institutional changes took place to allow CONACyT to respond to its new mandate.

Concurrently, at the academic institutional level there was a lack of programs providing incentives for collaborative approaches among institutions. Existing incentives for scientific productivity were measured by publications rather than by knowledge transfer and/or training of highly qualified personnel. As well, scientific collaborations between institutions had been historically scarce due to the lack of motivating incentives for researchers to seek affiliation with a diverse network of institutions. Such collaborations, including international collaborations, could increase access to a wider R&D capacity.

Similarly, communication and collaboration between R&D centres including the IES and business and industrial sectors were not efficiently facilitated. The state acted as the main liaising entity to foster and encourage collaboration. A crucial barrier to the success of these efforts was the historic mistrust from the business and industrial sectors towards these government initiatives, as well as the burdensome bureaucracy that is required to access them.

The Mexican government has taken impressive steps towards setting the foundation for a consolidated regulatory framework on which to base its S&T system. Since the 1970s however, the lack of continuity and consistency from one administration to the next has created an unstable political environment whose antagonisms create ruptures at the legislature level. When this is combined with the unfriendly legal framework for business and industrial sectors, it is virtually impossible for government to realize the targets established by successive administrations.

4.3 Objective 2: Increase the Country's Technological and Scientific Capacity

The second objective of the Mexican PECyT identifies the need for an increased scientific and technological capacity in Mexico (Table 12). Five critical strategies are identified to enable Mexico to achieve competitive knowledge creation. Once a cohesive and accessible S&T system exists, government expenditure in R&D would directly be applied by a congruent set of mechanisms to promote investment in development areas which are paramount for Mexico.

Table 12: PECyT Objective 2: The National Scientific and Technological Capacities

Strategic objective	*Strategies and action plan*
2) Increase the Country's Scientific and Technological Capacity	1. Increase the national budget for activities of S&T
	2. Increase the country's base of highly qualified personnel in S&T
	3. Foster basic and applied R&D
	4. Broaden the S&T basic infrastructure including the various levels of education system
	5. Strengthen international cooperation in S&T

Source: Adapted from CONACyT, 2001.

The OECD has indicated that in order to achieve S&T competitiveness countries would have to annually invest at least 1% of GDP in R&D activities. Mexico has struggled to reach roughly 0.38% of GDP as government contributions to the activities of S&T, measured by Gross Expenditure in R&D (GERD) in the 10 year period to 2003. As showed in Table 2 (Chapter 2), Mexico has lagged behind the pace of other OECD countries and in fact, it is now positioned behind other similar economies in the G5 block. After the debt crisis of the late 1980's, the country implemented a dramatic change in trade policy and became an open economy. Mexico became member of the General Agreement on Tariffs and Trade (GATT) and commenced the negotiations for the NAFTA. During the first half of 1990 Mexico also accessed World Bank lending in order to devote resources to strengthening its domestic capacity in S&T. The World Bank credit of over US$100 million was matched by the federal government and was used to invest in research infrastructure, scholarships and research incentives for retention of R&D personnel, among other programs in the states to promote regional development. Such initiatives paid off and by 1991 the GERD in Mexico rose to 0.33% of GDP, from slightly more than

0.20% in 1990. In 1994, this indicator reached 0.46% of GDP, partly closing the gap with other OECD nations. Then the crisis of the late 1994 and early 1995 put a stop to the anticipated economic growth. From 1994 and to the data presented in Table 2, Mexico has barely maintained minimum investment on S&T and has put the innovation agenda at a lower priority. In 2005, Mexico GERD was roughly at 0.46% of GDP while the average of OECD members has reached well above 2% of GDP, positioning Mexico last among OECD country members. The US in 2007, invested 2.68% of GDP, Canada 1.88%. Among G5 countries, Mexico also ranks last, with countries such as South Africa promoting GERDs of 0.92%, Brazil at 0.98% and China at 1.46%.

Furthermore, the federal government continues to be the main source of R&D financing, as business and private sector investment in R&D remains scarce, a manifestation of the lack of transference and knowledge mobilization as industries do not incorporate R&D into their production process. In industrialized economies, the majority of the R&D financing stems from the private and industrial sectors, as shown in Table 2, where the OECD average of GERD financed by these sectors in 2007 is 65%, while the R&D performed by industry sector average is 70% for OECD members. In Mexico the same indicators at 2005 were 46% and 49% of GDP respectively, once again falling behind other emerging economies such as China (70% and 72% of GDP respectively) and South Africa (43% and 58% of GDP respectively).

As previously stated and supported by the literature review of this thesis, scientific competitiveness is promoted among other factors by fostering knowledge creation in societies. In terms of human resources in S&T, Mexico falls to an extremely low level, relative to OECD country members. In fact, the OECD ranks Mexico at the lowest levels of human capital. In

Mexico, data to 2003 showed that only 20.6% of the employed population possess tertiary education, while in countries such Canada 42% of the employed population have attained tertiary education (37% in the US, 37% in Finland and 35% in Japan). The OECD average was 28.2%. (OECD, 2003). Of people actively employed who possess tertiary education in Mexico, 88% correspond to bachelor level, while graduate education is only reported by 12% of the employed population (11% at masters level; 1% doctorate) (CONACyT, 2007). Such data sheds light on one more reason for the low Mexican productivity and levels of specialization in producing technologically advanced products, industry and business sectors do not have the highly qualified base of human resources that other countries have. Mexico has not succeeded at providing a competitive level of education programs and infrastructure to strengthen its S&T human resources. As Table 3 shows, Mexico in 2005 had 43,922 (full time equivalency) total researchers, while countries such as the US, 1,394,682. Based on population, Mexico would need to have 11 times more researchers to match the US performance. The US has 9.7 researchers per each 1000 employed population, while Mexico had 1.2 pear each 1000 employed population.

Similarly, in terms of Mexican contributions to global knowledge, the country ranks 22nd among OECD members in terms of scientific publications in the total OECD country members, with 0.68% of total (1997-2006) (Luxemburg ranked 30th with .02% while the US is ranked 1st with 32.3%) (CONACyT, 2007). Relative to other Latin America countries and the G5 block, Mexico continues to be below Brazil (1.92%) and China (7.90%) in 2006. Moreover, in terms of the quality of the scientific contributions derived from scientific publication from Mexico, the country's impact factor relative to the world, positions it as 28th of the 30th OECD members statistics with a relative impact factor of .62. Switzerland is ranked 1st in terms of quality of publications with a relative impact factor of 1.54 and Turkey ranks 30th, just below Mexico at a 0.43 relative impact factor as supported by the data in table 3.

4.4 Objective 3: Increase the Competitive and Innovative Level of the Business Sector

The third objective focuses on the markets and adopters of S&T activities in Mexico Table 13). The objective and its strategies are concentrated on increasing the competitiveness of the business sectors by facilitating and strengthening the processes of commercial innovation.

Table 13. PECyT Objective 3: Competitive and Innovative Business Sector

Strategic objective	*Strategies and action plan*
3) Increase the competitive and innovative level of the business sector	1. Encourage private sector investment in R&D 2. Promote technological development and R&D participation among companies 3. Promote the incorporation/hiring of scientific-technical personnel in companies 4. Strengthen the infrastructure aimed at supporting and fostering competitiveness and innovativeness among companies

Source: Adapted from CONACyT, 2001.

This third objective represents a major challenge under the current framework and design of the Mexican S&T system. If it were possible to isolate this objective with its four strategies and analyze it separately, it would show the magnitude of the required effort to promote a shift in management practices from the business sectors. It would require years of educational efforts in order to prepare the Mexican society to be willing and ready to invest in R&D for competitive purposes. Table 2 shows the weak participation of the business sector as a key promoter and user of S&T. However, with the inception of the PECyT, the Mexican government also implemented strategies aimed at mending the historically disconnected linkages between the industrial and business sectors. One such initiative was a collaboration with the *Secretaría de Hacienda y Crédito Público* (Mexican taxation authority). The percentage of tax benefit to R&D was increased to 30% recovery rate from 20% since 1998 and the program budget also increased from roughly US$50 million to approximately US$370 million with the change in 2001. The OECD recognized this initiative and has noted that Mexico has the highest fiscal stimuli to R&D in private sector, among OECD member countries. Although no strong evidence has been shown to support the claim that this tax credit has indeed motivated the industrial sectors in the country to produce new product and processes transferred to global markets, it is worth noting that in the period from 2000 to 2006 the percentage of GERD financed by the private sector increased from 14% in 1993 to almost 40% in 2006. This is perhaps the greatest achievement of the PECyT.

The PECyT also worked to implement programs to increase the support to projects of technological development which incorporate activities of R&D. Two such initiatives were the 'sector funds' and 'mixed funds'. The sector funds were initiatives in conjunction with other federal agencies, matched by CONACyT, aimed at addressing national priorities (e.g. health, environment, agriculture and communications), as per the platform set forth by CONACyT in its new charter as the central S&T policy proponent. The mixed funds were initiatives also spread in the various Mexican states with matching funds from the CONACyT. The AVANCE program, managed solely by CONACyT had the purpose of providing support to innovation by funding transference of technologies in the last stages of the innovation process. This includes providing entrepreneurship support, angel investments through warranty program and spin off support for creating technology based local companies.

While the policies implemented in support of the third objective have been innovative and have stimulated interest from some industrial and private sectors in Mexico, there is still a high degree of mistrust by industry as the support from the government has lacked continuity and consistency, hindering achieving mildly positive results. Unfortunately, no concrete data has been developed to allow measurement of the concrete impact of the third objective and its strategies. That being said, it is important to note that there is strong evidence about the industrial and private sectors being receptive to policy changes, as per the result from the fiscal stimuli package, which increased the investment from these sectors to incorporate R&D in their processes. However, without proper consistency and follow up from the policy level, the momentum gained by such changes would likely dissipate.

The most crucial factor to note is that the federal budget for investment in R&D continues to be unchanged and lags behind all other global players as noted in the last two sections. The data presented in Chapter 2, which positions Mexico among OECD members and the G5 shows an urgent need from the country to increase the pace, and to maintain the momentum created from recent past efforts in order to take advantage of synergies brought about by its membership in international agreements and treaties.

This section has offered an analysis of the three objectives of the PECyT from 2001-2006, against the linear technology transfer model, selected for its relatively less complexity and better fit with the Mexican reality. Data has also been provided to measure Mexico’s S&T performance relative to other transition economies, as well as a selected group of developed nations.

4.5 Strategic Implications

As it is the case with most countries in the last few decades, Mexico has taken impressive steps towards setting the foundation for a consolidated regulatory framework on which to base its S&T system. Since the 1970s however, the lack of continuity and consistency from one administration to the next has created an unstable political environment where antagonisms create ruptures at the legislature level. When this is combined with the unfriendly legal framework for business and industrial sectors, it is virtually impossible for government to realize the targets established by successive administrations.

The linear technology transfer schema proposed by Feldman and Stewart, identifies an efficient and fluid system to move an innovative technology from one phase to the next. To a considerable extent, the three PECyT objectives attempt to establish a similar linear, efficient and fluid system of innovation and technology transfer in Mexico. This section offers a critical assessment of each of the three objectives, by highlighting gaps in the PECyT objectives and strategies as compared to the Feldman and Stewart schema.

The flaw of the first objective and strategies seems to be that while the Mexican government continues to revise, reform and restructure its S&T system, it does not appear to have achieved a truly nationally integrated system. Science and technology development should not be seen as a separate, independent, institutionalized sector of the country's development plan, but rather should be integrated into the priority areas. Science and technology needs to be an integral piece of every government sector, so that policies can move forward with greater certainty. As it stands, the legal framework for the S&T system fails to align with its own policies and efforts on economic growth, social growth, infrastructure, foreign and trade policy, among others.

Without this integration, where each stakeholder in the governmental structure identifies the importance of S&T for development and at the same time abandons the historic practice of competition, the country will continue to experience failed attempts to set an acceptable framework at the core of the S&T model.

Growth literature proposes (as generally accepted by competitive nations) that in order to compete and succeed in the global scheme, countries must commit to invest at least 1% of their GDP to the activities of R&D, in order to both create locally useful technology and innovation, as well as to support the capacity to adapt and adopt foreign technologies. Although Objective 2 of the PECyT had this goal at its core, the reality presented by the analysis of the relevant indicators, suggests that Mexico has failed to meet its objective. The country's investment in the promotion and consolidation of its scientific capacity has lagged relative to other emerging and transitioning economies. Once a system of innovation is properly structured, the investment of resources in S&T education, as well as in proper systems to transfer the results of the benefits of such investments, will be crucial if Mexico is to take part in the knowledge economy, with an active role in contributing to the creation and transfer of such knowledge and innovations.

Once the system of innovation is ready to transfer its outcomes into newly commercializable goods for the benefit of society, a strong bridge must exist with the business sector in order to succeed in the technology transfer activities. The analysis of the third objective of the PECyT, which calls for a competitive and innovative business sector, reveals another important area of opportunity for the country. The Mexican business enterprise is not actively involved in the activities of S&T; it has minimal participation in the financing of activities of R&D (although it has resulted a fiscal stimuli package brought about by the PECyT). According to the OECD, Mexican companies do not contribute to the development of new technologies, but rather adopt what is already available. The country must continue to create incentive mechanisms so that the business sector actively participates and increases their stake in R&D, as well as in the results. It must also mend the historically broken relations between government and the industrial sectors, moving toward achieving a more chain-link type of interactions, such as proposed by the literature on developed nations. Mexico should strive to create a Triple Helix III type of approach to innovation and technology transfer.

This study began as an analysis of technology transfer potential for Mexico as a transitional economy. The goal is to determine how Mexico can reap the benefits and promise of the knowledge economy and position in the global era. The literature review and interdisciplinary analysis focused on the factors and flaws believed to be exclusively inherent to the subject of technology transfer and the evidence suggest Mexico still has a long way to go to transform its policy approach to S&T. Before the country can begin to worry about transferring technology goods and services, both to its own society, it is clear that it must achieve a coordinated functioning of the National System of Innovation.

Technology transfer efforts and the respective literature abundantly available show that a degree of caution must be observed when testing theoretical models that have resulted from contributions drawn from diverse, advanced economic realities. The developed-developing country dichotomy proves to hold when comparing models of S&T. Most technology transfer theory has stemmed from the experiences in industrialized nations where sound financial and economic policy and management allow for a cohesive and relational functionality of all the actors in their respective S&T systems. In a developing, or transitioning economy, such as Mexico, a high degree of economic vulnerability and lack of sound social, political and economic policies limits the impact of economic growth based in knowledge generation.

Chapter Five

Conclusions

5.1 Summary of Results

While Mexico has managed to position itself as one of the top 15 nations in terms of GDP growth in the last couple of decades, this growth has not being transferred to activities of R&D by the country. Mexico remains consistently positioned among the lowest levels of performers of R&D in the OECD.

In the search for a viable alternative to understand the growing gap in the pace of development and economic growth based on scientific and technological development in Mexico, this thesis analyzed the contemporary state of the S&T capacity in Mexico showing that the country remains at considerable lower levels of competitiveness in major S&T indicators, relative to G5 and G8 countries. Given Mexico's underperformance in S&T indicators, the analysis of innovation models to base the policy framework in Mexico found limited to the adaptation of an early linear model of innovation, concluding that chain-link models are too theoretically complex to be adopted and adapted by transitional economies. The literature analysis in this thesis concludes that Mexico's S&T present stage is better suited for a linear model of innovation, such as the proposed by Feldman and Stewart (2007), while it has characteristics of a Triple Helix I model. The country should focus its efforts to develop into a relational type innovation system such as the Triple Helix III. Lastly, the analysis of the innovation policy change proposed in 2001 by the PECyT in Mexico concludes that while the PECyT was an encouraging policy effort, it lacked continuity and consistency in its application. While a few minimal accomplishments were observed as a result of the plan objectives and its implementation, the overall assessment of the PECyT reveals that Mexico's plan failed to project the country to position itself as one of the ten most important economies in the world and among the twenty most advanced in science and technology as postulated by the government through the PECyT (CONACyT, 2001).

This thesis has assessed the Mexican PECyT context, its objectives and their related strategies. This analysis highlights the fundamental, structural gaps in Mexico’s S&T strategy. The lack of success from the 2001-06 plan is underpinned by the lack of trust in government initiatives by the Mexican society and its economic sectors. This is a basic societal challenge that is present in many, if not all, transition economies. This underlying issue has to be addressed if transitioning economies are to develop and advance. As this study suggests, the literature about technology transfer, as well as the majority of the proposed models do not reflect the reality of developing or transition economies. This analysis about Mexico serves as an example of the need to study a broader set of factors that are present in developing countries but may not be in the industrialized world. Rather than transplanting models developed from economies where systems are confronted by a different set of factors (which include at the core, sound and mature policy development) appropriate models are needed.

5.2 Limitations

The major limitation of this research is that some of the data required for more detailed assessment, simply is not available. Exhaustive and knowledgeable searches revealed that some of the data that would have facilitated a more in-depth assessment is not generated by the Mexican government. The inclusion of this data would have strengthened the central argument that existing technology transfer models are too closely related to OECD economies to provide considerable depths of insight for transitional economies.

5.3 Extensions

Further research is necessary in order to unveil the core of the issue. An analysis of policy development in Mexico is needed in order to understand the lack of functionality and effectiveness of the institutions that promote and move forward the S&T agenda in the country. As a priority in continuation of this case study, it would be valuable to undertake a deep policy analysis of the education system in Mexico. While the structure of the system of innovation and the structure of the institutions that participate in it are important, they vary widely between countries. The one constant variable among nations is the need to generate knowledge. Such capacity stems from the level of education of a society, as does the receptiveness of a society to embrace innovation S&T as a factor of economic growth on the one side, and to recognize the importance of knowledge mobilization and incorporation of technologies to production system. Mexico needs to reform its education system and promote the development of its most valuable asset—its people.

Another consideration is that a common denominator in the analysis of the models explored by this thesis is a marked relational characteristic among the pieces that compose each model. As the search for an adaptable model to illustrate the Mexican potential resulted in the flow chart offered by Feldman and Stewart, an underlying characteristic of independency of each of the pieces was evident. This is not surprising as there is an obvious lack of cohesiveness moving forward of the system as a whole, as manifested by the results presented. The PECyT 2001-2006 substantially failed to deliver its highly publicized strategies and achieve its strategic goals. As the country continues to transition, once again in the wake of financial crisis and global recession in 2008-2009, a new S&T plan was launched in 2007. The *Programa Especial de Ciencia, Tecnologia e Innovacion 2007-2012* –PECiTI (Special Program for Science, Technology and Innovation) (CONACyT 2008). A deeper policy analysis and fundamental changes to the policy framework on which such effort is founded is critically necessary, or the hope for success of the new program and onwards advancement would be difficult to achieve; Mexico needs to reform its policy framework if it is seriously interested in joining in the synergetic dynamism of the knowledge based economic era.

Bibliography

Aghion, P. and Howitt, P. 1998. *Endogenous Growth Theory*. Cambridge MA. MIT Press.

Balzat, M. and Hanusch, H. 2004. *Recent trends in the Research on National Innovation Systems*. Journal of Evolutionary Economics 14:197-210.

Bercovitz J. and Feldmann, M. 2006. Entrepreneurial Universities and Technology Transfer: A conceptual framework for understanding knowledge based economic development. *Journal of Technology Transfer* 31: 175-188

Bozeman, B. 2000. Technology transfer and public policy: A review of research and theory. *Research Policy* 29: 627-655.

Camacho-Gutierrez, P. 2009. Mexico's current account deficit: A time series analysis. *International Journal of Business Research*. FindArticles.com. 14 May, 2010.

Cimoli, M. and Correa, N. 2002. Trade Openness and Technological Gaps in Latin America: A Low Growth Trap. LEM Papers Series 2002/14, *Laboratory of Economics and Management (LEM)*, Sant'Anna School of Advanced Studies, Pisa, Italy

CONACyT 2008. *Programa Especial de Ciencia, Tecnología e Innovación 2008-2012*. México, D.F. Consejo Nacional de Ciencia y Tecnología. Available online at: www.conacyt.mx

CONACyT 2007. *Informe General del Estado de la Ciencia y la Tecnología en México*. México D.F. Consejo Nacional de Ciencia y Tecnología. Available online at: www.conacyt.mx

CONACyT 2005. *Informe General del Estado de la Ciencia y la Tecnología en México*. México D.F. Consejo Nacional de Ciencia y Tecnología. Available online at: www.conacyt.mx

CONACyT 2001. *Programa Especial de Ciencia y Tecnología 2001-2006*. México, D.F. Consejo Nacional de Ciencia y Tecnología. Available online at: www.conacyt.mx

Drucker, J. and Goldstein, H. 2007. Assessing the Regional Economic Impacts of Universities: A review of current approaches. *International Regional Science Review* 30: 20-46.

Easterlin, R.A., 1981. Why isn’t the Whole World Developed? *Journal of Economic History* 41:1: 1-19.

Etzkowitz, H. and Leydesdorff, L. 2000. The dynamics of innovation: From national systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy* 29: 109-123.

Feldman, M.P. and Stewart, I.I. 2007. Well-springs of Modern Economic Growth: Higher Education, Innovation and Local Economic Development. *Annual World Bank Conference on Development Economics*, Beijing, China 2008.

Friedman, Y. 2004. Building Biotechnology: Starting, Managing and Understanding Biotechnology Companies. Amherst, NY: *ThinkBiotech LLC.*

Gilpin, R. 2001. *Global Political Economy: Understanding the International Economic Order*. Princeton University Press.

Godin, B. 2009. The Linear Model of Innovation (II): Maurice Holland and the Research Cycle, Working Paper no. 3, *Project on the Intellectual History of Innovation*, Montreal: INRS.

Godin, B. 2005. The Linear Model of Innovation: The Historical Construction of an Analytical Framework, Project on the History and Sociology of STI Statistics, Working Paper no. 30, 35 p. *Science, Technology, and Human Values*, 31 (6), November 2006: 639-667.

Grossman, G. M. and Helpman, E. 1994. Endogenous Innovation in the Theory of Growth. *The Journal of Economic Perspectives,* Vol. 8, No.1, 3-22.

Grossman, G.M. and Helpman, E., 1991. *Innovation and Growth in the Global Economy*, Cambridge: MIT Press.

Hartwich, F. Tola, J. Engler, A. González, C. Ghezan, G. Vázquez-Alvarado, J. M. P. Silva, J. A. Espinoza, J. de J. and Gottret, M. V. 2007. *Building Public–Private Partnership for Agricultural Innovation*. Food Security in Practice Technical Guide series. Washington, D.C.: International Food Policy Research Institute.

Hérnandez-Ramírez, R.M. 2002. La Política de la Ciencia y la Tecnología en México. La educación científico-técnica y la formación de recursos humanos. *Aportes: Revista de la Facultad de Economía*, México, D.F. BUAP VII 20. 87-94

Hill, S. 1986. The Hidden Agenda of Science Studies for Developing Countries. *Science and Technology Studies*4: 3/4: 29-32.

International Monetary Fund. 2000. *Globalization: Threat or Opportunity?* World Economic Outlook. Washington, DC. April 2000.

Kline, S., and Rosenberg, N. 1986. An Overview of Innovation. In R. Landau and N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275-306). Washington, DC: National Academy Press.

Lucas, R., 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22:

Lustig, N.C. 1997. *NAFTA: Setting the Record Straight*, The World Economy, Blackwell Publishing, vol. 20(5), pages 605-614, 08

MIHR/PIPRA. 2007. *Glossary in Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices* (eds. A Krattiger, RT Mahoney, L Nelsen, et al.). MIHR: Oxford, U.K., and PIPRA: Davis, U.S.A. Available online at www.ipHandbook.org.

Misa, T. 1992. Theories of Technological Change: Parameters and Purposes. *Science, Technology and Human Values*, Vol. 17, No.1, 3-12.

Mokyr, J. 1992. Technological Inertia in Economic History. *The Journal of Economic History* 52: 2: 325-338.

Moreno-Brid, J.C. 1999. Mexico's Economic Growth and the Balance of Payments Constraint: A cointegration analysis. *International Review of Applied Economics*, 13: 2: 149-159.

Moritz, C. 2008. Can Free Trade Guarantee Gains from Trade? Working Papers RP2008/97, *World Institute for Development Economic Research* (UNU-WIDER).

Nonaka, I, 1994. A Dynamic Theory of Organizational Knowledge Creation. *Organization Science* 5:1: 14-37.

OECD 2010. *Measuring Innovation: A New Perspective*. Available online at www.oecd.com

OECD 2009a. *Main Science and Technology Indicators*. Available online at www.oecd.com

OECD 2009b. *Science, Technology and Industry Scorecard*. Available online at www.oecd.com

OECD 2008. *Science and Technology Outlook, Mexico*. Available online at www.oecd.com

OECD 2007. *Main Science and Technology Indicators*. Available online at www.oecd.com

OECD 2005. *Main Economic Indicators*. Available online at www.oecd.com

OECD 2004. *Economic Surveys, Mexico.* Available online at www.oecd.com

Oliver, R. 2003. *The Biotech Age: The Business of Biotech and How to Profit from It*. New York, NY: McGraw-Hill Publishing Inc.

Paarlberg, R. L. Hopkins, R. F. and Ladewski, L. 2004. Regulation of GM Crops: Shaping an International Regime. In R. E. Evenson and V. Santaniello (eds.) *The Regulation of Agricultural Biotechnology*. Wallingford, UK: CABI Publishing.

Pacheco-López, P. and Thirlwall, A.P. 2004. Trade Liberalization in Mexico: Rhetoric and Reality. *Studies in Economics 0403*, Department of Economics, University of Kent.

Petrescu, A. S. 2004 Science and technology for economic growth. New insights. *Paper presented at the annual meeting of the Midwest Political Science Association, Palmer House, Chicago, Illinois*. Available online at: www.allacademic.com

Phillips, P.W.B. 2010. *Research and Innovation Delivery Models in Agri-based Innovation Systems*. Annotated Outline submitted to Agriculture and Agri Food Canada. Contract 01B68-10-0121

Phillips, P.W.B. 2007. G*overning Transformative Technological Innovation: Who is in Charge?* Oxford, UK: Edward Elgar.

Phillips, P. W. B. 2005. Regional Systems of innovation as Modern R&D Entrepots: The Case of the Saskatoon Biotechnology Cluster. *Innovations and Entrepreneurship in Western Canada.* Chapter 2. 31-58.

Robbins-Roth, C. 2000. *From Alchemy to IPO: The Business of Biotechnology*. Cambridge, Mass: Perseus Publishing Inc.

Rogers, E. M. 1962. *Diffusion of Innovations*. Glencoe: Free Press.

Romer, Paul M. 1994. The Origins of Endogenous Growth. *The Journal of Economic Perspectives*. Vol. 8, No.1, 3-22.

Romer, Paul M. 1990. Endogenous Technological Change. *Journal of Political Economy* 98: 71-102.

Schumpeter, J. 1939. *Business Cycles: A theoretical, historical and statistical analysis of the capitalist process*. New York: McGraw-Hill.

Scott, M. F. G. 1993. Explaining Economic Growth. *The American Economic Revie*w, 83: .2: 421-425.

Solleiro, J.L. and Castañon, R. 2002. Competitividad y Sistémas de Innovación: Los Retos para la Inserccíón de México en el Contexto Global. *Temas de Iberoamerica*, *Globalisación, Ciencia y Tecnología*. 165-197

Solleiro, J.L. 2002. El Programa Especial de Ciencia y Tecnología 2001-2006 y el Sistéma Nacional de Innovación. *Aportes: Revista de la Facultad de Economía*. Mexico, D.F. VII, 20. 41-53.

Spielman, D. J. and von Grebmer, K. 2006. Public-Private Partnerships in International Agricultural Research: An Analysis of Constraints. *Journal of Technology Transfer* 31: 291-300.

Stiglitz, J.E. 2006. Making Globalization Work – The 2006 Geary Lecture. *The Economic and Social Review*, 39: 3: 171-190.

Stiglitz, J.E. 2002. *Globalization and its Discontents*. WW Norton & Company Editors.

United Nations Development Programme. *Human Development Indices.* Available online at: www.undp.org

UNESCO. 2010. A Global Perspective on Science and Technology Statistics. Available online at: www.uis.unesco.org

Wolf, M. 2004. *Why Globalization Works*. New Heaven: Yale University Press

Wonglimpiyarat J. and Yuberk N., 2005. In support of innovation management and Roger's Innovation Diffusion theory. *Government Information Quarterly*, 22: 3: 411-422.