Globalization of R&D in the Automotive Industry: Applying Current Knowledge to a Mexico Case Study

by

Kenneth Harris Reyes

Submitted to the System Design and Management Program
In Partial Fulfillment of the Requirements for the Degree of

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Abstract

This thesis presents the challenges, opportunities and key themes of globalization of R&D from the point of view of a growing product development office in Mexico belonging to a large multinational automotive company. The study finds that Mexico has a very large domestic market with a growing middle class and access to an even larger international market due to one of the most open economies. It is also finds that Mexico has a growing pool of skilled human resources in S&T and is well positioned to keep growing the number of researchers in the near future. The study also shows that even though the research in Mexico is not quantitatively significant in the world yet, it is qualitatively competitive with all the BRICS and that there is a presence of agglomeration and clusters in the aerospace, automotive, electronics and software industry which is a positive sign for establishing R&D operations in those fields.

The review concludes that in order to increase Ford of Mexico's (FoM) ability to contribute to innovation efforts to the company globally, it is recommended to have a small group of dedicated people to oversee and manage a portfolio of R&D projects in 4 areas of opportunity:

- Process innovations including manufacturing operations
- Product Innovations supporting FoM's core commodity responsibilities or targeted at commodities in which FoM has global design lead.
- Projects directly geared at improving FoM's ability to deliver top hats
- Building core competencies in niche areas currently not present in the company.

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Glossary of Acroynms

BERD	Business Enterprise expenditure on R&D
BUAP	Autonomous University of Puebla
CIATEQ	Advanced Technology Center of Queretaro
CINVESTAV	Center for Research and Advanced Studies
COMIMSA	Mexican Corporation of Materials Research
CONACYT	National Council on Science and Technology
D&R	Design and Release
DoD	Department of Defense
ESI	Employee Satisfaction Index
FCCT	Scientific and Technological Consultative Forum
FDI	Foreign Direct Investment
FoM	Ford of Mexico
FUMEC	The Mexico-United States Foundation for Science
GDP	Gross Domestic Product
GERD	Gross domestic expenditure on R&D
HEI	Higher Education Institution
INFOTEC	Fund for Information and Documentation for Industry
IPN	National Polytechnic Institute
ITESM	Monterrey Technological Institute for Higher Education
MIT	Massachusetts Institute of Technology
MNC	Multinational Corporation
NASA	National Air and Space Association
NIS	National Innovation System
OECD	Organization for Economic Co-operation and Development
OICA	International Organization of Motor Vehicle Manufacturers
PD	Product Development
R&AE	Research and Advanced Engineering
R&D	Research and Development
RENACECYT	National network and state councils of Science and Technology
RNGCI	National Network of Groups and Research Labs
S&T	Science and Technology
SDM	System Design and Management
SNI	Researchers National System Database
STA	Scientific and Technological Activities
STET	Scientific and Technical Education and Training
STS	Scientific and Technical Services
TRL	Technology Readiness Level
UAM	Metropolitan Autonomous University
UdG	University of Guadalajara
UNAM	National Autonomous University of Mexico
UNCTAD	United Nations Conference on Trade and Development
US	United States
WEF	World Economic Forum
WIPO	World Intellectual Property Organization

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Introduction

Motivation

I have been working in Product Development (PD) in the Automotive Industry for over 6 years and have found the challenge of bringing new and exciting products to market very stimulating. I have always been interested in technology and innovation but the last two years at the MIT System Design and Management (SDM) program have fueled an ever growing passion for innovation. I was always fascinated by the new technologies and products I read about in the press releases and wondered how I could get involved in advanced research work streams that could contribute to technological advances and innovative new products and services. Hence my motivation to write this thesis on the topic of Research and Development (R&D) is at least partially due to a personal interest in innovation and how R&D contributes to the innovation process. Often, my supervisors and managers would advise me to write a thesis on a topic that would be of use to the company and during my time in the SDM program I became convinced that the innovation process and its globalization will be important for the company's future success and merits this study.

Innovation is encouraged in the company at all levels and even though anyone can contribute innovations to the company no matter what department he or she works in, to work in a dedicated research and innovation work stream is a privilege to just a few and geography matters. Research and advanced engineering is mainly carried out in the United States and European offices in a regular and formal fashion at Ford Motor Company. In my Product Development responsibilities throughout the years, I have interfaced with many people all over the world, both internally at Ford and externally with suppliers. Working in a global environment has become a common everyday practice under the company's efforts to leverage the globally dispersed resources in Product Development and the pursuit of global platforms for new products. This experience of working in global teams and on global product development has also sparked an interest in globalization over the course of my career. It was my observation that the technology development activities of the company, namely research and advanced engineering, were a lot less global than the engineering, purchasing, marketing and other operations. This observation led me to combine my passion for innovation with my curiosity about globalization and understand why the company has some activities more dispersed than others. It made sense to study the innovation process in a global context hence I felt the need to focus this thesis not just on R&D but how globalization affects and interacts with R&D and innovation.

The Ford of Mexico (FoM) Product Development (PD) office has seen a huge growth in the past few years and is really beginning to partake and contribute to the global scheme of product development in the company. Jumping from being a small local product development office that made minor adaptations to tailor products for local suppliers and for the local market, to having major responsibilities in global product development was a huge step for the Mexico PD organization. The engineering and purchasing responsibilities growth in themselves have been challenging and delivering results in these work flows has been the main focus of the Mexico PD office during my career. The Mexican PD office is still learning to deal with the new challenges and responsibilities and is still highly dependent on its home base in the United States to conduct its engineering responsibilities but FoM is well on its way to having top hat development capability. The product strategy at Ford is geared towards having single global platforms with different "hats" that are tailored products for each market; this top hat development capability is where the FoM's strategy is currently focused. Having watched the engineering group in Mexico grow from an office of less than 100 engineers to over 900 and growing has made me realize that the potential for more exists. The ever increasing talent in Ford of Mexico has been delivering in product development activities and is eager to prove themselves capable of larger responsibilities. I have personally met several people who are as passionate about innovation and technology as I am and willing to put in the extra work in a project that is innovative and interesting. This has led me to further focus this thesis on how it is that the engineering talent in the Mexico PD office could contribute to the company's strategic objectives through formal and informal R&D, advanced engineering and innovation work streams.

This thesis builds on the Ford of Mexico strategy to increase the systems thinking capability through participation of the SDM program at MIT and a framework set in Aguirre (2008) to aggregate the effort of multiple theses aligning work toward creating a better product development organization. Much of the previous work in the FoM participation in the SDM program has been devoted to the engineering activities in Product Development and I felt the topic of research and innovation needed some further thought to complement the FoM product development system. Using a systems thinking approach, this study will investigate what role the product development office in Mexico, mainly an engineering office, could develop in innovation, research and advanced engineering. The Mexico product development office has many product development responsibilities but it's involvement in research and Ford's global innovation effort is minimal. It is the objective of this thesis to evaluate if, from an overall Company perspective, it is worth extending research and advanced engineering work streams to the Mexico PD office and setup a plan to increase capabilities for the Mexico organization in order to contribute innovations in the future. Location factors affecting Multinational Corporations (MNC's) decisions to locate R&D abroad will be studied in order to aid evaluating the value of establishing a formal R&D structure in Ford of Mexico.

To a lesser extent, this thesis also represents my interest in Mexico's National Innovation System (NIS) and the transition of a developing country to a knowledge economy. Even though the thesis is written from the point of view of a MNC's subsidiary, firms that operate in Mexico are a huge component of the National Innovation System and thus are important to the development of the country. The performance and interaction between government, universities and research centers are vital components for firms seeking to perform R&D in a specific country. I feel the world is moving faster and faster to a more globalized innovation processes and knowledge is ever more dispersed so companies must learn to deal with integrating and exploiting knowledge from around the world. Multinational corporations can take advantage of the already globalized Manufacturing and Product Development operations to also globalize their research and innovation structures and processes. The Mexico case study is represented as a first step of a larger idea to replicate the analysis in other strategic locations and continue building a more global research and innovation operation.

Method

Data Gathering Process

The primary methods for acquiring data and knowledge for this thesis were by performing literature reviews and gathering data from journals, books and international research institutions. Internal company information was also used to verify the company's internal landscape in globalization and innovation practices as well as formal R&D structures and compare this to what the literature indicated as trends in these fields.

Once the main trends, issues and themes had been discovered from the background studies and literature reviews, a series of interviews was conducted with a wide variety of people in related fields. In order to account for sufficient depth and breadth, interviews were conducted internally in the United States and Mexico offices in both the engineering and research departments and externally in non-automotive companies, suppliers, entrepreneurs, academia and the Mexican government. Interviews were conducted at different levels of the organizations such as R&D directors, engineering managers, product engineers, research scientists, professors and subject matter experts in diverse fields so as to cover the perspective of the issues at several different levels.

The Ford of Mexico leadership was also highly involved in the development of the proposal for improvement in order to obtain feedback on the concepts and ensure the proposal aligned with the strategic vision of the Ford of Mexico Product Development office.

Layout of Thesis and Study

This thesis is divided into 3 main sections: a background section, an analysis on Mexico's National innovation System and a discussion on the application of lessons learned to Ford of Mexico.

The background section is divided into four subsections: R&D, Innovation, globalization of R&D and globalization in the Auto Industry. The first two sub sections of the background component will present the two main concepts that will be discussed throughout the rest of the study: R&D and Innovation. These sections will provide definitions for these terms and discuss why R&D and innovation is important for firms.

The third subsection is the main literature review in the subject of globalization of R&D. This subsection will describes the trends of globalization in the form of increases in Foreign Direct Investment (FDI) and cross border trade to internationalization of production and how these activities translate into globalization of R&D. The six main decision factors used by MNC's for locating R&D abroad will be identified in this section for the analysis in subsequent sections.

The fourth subsection will present the landscape of globalization in the automotive industry pointing out specific characteristics of this industry. First a brief general view of the automotive industry will be described but then narrowing the focus to the internationalization of the automotive industry in Mexico.

The second section introduces the main stakeholders in Mexico's National Innovation System and then analyzes five of the six decision factors identified in the globalization of R&D section in the context of the Mexican National Innovation System: access to a large market, availability of skilled human resources, performance of university and/or public research system, presence of clusters and/or centers of excellence and government incentives/policies aimed at attracting R&D.

The last section will discuss the topic at the firm level including the remaining decision factor, strategy, from the perspective of Ford Motor Company globally and then focus on applying the lessons learned from the study to the Ford of Mexico organization in the form of opportunities and challenges for increasing R&D capacity in FoM.

Background

Research and Development

This section will define what R&D is and why studying R&D is important. Research and Development is a term that is commonly confused or used interchangeably with innovation, and even though these two concepts may be related, they are not the same. The next section will deal with innovation and how R&D contributes to the innovation process.

R&D is important for companies because R&D results in the technology that brings new products and services to the market. International research has consistently demonstrated the positive correlation between R&D investment intensity and company performance measures such as sales growth and share price in the sectors where R&D is important. There is also a high correlation between countries that have shown significant economic improvement in the past and those countries that have made substantial investment in R&D capacities. Technological change and innovation which is mainly driven by R&D have been the most important sources of productivity growth and increased welfare (Edquist 2000). Companies are in a better position to achieve and maintain competitive advantage in the increasingly global marketplace with sustained R&D and innovation practices.

R&D can be a confusing term so first we need to look at the definition. The most widely accepted definition of Research and Development (is the one contained in the Frascati Manual. The Frascati Manual was written as a reference and means to collect statistics and data on R&D in OECD member countries but also it has become a standard for R&D surveys worldwide. The definition for R&D is:

> "Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications."
> (OECD 2002 pp. 30)

Based on the Frascati Manual, the term R&D covers three activities:

- "Basic research
    - Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

- Applied research
    - Original investigation undertaken in order to acquire new knowledge directed primarily towards a specific practical aim or objective.

- Experimental Development
    - Systematic work drawing on existing knowledge gained from research and/or practical experience which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed."

(OECD 2002 pp. 30)

The term R&D has evolved over the years; initially, research in the social sciences was not clearly identified to be R&D but now is widely recognized as such. The term R&D covers both formal R&D and informal or occasional R&D. R&D activities are closely linked with many science and technology (S&T) related activities, for this reason it is important to point out some of the closely related activities that are not considered R&D. UNESCO in its "Recommendation concerning the International Standardization of Statistics on Science and Technology" has defined a broader concept of Scientific and Technological Activities (STA) which includes Scientific and Technical Education and Training (STET) and Scientific and Technological Services (STS) which are excluded from the R&D concept. Also excluded from the R&D term are the broader technological innovation activities that support the implementation of technologically new or improved products and processes such as financial, administrative, organizational or commercial activities. Excluded activities from the term R&D are:

- Education and Training
- Scientific and Technical information services
- General purpose data collection
- Testing and Standardization
- Feasibility Studies
- Specialized Health Care
- Patent and License Work
- Policy Related Studies
- Routine Software Development
- Scientific, Technical, Commercial and Financial steps other than R&D
    - Tooling
    - Acquisition of Technology
    - Industrial Design
    - Capital Acquisition
    - Production Start-Up
    - Marketing for new or improved products
- R&D financing activities
- Indirect Supporting Activities

- Transportation
- Storage
- Cleaning
- Repair
- Maintenance
- Security
- Administration

(OECD 2002)

This guideline should be taken with some caution since a particular project or task could be considered as R&D based on the reason it is undertaken. We must take in mind the definition is used to collect statistics on R&D particularly spending on R&D and thus an activity that is normally excluded sometimes can qualify as R&D based on the project's purpose. For example: patent study is considered R&D if directly related to the goals of an R&D project but the administrative and legal work connected with patents and licenses (in general) is not considered R&D. Education and Training is not considered R&D with the exception of PhD Thesis and Research publications. A feasibility study on research projects can be considered R&D if analyzing feasibility of projects that qualify as R&D but not for routine feasibility analysis companies carry out for delivering new products with existing technologies. For further information on these guidelines refer to the Frascati Manual (OECD 2002).

Many companies have an R&D department that is heavily involved in basic research, applied research or experimental development or a combination of these activities. R&D departments can be a sub group to the larger Product Development department that executes all the necessary activities required to bring new products to market including: investigating market needs, industrial design, engineering of components, material selection, sourcing suppliers, marketing, packaging of products, etc. Activities carried out in product development tend to vary by company and industry but in general will have some degree of engineering and R&D. Many of the Product Development activities are not considered R&D based on the definition we have given but in some cases, particularly the engineering activities, may be considered R&D. With this idea in mind, I will make a further distinction between the R&D activities in the Product Development Engineering departments and R&D activities in the Research and Advanced Engineering departments that is particular to Ford Motor Company but may be analogous to many other organizations.

Using NASA's and the DoD's guidelines for technology readiness level (TRL) assessment, I will make the distinction that the engineering departments tend to work in the range of Technology Readiness Levels 6-9 and Research and Advanced Engineering Departments tend to work in the Technology Readiness Levels 1-6 (see **Figure 1**). In other words, R&D performed in the engineering departments of product development tends be related to technologies that are mature and close to implementation, whereas R&D performed in the Research department tends to be with technologies that are farther from implementation. Engineering tends to focus on experimental design whereas R&AE tends to have higher levels of basic and applied research.

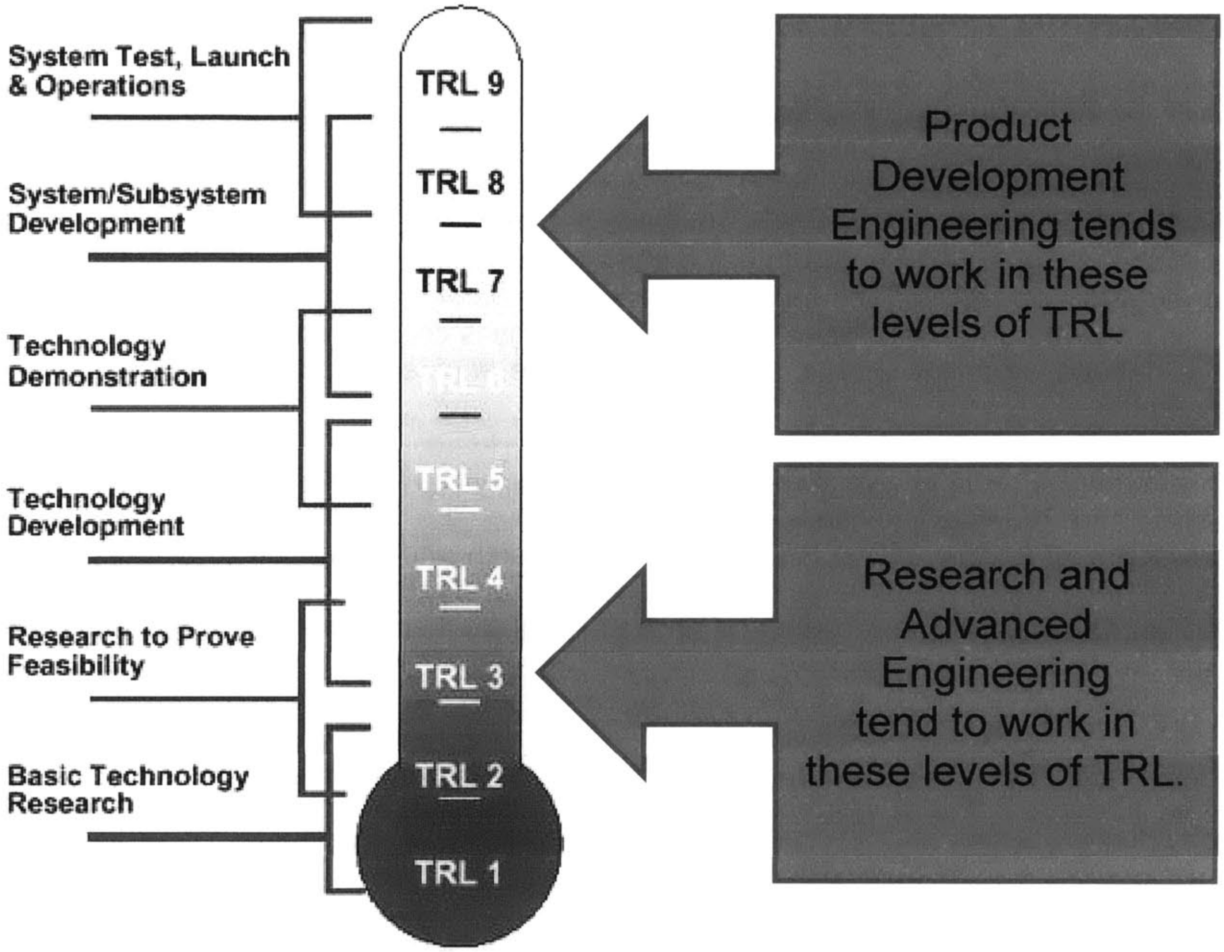


Figure 1: Technology Readiness Levels
(Modified from NASA website, retrieved November 2012 from http://web.archive.org/web/20051206035043/http://as.nasa.gov/aboutus/trl-introduction.html)

In order to fully grasp the difference, first we must understand a few key points about the company's organizational structure in Product Development and how this is reflected upon the Ford of Mexico office. Product Development in the Ford of Mexico office has always mirrored the various engineering departments that exist in the Product Development organization in the US but not all of them. Ford of Mexico is mainly an extension of the US core engineering departments and product programs. The core engineering departments being: Body Interior, Body Exterior, Electrical and Electronics, Digital Innovation and CAE, Chassis and Powertrain. The product programs consist mainly on specific vehicle teams as well as Vehicle Engineering and Vehicle Testing. In essence, the PD activities in Ford of Mexico are heavily focused on delivering new products to market within a relatively short time frame. This refers to local adaptations for the Mexican market, ongoing product development as well as new model global programs that will be delivered in a timeframe of 1-5 years (approx. numbers). The primary function of these departments is to deliver the new products within the performance, quality, cost and weight targets set by the company.

With the understanding that there are many departments and functions in the US PD organization that have not extended operations to the Mexico PD office we will now define what is meant by research and advanced engineering (R&AE). Research and Advanced Engineering has a different focus than the core engineering activities and that is to identify and develop the future technologies and features to enable business and /or strategic objectives. The focus of advanced engineering activities is typically 5 to 10 or more years out in the future. Once a technology is considered implementation ready it is handed off to the product development core engineering departments to bring to market.

In summary, Product Development Engineering activities have a shorter term focus (1-5 years), are directed towards new products and are heavily geared towards the development portion of the R&D concept. Research and advanced engineering has a longer term focus of 5-10 years or more, and is directed toward new technologies tending to carry out more basic and applied research than the engineering departments (see **Table 1**).

	Type and focus of R&D	**Typical Activities**	**Time Frame (years)**
Core Engineering Departments	More experimental development More focused on new Products	Technology Development (minimal) Technology Demonstrations System/Subsystem Development Testing, Launch and Operations	1 to 5
Research and Advanced Engineering Departments	More basic and applied research More focused on new Technologies	Basic Technology Research Research to prove Feasibility Technology Development Technology Demonstration	5 to 10 or more

Table 1: Comparison of R&D conducted in Core Engineering and R&AE departments

Now that we have a basic understanding of the definition of R&D and what the term encompasses, let us move on to innovation and make the distinction between these two terms.

Innovation

According to the Frascati Manual, a great source of error in measuring R&D is the difficulty of locating the cut-off point between experimental development and the related activities required to realize an innovation. Innovations are the embodiment or end result of a creative process. There really are no rules or limits on how to be innovative and creative ideas can spring up from many different sources. Commonly, product manufacturers are thought of as innovators mainly through conducting R&D but innovations have also been shown to come from other sources such as lead users (Von Hippel 1988). Innovation results in high quality jobs, successful businesses, better goods and services and more efficient processes. Innovations historically have been classified as product innovations or process innovations. More recently, the Oslo Manual (OECD 2005) has included organizational and marketing innovations as types of innovation in order to account for a more comprehensive understanding of innovation. Innovation is a broader concept than R&D encompassing many activities and can include non-R&D related innovations. The Frascati Manual referred to innovation as technological innovation; in the latest version of the Oslo Manual (that deals with Innovation) the word technological has been removed from the definition of innovation so as to not give the impression that all innovations involve high technology.

> "Technological Innovation activities are all of the scientific, technological, organizational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes. R&D is only one of these activities and may be carried out at different phases of the innovation process. It may act as the original source of inventive ideas but also as a means of problem solving which can be called upon at any point up to implementation."
> (OECD 2002 pp. 18)

> "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations...The minimum requirement for an innovation is that the product, process, marketing method or organizational method must be new (or significantly improved)to the firm... Some innovation activities are themselves innovative, others are not novel activities but are necessary for the implementation of innovations. Innovation activities also include R&D that is not directly related to the development of a specific innovation."
> (OECD 2005 pp. 46-47)

In this context, R&D is only one of many activities of the broader innovation process as shown in **Figure 2** below. This thesis will primarily study the feasibility for a formal R&D structure or work stream in the subsidiary product development office in Mexico while recognizing that a formal R&D structure may not be necessary to achieve the goal of contributing to global innovation.

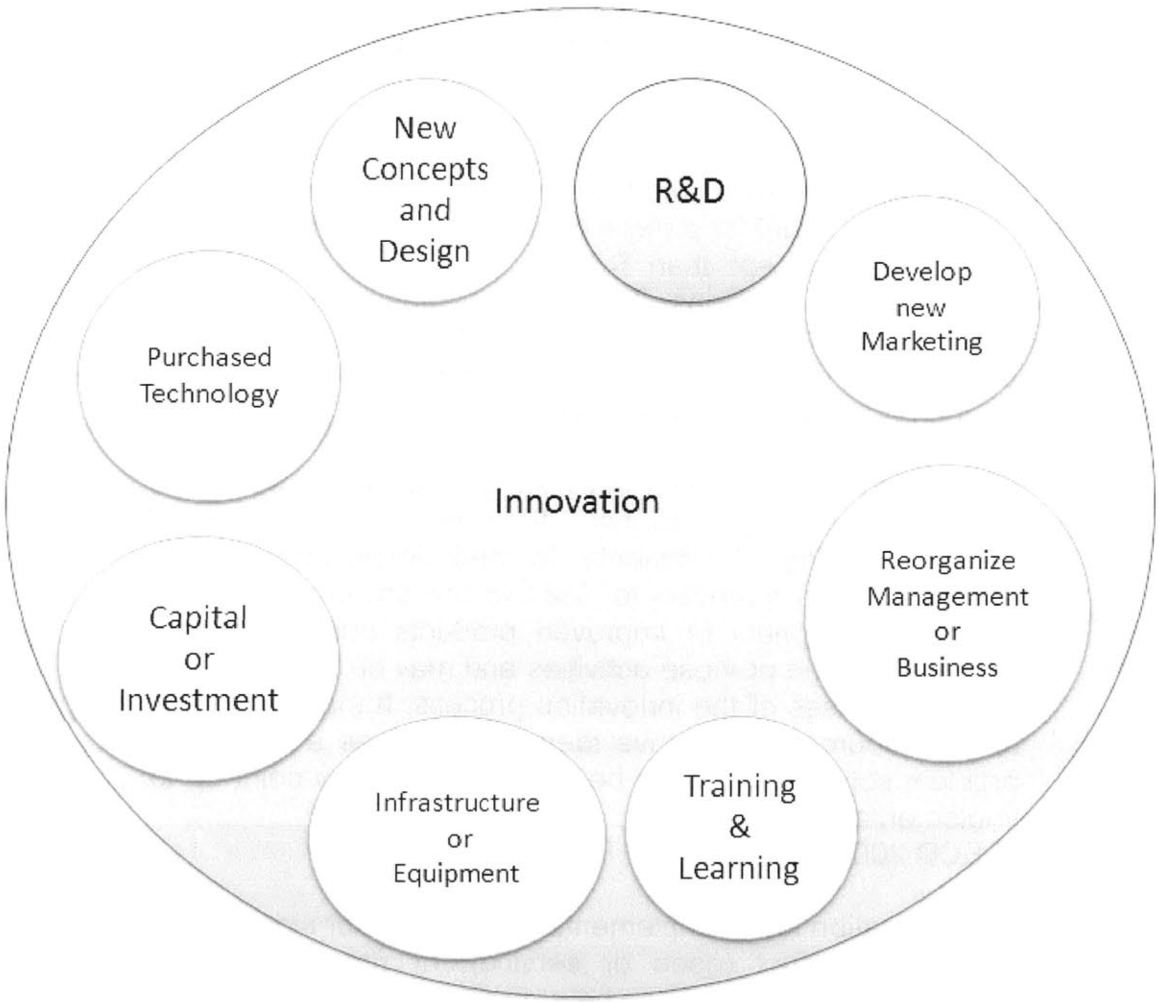


Figure 2: R&D's Role in Innovation

Innovation typically requires going through several stages. One path to innovation is commonly modeled as going from science to technology to engineering to commercialization. R&D can contribute to technological innovation as the source of the inventive idea or through problem solving or act as an enabler in any of the stages.

Innovation is increasing in importance as the world stage becomes more competitive and global. Outsourcing of cheap labor and economies of scale are very common today and are no longer a long lasting competitive advantage as these strategies are easily replicated by competitors. Companies achieve and sustain competitive advantage through acts of innovation and upgrading (Porter 1990). According to Porter, standard economic theory suggest that land, natural resources, capital, infrastructure, and other factors of production determine the flow of trade yet what is fundamentally overlooked is that the most important factors of production are human-based and created (such as a talented scientific base and skilled human resources). The work of Joseph Schumpeter, who greatly influenced innovation theory and entrepreneurship, was one of the first who suggested that the agents that drive innovation and the economy are large companies which have the resources and capital to invest in research and development. According to innovation economics, innovation is the determinant responsible for most growth when an economic boom begins in a period of depression (originally thought of as entrepreneurship). Though the notion that innovation is a major driver of economic development is not part of mainstream economic theory and most economists would not fully agree to this idea, today this notion has grown in importance particularly in light of economic crises when entrepreneurship is sought in order to generate economic activity (Sundbo 1998).

For firms, differentiation through innovation in order to maintain a competitive advantage requires managing technology in order to exploit its benefits and includes developing, retaining or building new "core" technological competencies. These new core competencies are enhanced mainly by employees' skills but also company culture, values and processes. The need for a competitive advantage based on innovation together with global market pressures stresses the importance for companies in managing innovation strategies, structures and processes and developing employees' skills and capabilities worldwide.

When people are asked to think of innovative places, names like Silicon Valley pop into people's head. This is due to the idea that innovation mainly takes place in highly specialized and concentrated clusters. There is some truth to this notion and in fact a lot of innovation occurs in clusters but this phenomenon is still not well understood. Innovation can occur anywhere in the world; even some of the very innovations that sprung up Silicon Valley had their origins in unknown remote locations. Also interesting is that the specialized clusters that are appearing all over the world are increasing their interactions as part of global innovation efforts by companies. Global innovation literature has shown an interest in how dispersed clusters combine highly specialized knowledge to create innovations that were previously not possibly under the strategy of only innovating locally or in headquarters, this process is also still not fully understood.

Creating new combinations and coming up with new ways of doing things, in essence innovation is fundamental to any company's long standing survival. Today the challenge is even greater than before since pockets of knowledge can be largely dispersed across the globe and global markets span a wide range of geographies. For multinational companies, this represents both a challenge to innovate in different ways and an opportunity to exploit globally dispersed knowledge. Acquiring and utilizing dispersed knowledge can be difficult and costly but can also spark new innovation that would not be found in the company's home base (Doz, Santos & Williams 2001). Not every company needs a global innovation strategy, but many industries have competitive forces that increase the need for MNC's to maximize responsiveness and integration including knowledge and innovation within the entire firm's network (Bartlett & Ghosal 1989). The decisions to innovate globally is based on the premise that success today depends on performance in a global marketplace and utilizing the best knowledge available globally can provide a competitive advantage and be more efficient if executed properly.

Globalization of R&D literature review

There is an abundance of literature and international research that show the globalization patterns of Foreign Direct Investment (FDI) and cross border trade that has significantly increased since the late 1980's. **Figure 3** shows the inward and outward FDI flows of the world by year from 1970 to 2011. A decline occurs in 2009, notably in developed economies and to a lesser extent in the developing world, but then FDI growth shows a gradual recovery. Developing and transition economies, accounting for nearly half of global FDI inflows, are expected to increase further in importance as FDI destinations as interest in developed countries as foreign investment destinations continues to decrease.(UNCTAD 2010)

FDI can serve many purposes in the overall context of a country's economic development and represents foreign presence necessary for international R&D and technology spillovers which in turn may stimulate innovative activity. Higher inward FDI increases competitive pressures in the economy which can lead companies to seek more efficiency in global networks such as by establishing R&D in foreign subsidiaries. The more intensive competition in international markets is, the greater the need for firms to develop innovative products in order to remain competitive. But FDI can be an imperfect indicator of R&D activity worldwide and a more in depth look at globalization is needed. Next we will look at the internationalization of production as a precursor to globalization of R&D.

International expansion of technological capabilities in MNC's appears to occur with accumulating international experience of firms and increasing commitments to foreign markets (Aharoni, 1966; Johanson and Vahlne 1977).

Many corporations expanded internationally in order to penetrate world markets and look for cost efficient operations by establishing subsidiaries that would aid in selling, producing or providing services to local markets. Manufacturing and Sales were the first activities to be internationalized through outsourcing and offshoring by Multinational Corporations seeking low cost labor and economies of scale. One of the main decision factors for globalizing production and subsequently R&D was access to large foreign domestic markets and/or international markets as well as the exploitation of cheap labor.

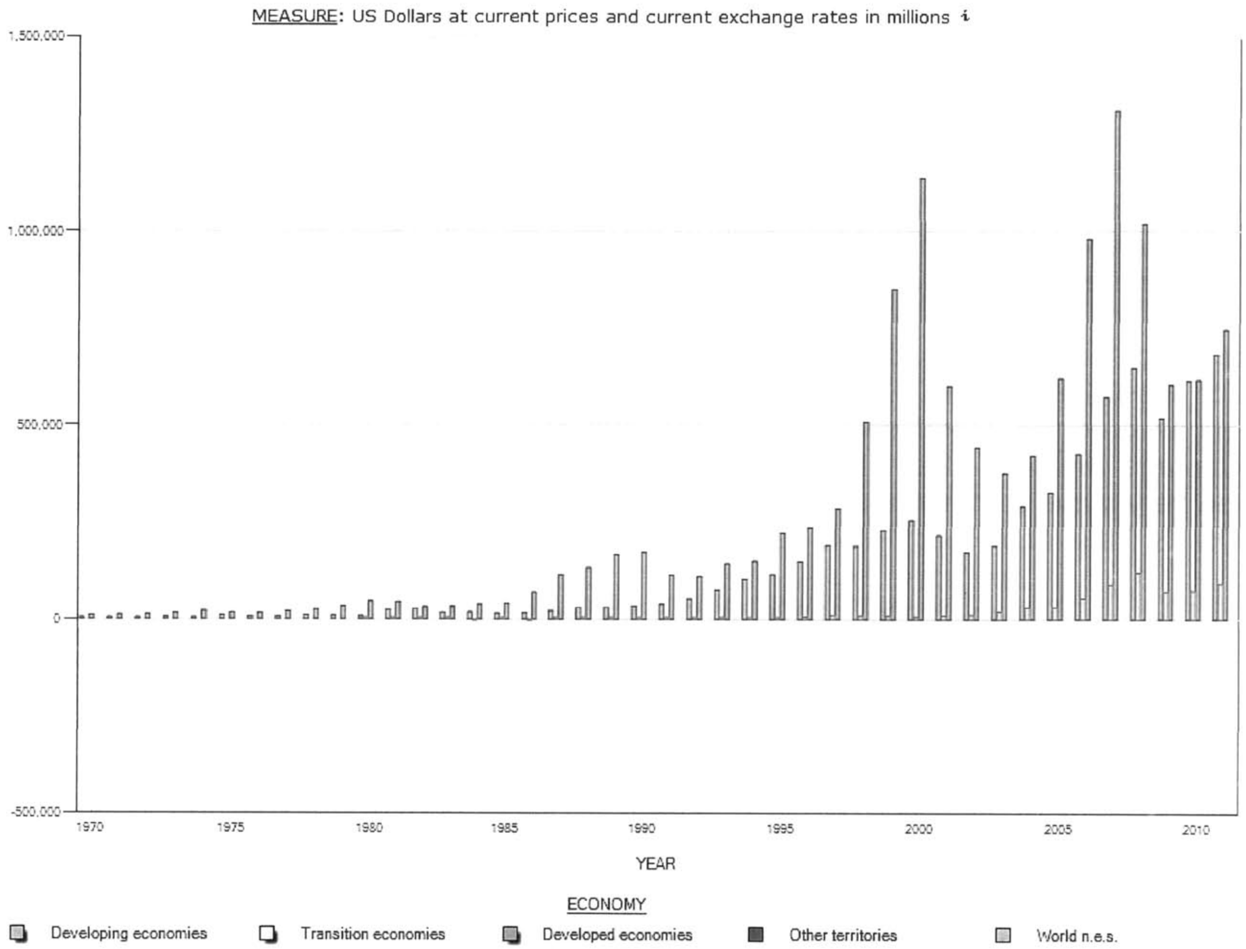


Figure 3: World Inflows and Outflows of FDI (UNCTAD, retrieved from http://unctadstat.unctad.org)

The globalization of manufacturing facilities was then followed by globalization of R&D rising from the need to adapt products to local markets. R&D was primarily undertaken abroad in order to adapt products and services to local requirements, with knowledge being transferred to the host from headquarters (Kuemmerle 1997). R&D activities were further globalized in order to exploit foreign centers of excellence, deploy home based innovation to local offices (technology transfer), customize operations or access abundant skilled labor. Globally dispersed R&D can create high coordination and overhead costs but can also provide the company with innovations that it would not be able to generate otherwise. Kuemmerle also points out that a centralized R&D approach is no longer adequate for two main reasons: the first is that large amounts of relevant knowledge is increasingly dispersed and companies should therefore be located in a number of places in order to gain access to that knowledge which is generated in foreign universities and firms. Second, there is a need to increase speed of products to market by leveraging global knowledge networks and centers of excellence that can perform research in their specialized fields more efficiently.

The global projector model where the home base projects to its subsidiaries the knowledge created in the home base was the traditional approach to globalization by MNC's. Traditional global projectors built distinct competencies in their home market and were able to project those qualities from their home market success to the global marketplace (Doz, et. al. 2001). Initially the coordination of technological capabilities, namely R&D, was done from the home country with more peripheral and less sophisticated activities performed in the foreign units of the firm (Cheng & Bolon 1993; Granstrand, Hakansson & Sjolander 1993).

The trend shows R&D is following the globalization of manufacturing operations but to a much lesser extent. R&D is much less internationalized than other corporate activity such as production and sales. The skills and know-how that give firms competitive advantage are less internationalized than all other dimensions of corporate activity. Even very large corporations in most cases perform most of their R&D at home. (Patel 1995 ;[3] Patel and Pavitt 1991; Pavitt and Patel 1999; Patel and Vega 1999).

> "The evidence, based on the US patenting activities of 569 of the world's largest firms (based in 13 countries, and covering 17 product groups), shows that for an overwhelming majority of them technology production remains close to the home base." (Patel 1995)

> "In the interwar and early post war years, large firms tended to diversify their technological competence by taking advantage of scale economies, especially via exports from the home country. Their internationalization was aimed primarily at the wider exploitation in foreign markets of the basic competence they had already established at home. R&D activities were internationalized only to a limited extent and mostly oriented to adapting products to each market." (Carlsson 2006 pp. 61)

> "Since the early 1980's, the extent of internationalization of R&D has increased considerably, both in quantitative and in qualitative terms. During earlier periods of global expansion (the 1960s and 1970s) multinational corporations first built up foreign sales and manufacturing operations in foreign countries. In later phases (late 1970s/ early 1980s), efforts were directed towards supporting foreign subsidiaries with complementary design and development capabilities. Although initially, foreign R&D locations were limited to application engineering, and to the adaptation of product and process technologies to host country requirements, there was a clearly recognizable trend, since the mid -1980s, towards strengthening R&D in foreign locations. The formation of more advanced national innovation systems as

> well as more sophisticated markets in the OECD countries has resulted in polycentric learning environments, and multinational companies were increasingly extending their R&D and competence portfolio on a global scale. Foreign locations became more involved in exploration and advanced development, as opposed to exploitation and adaptation of centrally-developed, home-country-based technologies." (Gerybadze and Reger 1999 pp. 254)

Internationalization of advanced technological capabilities first became associated with new growth opportunities and flexibility advantages (Vernon 1979; Kogut 1989) but then more explicit suggestions about beneficial effects of continuous knowledge exchange and cross-fertilization within the MNC's network (Prahalad and Doz 1987; Bartlett and ghoshal 1989, 1990; De Meyer 1993; Doz et. al. 2001), namely worldwide learning and global synergies that can be used to enhance the innovation process.

Cantwell (1995) describes the extent and character of change in international R&D activities of MNC's over time. Instead of exploiting home country-based advantages abroad MNC's are now doing R&D abroad. There is a growing need in firms to look outside the boundaries of the firm and home country for the knowledge they need to better develop innovative solutions that satisfy the firms' product market needs (Chesbrough, 2003; Chesbrough & Appleyard, 2007). Cantwell (1995), though recognizing the shift in MNC's R&D location decisions, also points out that the home base is still the single most important site for corporate technological development and the knowledge base at home still plays an important role. Firms seek out technologies abroad in fields that lie outside their own knowledge base or core technological competencies (Cantwell and Santangelo 2000). This latter point is supported by Meyer-Krahmer and Reger (1999) who argue that location of international R&D is increasingly selective to a few specialized locations distinguished as international centers of excellence. Geographical specialization and the utilization of these centers of excellence by MNC's occurred in order to increase speed in the innovation process by leveraging highly efficient and specialized clusters of knowledge. The cooperation of clusters is further stimulated by Industries which are not geographically co-located and are converging. Companies seek out allies in distant geographical locations who possess needed knowledge and this is further being driven by technological complexity (Doz et. al. 2001). We can infer from the literature that clusters and agglomeration are important factors for location decisions by MNC's looking to locate R&D abroad and adopt a global innovation process.

Additionally, Meyer Krahmer and Reger (1999) show that internationalization of technological activity is largely concentrated in the Triad (US, Japan and Europe). This point is further supported by studies conducted by the OECD (OECD 2005) on trends in globalization of R&D. But the Triad dominance of the innovation landscape may be changing. China, India and South Korea have now witnessed a substantial growth in R&D investments by MNC's (Ernst, 2006; Ho, 2006). Developing countries, particularly the BRIC's (Brazil, Russia, India and China) have developed innovative capabilities and emerged as important stakeholders in technology intensive sectors such as electronics and information technology. Not to mention that large numbers of patents issued to MNC's from developed economies are now being generated in emerging economies (Gassmann and Han, 2004). Eleven of the top twenty countries in terms of patent applications in 2006 were emerging economies (WIPO 2007). A study conducted by Kumar (2001) indicates that inadequate IP protection in a country does not adversely affect the attractiveness of the country if well suited for R&D activity. MNC's are able to overcome a host country's patent system by registering patents in their home country. This practice must be taken into account when studying patent activity because patent indicators could be misleading if not considered. According to Kumar (2001), the factors affecting MNC's decision to take in-house R&D activity across countries are primarily: market size, availability and cost of R&D personnel as well as government policy and incentives regarding technology development and the need to follow leaders in their fields (centers of excellence). A large domestic market, low R&D costs, high availability of qualified manpower, high levels of R&D activity and presence of clusters are therefore factors that significantly improve the chances of locating R&D in a particular location.

While the decision to pursue a global R&D strategy is taken at the firm level, the actual location choice is greatly determined by national factors (Fey and Birkinshaw, 2005; Patel and Vega, 1999; Pearce, 1999). The literature suggests that MNC´s decision to establish formal R&D operations abroad is strongly linked with the host country´s National Innovation System. Carlsson (2006) points out that NIS's are being internationalized even though the institutions that support them are country specific and that numerous studies on internationalization of corporate R&D point out the importance of national institutions in innovative activity. Therefore, it is important for MNC's to examine the performance of a country's National Innovation System in order to determine good location choice. A National Innovation System is the institutionalization of the innovation process at the national level and includes universities, industries and governments and how these stakeholders interact with each other in order to produce technological innovation. A high performing National Innovation System is desired and will include a highly educated and flexible workforce, access to capital, high quality universities or public research system, IP protection and a stable regulatory system, access to a large market (local or international) and access to foreign technologies. The literature also suggests that governments play an active role in making their economies attractive for R&D investment (UNCTAD 2005). As a result of these policies we are increasingly seeing growth in research output of countries with the most attractive incentives. Thus, attractive financial and tax incentives to stimulate foreign direct investment and particularly investments in R&D are important location decision factors. These incentives often play a role in determining location choices for MNC's particularly when looking to obtain either political favor or cost advantages.

One of the main drivers of the internationalization of R&D is Multinational Corporations (MNC's) and since many of MNC's operations are dispersed already, MNC's are in an ideal position to conduct global R&D and innovation. The question for MNC's to internationalize R&D operations is thus one that should be carefully examined considering the risks, costs and potential benefits.

> "[MNCs'] growing interest in developing and transition economies is not related only to cheaper labour costs. Large and/or fast growing local markets, and in some cases, growing pools of skilled manpower, are also proving increasingly attractive. Consequently, FDI to developing and transition economies is not, and will not be, only directed at the most labour-intensive, low value-added components of the value chain, but, increasingly, at more innovative and technology-intensive activities." (UNCTAD 2010 pp. 25)

Another factor contributing to expansion of R&D is the growing pools of skilled human resources in emerging economies. For example, in China PhD candidates in S&T enrolled in Universities has grown six times from 1995 to 2003, to over 48,000 (Freeman 2005). Also important is to note that the wealth of talent is available for less than a fourth of the cost in a developed economy (Ernst 2006). Salaries are a major factor in the cost of R&D and reducing them significantly can be a compelling factor for MNC's. The emerging shortage of highly skilled science and engineering talent in the US is driving the need to access qualified personnel abroad. Companies are entering a global race for talent which is influencing offshoring innovation operations (Lewin, Massini & Peeters 2009). Though the cost factor can be attractive, global innovation needs not be a zero sum game where if one location wins R&D capacity another location loses. Globalization of R&D should be seen as a means to create new knowledge and tap into the knowledge not found at home to enhance innovation rather than a means to replace jobs at headquarters at a cheaper rate.

Additional factors affecting spread of R&D is the management attitudes towards internationalization, strategy and dispersion of technological capabilities (Patel and Pavitt, 1997).

Key takeaways from Introduction and literature review.

In summary, Innovation is at the heart of maintaining a competitive advantage and necessary for the long term competitiveness and survival of firms. R&D performs a crucial role in the innovation process, particularly in technological innovation and international research has proven a positive correlation between sustained R&D activities and company performance. Deciding to have a local innovation strategy or global innovation strategy is important for organizations particularly since the world is becoming more and more competitive and knowledge is increasingly being created in more dispersed locations. R&D historically is one of the least internationalized activities remaining close to company headquarters but the innovation landscape has been changing and global R&D is becoming more relevant in the world. Multinational corporations are particularly well positioned for global innovation by leveraging already internationalized assets and communication channels for extending Innovation activities such as R&D across dispersed locations. Favored locations for the establishment of formal R&D structures and work streams are those that:

- are strategic
- have access to a large market
- have abundant skilled human resources
- have a good university and/or public research system.
- have the presence of clusters or centers of excellence
- have attractive government incentives and policies

Globalization of the Automotive Industry

The automotive industry is one of the most global industries with firms virtually selling their products everywhere in the world. Not just vehicle manufacturing has had a global presence but also the auto parts sector and supply chain is widely dispersed. This section will present important themes on the auto industry in the context of globalization.

Sturgeon et. al. (2009) point out four major distinctions of the auto industry:

1. First, the automotive industry is extremely concentrated in a small number of very large companies that exert an extraordinary amount of power over smaller firms. Eleven lead firms from three countries: Japan, Germany and the USA, dominate production in the main markets (see **Figure 4**).

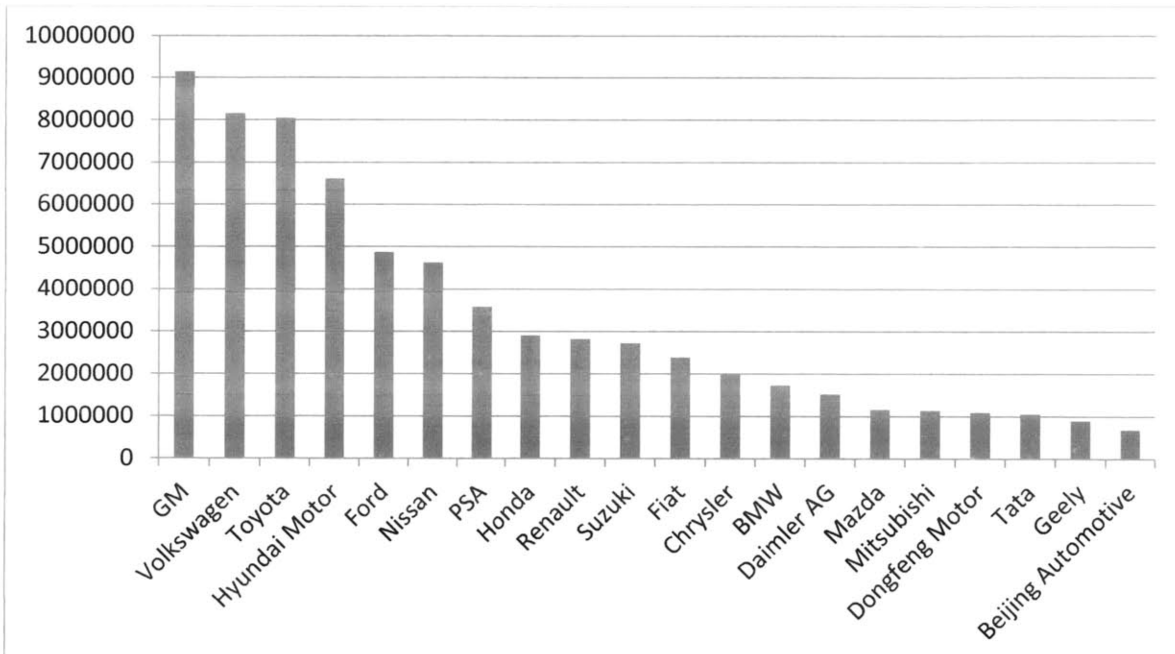


Figure 4: Vehicle production volumes by Manufacturer in 2011 (Source OICA)

2. Second, final vehicle assembly and parts production has largely been kept close to end markets because of political sensitivities. The tendency for automakers to 'build where they sell' has also encouraged the dispersion of final assembly, which now takes place in many more countries than it did 30 years ago. In 1975, seven countries made up around 80% of world production.

Today's landscape is shown in **Table 2** showing the top 20 motor vehicle producers by nation and **Figure 5** showing top 10 nations by percentage.

Rank	Country	Production Total	World %
1	China	18,418,876	23.03%
2	USA	8,653,560	10.82%
3	Japan	8,398,654	10.50%
4	Germany	6,311,318	7.89%
5	South Korea	4,657,094	5.82%
6	India	3,926,517	4.91%
7	Brazil	3,406,150	4.26%
8	Mexico	2,680,037	3.35%
9	Spain	2,353,682	2.94%
10	France	2,242,928	2.80%
11	Canada	2,134,893	2.67%
12	Russia	1,988,036	2.49%
13	Iran	1,648,505	2.06%
14	UK	1,463,999	1.83%
15	Thailand	1,457,798	1.82%
16	Czech Rep.	1,199,834	1.50%
17	Turkey	1,189,131	1.49%
18	Indonesia	837,948	1.05%
19	Poland	830,631	1.04%
20	Argentina	830,158	1.04%

Table 2: Top 20 Vehicle Production by Nation (Source OICA)

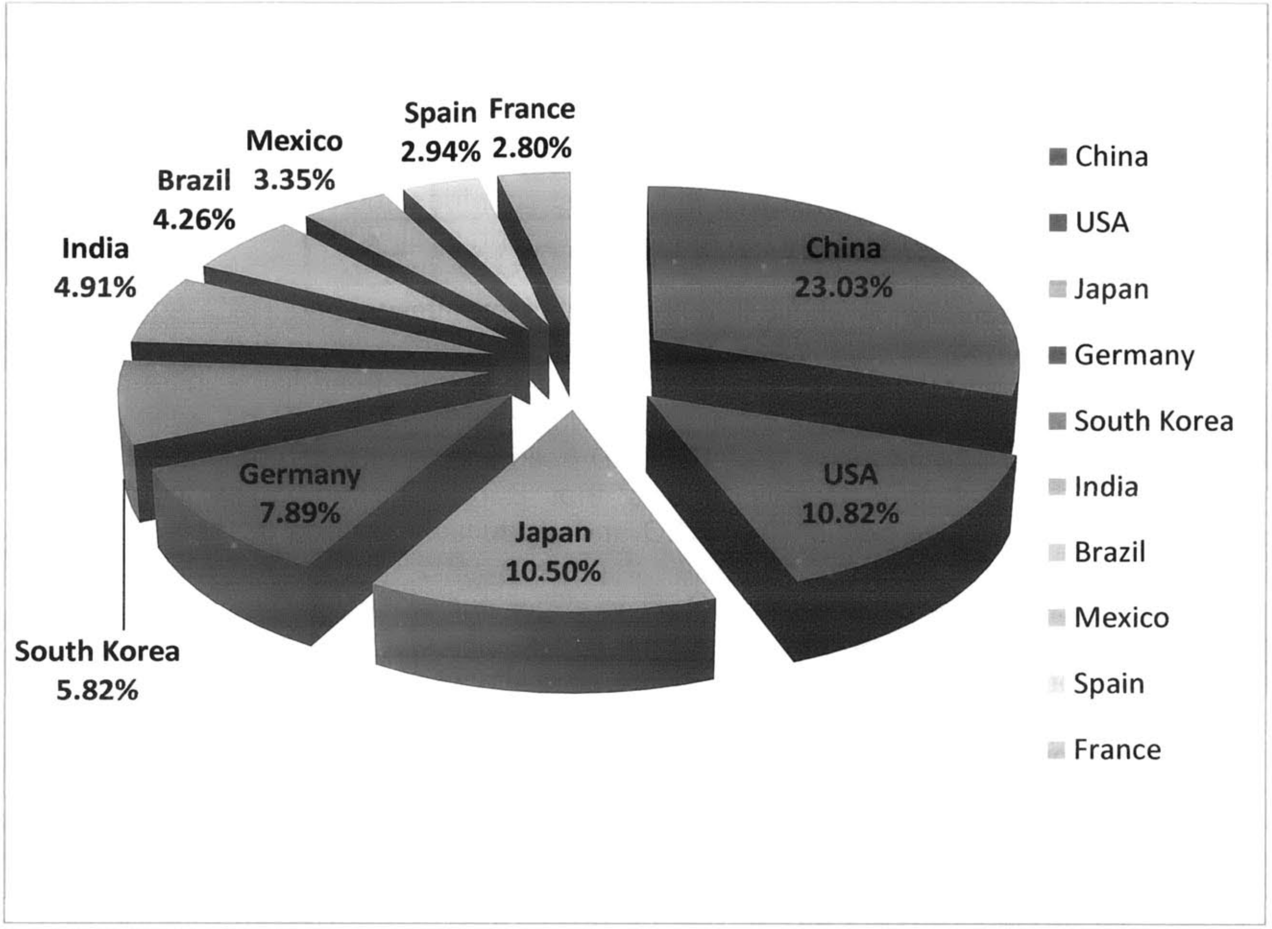


Figure 5: Top 10 Motor Vehicle production per country in percentage (Source OICA)

3. Third, a strong regional structure. Even though the auto industry has become more globally integrated, it developed strong regional patterns of integration perhaps influenced by significant transportation costs for large items (in contrast to industries like electronics and apparel which developed global-scale patterns of integration).

4. Fourth, there are very few generic parts that can be used in a variety of end products without extensive customization. Parts tend to be specific to vehicle models or manufacturers due to the absence of industry wide standards. This increases the need for close collaboration with suppliers who tend to locate near lead firms´ headquarters. Design of vehicles tends to be integrated and modularity of components is limited.

Even though the automotive world is still mainly located in the triad nations (production, design and R&D), sales in these regions has been stagnant for quite a while. Future growth will mainly be seen in the developing world (Accenture 2009).

The globalization in the auto industry has led to the development of fewer but more powerful external suppliers, a concentration on the distribution side and policy issues (OECD 2008). Automobiles are highly regulated including production, design, traffic, safety and environmental matters. Contrary to the notion that companies establish production where it would be most profitable, Japanese German and Korean firms have not abundantly established themselves in low cost countries such as Mexico in order to avoid political backlash among the US market (Sturgeon et al. 2009).

Colovic & Mayrhofer (2011) show that the role of production and R&D units based abroad in the automotive industry has changed. Manufacturing which was initially set up in emerging countries to meet local demand is now being targeted to be meet demand in high income countries while R&D facilities which initially focused on adaptation to local markets is now contributing to global R&D (following the pattern of globalization of R&D of many industries). Colovic shows that European companies continue to concentrate an important part of their R&D and production facilities in their country of origin or other EU countries while Japanese and American MNC's have internationalized their production and R&D to a greater extent. Japanese companies have based R&D activities abroad due to the limited size of their domestic market. For example, Toyota has R&D centers in Belgium, the US, Australia and Thailand in order to adapt vehicles to local markets and also to contribute to global R&D. For American companies, Chrysler produces 99% of its vehicles within NAFTA while Ford and GM have more diversified production and important R&D centers abroad.

The Auto Industry in Mexico

> "The automobile industry is the largest branch of Mexico's manufacturing. In 2005, the sector accounted for 15.1% of manufacturing GDP, 13.7% of manufacturing employment and close to 20% of manufactured exports. In the past decade, it has gone through several export phases, with vehicle and parts exports to the United States growing by an average of 21% from 1995 to 2000, before falling by an average of –2% between 2001 and 2005. In 2006, following a period of re-tooling, vehicle and vehicle part exports grew at 26%. Going forward, export growth will principally depend on the strength of the US market and also the auto product cycle. Part of the strong export growth in 2006 was due to an upswing in production from the launch of new models. Developments in the industry suggest that Mexico has a growing comparative advantage in auto manufacturing. In January 2005, the Ford Motor Company announced the shutdown of 12 of its plants in the United States by 2012. At the same time it projected an increase of its operations in Mexico. Today Mexico is exporting a range of higher value cars to the biggest markets in the world, while importing cheaper cars for domestic use" (OECD 2007).
>
> "The development of the Mexican automobile sector has gone through periods of contrasting policies, from import substitution in the 1950s and 1960s to export promotion in the 1980s. The most important rules

governing automobile exports are set out in NAFTA. In the case of new cars, NAFTA requires around 60% of the car to be produced in NAFTA countries in order for it to be exported from Mexico to the United States and Canada. Over time different factors have determined the establishment of factories in certain regions of Mexico. Initially, car factories were established near Mexico City because of its large market. Later, the companies were established in the northern part of the country, close to in-bond industries (maquiladoras). There is evidence that this later localisation was due to productivity advantages rather than low wages. The more recent localisation of investments seems to be dictated by the systemic competitiveness that can be gained from the integration of car industries with large local supply chains. This is reflected in increasing regional specialization in the north and two central areas of Mexico."
(OECD 2007)

Mexico is ranked 8th place in automotive manufacturing volume by the international organization of automobile manufacturers (OICA) (**see table 2**) and is one of the largest auto manufacturer in the America´s. Mexico has one of the most competitive manufacturing costs anywhere in the world. In the automotive sector, Mexico has an internal growth market, which will increase by 8.0% between 2013 and 2016. (Promexico n.d.)

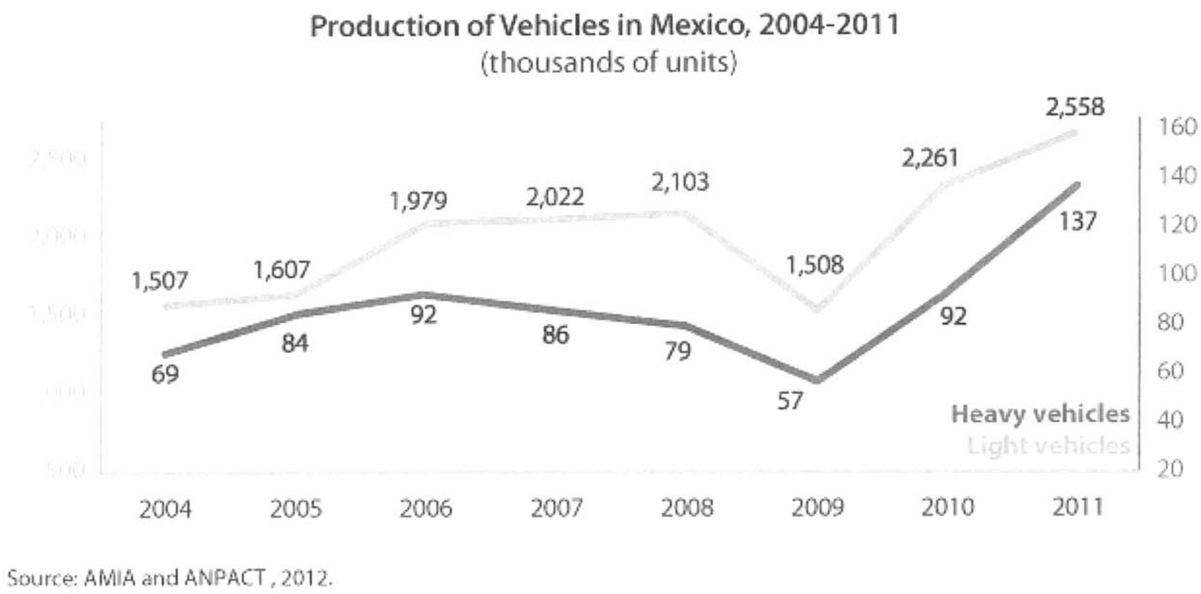


Figure 6: Production of Vehicles in Mexico 2004-2011 (Promexico website, retrieved October 2012 from http://mim.promexico.gob.mx/wb/mim/auto_perfil_del_sector)

"In the automotive industry mostly US FDI in new plants during the 1990s converted an uncompetitive industry focused on the national market into a highly competitive platform aimed at the North American market. Investment has been driven by proximity, lower salaries, and preferential

> market access through NAFTA, all in the context of increasing competition from Asian auto manufacturers. Between 1985 and 2002, the production capacity of the Mexican automotive industry rose from 400 000 to almost 2 million units. Exports rocketed from almost zero to about 1.4 million units with Mexican plants accounting for 14% of vehicle imports to North America." (Mortimore 2006)

Dussel Peters et. al. (2007) finds a negative association between foreign direct investment and expenditures on technological R&D by big manufacturing firms in Mexico (primarily automotive and electronics), R&D seem to be more intensive in firms that serve the domestic market and not in firms that are part of a global value chain. The study shows that:

1.- Firms with no FDI have the highest R&D intensity
2.- Followed by those with more than a 50% FDI capital share
3.- Firms with less than 50% FDI have the lowest R&D intensity

"This pattern is reproduced in two of the main FDI sectors in Mexico: Automotive and Electronics. Taken together, these results suggest that Mexican subsidiaries of [MNC's] and the firms that supply them do not, on the whole, function as innovation platforms in Mexico" (OECD 2009 pp. 121). In Mexico, most FDI is aimed at increasing efficiency in regional or international production systems of MNC's. Manufacturing operations are primarily cost centers for high- and medium-technology manufacturing, such as automotive and electronics. Global competition pressures account for MNC's search for lower-cost, large-scale production sites close to major markets for the labour-intensive aspects of their production processes. Automotive MNC's have not pursued the exploitation of skilled human resources or the accumulation of technological capabilities in Mexico (Mortimore 2006).

The recent growth in the Ford PD organization could be proof of a changing strategy aimed at exploiting skilled human resources in Mexico but this strategy may not be prevalent in the entire auto industry in Mexico. In summary, production in the automotive industry in Mexico is very widespread and growing while R&D is very limited so far but at least one company is showing interest in further exploiting skilled human resources.

Mexico's National Innovation System

This section will present the Mexican National Innovation System and provide an assessment on the quantity and quality of output that is performed. Focusing on the factors that were found to be significant in the literature, this section will evaluate the potential of Mexico as a location choice for establishing research and advanced engineering activities. The factors considered are:

- Access to a large market, domestic and/or international.
- Availability of abundant skilled human resources
- Quality and quantity of university and/or public research system.
- Presence of clusters and/or centers of excellence
- Government incentives and policies aimed at attracting R&D

Stakeholders

This section will introduce the main stakeholders in government, universities and industry.

Government

By far the most important governmental organism is the National Council on Science and Technology (CONACYT). CONACYT was formed in December 1970 as a decentralized public organization and is in charge of setting Mexico´s Policy on Science and Technology (S&T). CONACYT´s primary goals are to set National Policy in Science and Technology matters, increase the scientific and technological capacity of Mexico and increase the quality, competitiveness and innovation levels of businesses that operate in Mexico. The bulk of CONACYT's budget is spent on the assignment of scholarships for postgraduate studies, the Researchers National System (SNI), and CONACYT's public research centers.

The scholarship program is one of the biggest programs accounting for 37.6% of CONACYT´s budget in 2006. The scholarship program began in the 1990´s and has been seen as a success in the form of a clear increase in registered postgraduate students in the country. The scholarship program is not the only reason for the increase in matriculation but has promoted the formation of skilled Human Resources in S&T; funds for the program have increased over the years. (Dutrenit et. al. 2010)

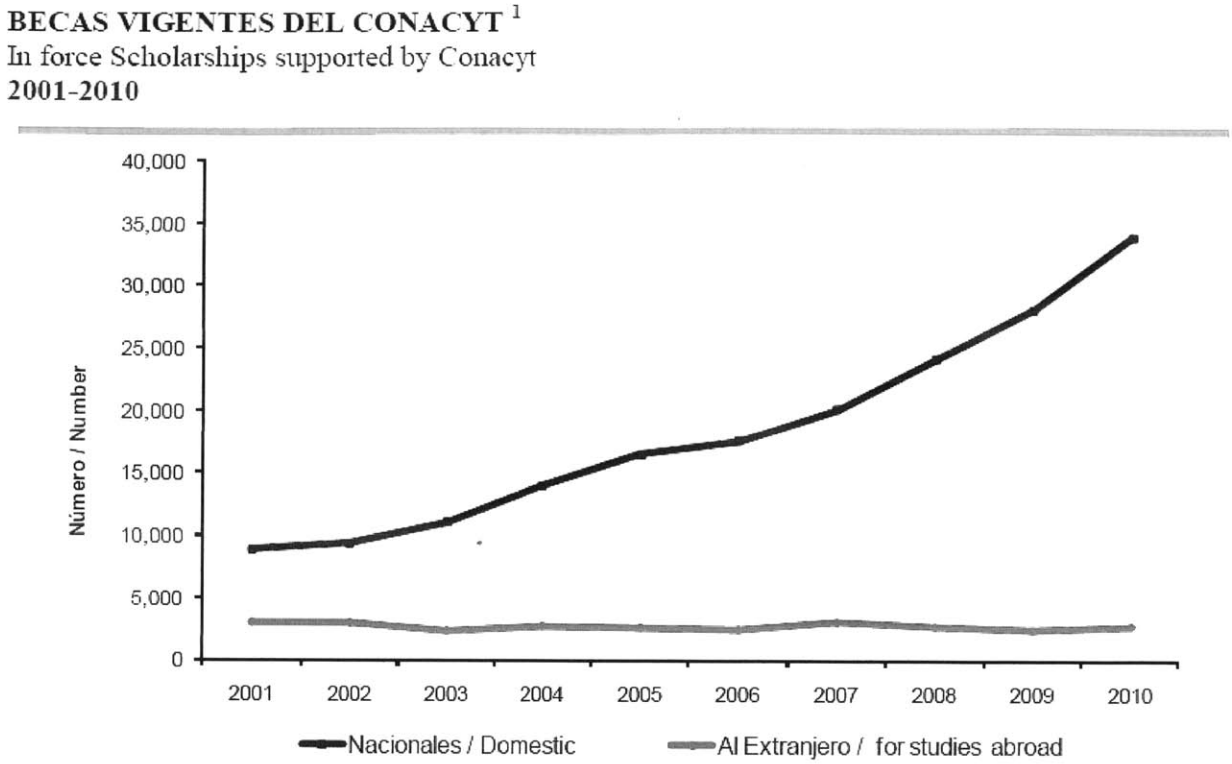


Figure 7: In Force Scholarships supported by CONACYT (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

As we can observe in **Figure 7,** scholarships increase year over year (particularly domestic scholarships) and this trend appears to continue in the future. **Figure 8** shows the scholarships are geared primarily towards Masters and PhD's with the latter representing 37.5% of scholarships. For many Mexicans, these scholarships represent their main source of funds for higher education and represent the largest source of funds sought out for obtaining higher education by Mexicans.

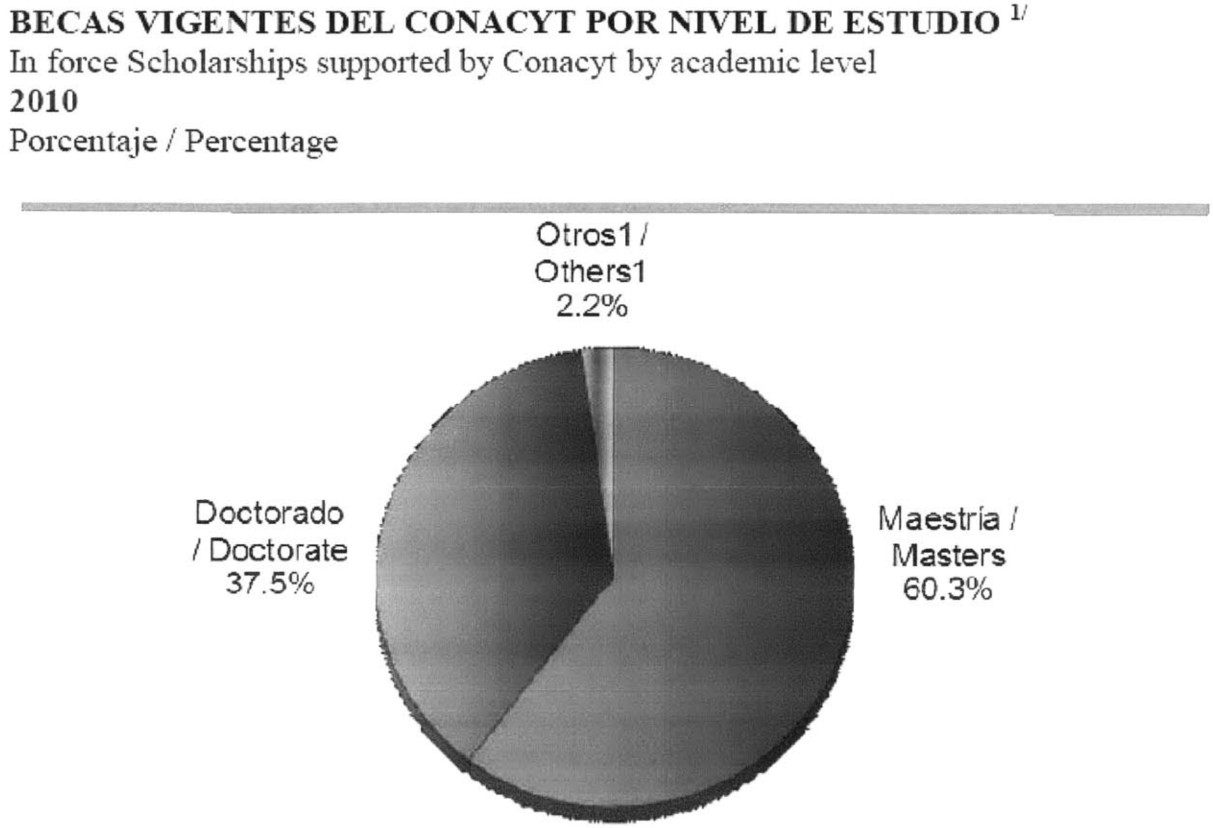


Figure 8: CONACYT in force Scholarships by Academic Level (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Another program considered successful is the Researchers National System (SNI) where researchers apply for membership and if successful become part of the SNI database. The National System of Researchers program has been running since 1984 and was a means to register personnel in S&T fields and keep track of scientific production, mainly published papers. Money incentives are provided to researchers in the program by complementing their salary in order to retain talent in the country and make pay more competitive for research in Mexico. Researchers are ranked (candidate, level 1, 2 &3) based on quantity and quality of research produced as well as roles in the science and technology community (recognized leader, mentor, impact of research, etc.). Researchers also receive non-monetary benefits such as recognition and the program is meant to promote a high valuation of research work streams in society. (Dutrenit et. al. 2010). One criticism of the SNI is that it has neglected applied science and development through generation of patents and industry projects because it rewards publication of papers and research rather than invention and applied science. This criticism is voiced in the media, such as in CNN Expansion, claiming only 0.5% of SNI researchers patent or invent technology so research remains theoretical (CNN Expansion 2011).

MIEMBROS DEL SNI POR CATEGORÍA Y NIVEL
Members of the SNI by class and level
2000-2010
Número / Number

Año / Year	Candidato/ Candidate	Investigador Nacional por nivel / National Researcher by level			Subtotal	Total
		I	II	III		
2000	1,220	4,345	1,279	622	6,246	7,466
2001	1,128	4,682	1,556	652	6,890	8,018
2002	1,325	5,384	1,728	762	7,874	9,199
2003	1,325	5,384	1,728	762	7,874	9,199
2004	1,634	5,782	1,897	876	8,555	10,189
2005	1,876	5,981	2,076	971	9,028	10,904
2006	2,109	6,558	2,306	1,123	9,987	12,096
2007	2,389	7,565	2,428	1,103	11,096	13,485
2008	2,589	8,165	2,814	1,113	12,092	14,681
2009	2,706	8,567	3,057	1,235	12,859	15,565
2010	3,052	8,970	3,172	1,406	13,548	16,600

p/ Datos preliminares/ Preliminary data.

A partir de 2003 incluye las nuevas evaluaciones positivas a ser vigentes el 1° de Enero del siguiente año. / Since 2003 includes new possitive evaluations of the SNI members, to be in force on january firts of the following year.
Fuente / Source: Base de datos del SIICYT 2000-2010 / SIICYT database.

Table 3: Members of SNI by class and level (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Dutrenit et. Al. (2010) estimate that the SNI accounts for roughly 23% of researchers in Mexico and as such represents a significant portion of the researchers in Mexico. These researchers can be from government, academia or belong to firms and perform research as their main activity.

MIEMBROS DEL SNI
Members of the SNI
2010
Porcentaje / Percentage

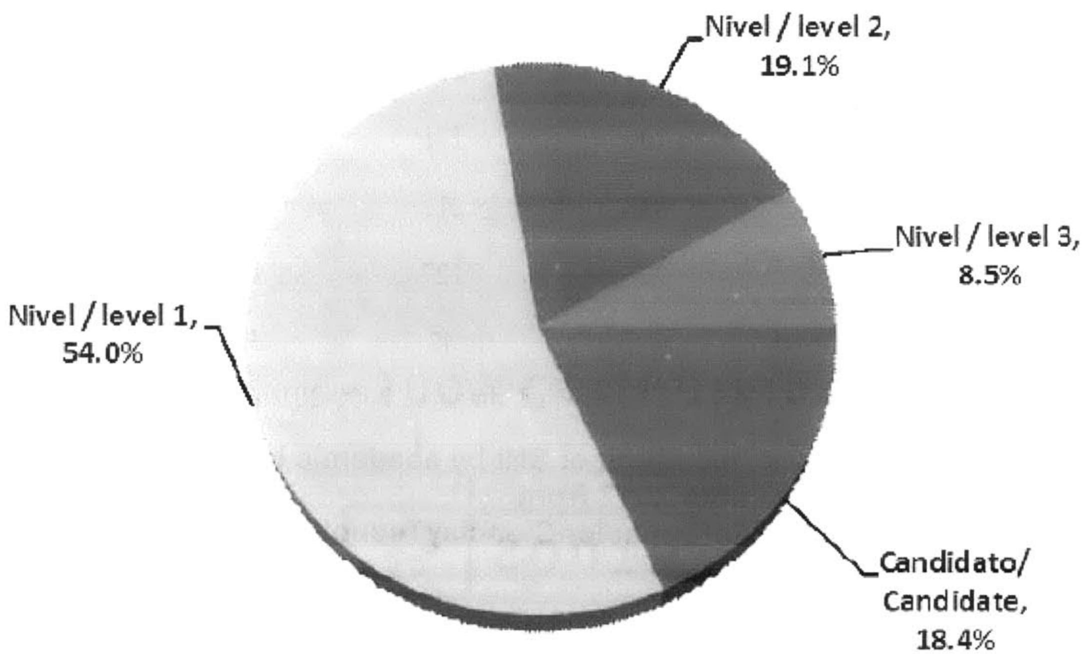


Figure 9: Members of SNI by class and level in percentage (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Figure 9** we can see the percentage of SNI members by class/level, we notice a large percentage in the lower levels and less membership in the higher levels. In **Table 4** and **Figure 10** we can observe the percentage of SNI researchers by academic level and notice that the majority of SNI members hold a Doctorate degree and only a small percentage has a Masters or other degrees.

MIEMBROS DEL SNI POR NIVEL DE ESTUDIOS
Members of the SIN by academic level
2004 - 2010

Año / Year	Doctorado / Doctorate	Maestria / Masters	Licenciatura / Graduates	Otros / Others	Total
2004	9.350	549	154	136	10.189
2005	9.998	569	146	191	10.904
2006	11.066	625	154	251	12.096
2007	12.236	790	171	288	13.485
2008	13.378	813	211	279	14.681
2009	14.545	725	127	168	15.565
2010	15.501	687	42	370	16.600

Fuente / Source: Base de datos del SIICYT / SIICYT database.2000-2010

Table 4: Members of SNI by academic level (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

From the data we can assume that people with doctorates are primarily the ones pursuing SNI membership, since the percentage of SNI members with a doctorate is very high, to obtain the benefits of such membership such as the financial rewards for publications. Interviews with researchers also revealed that the great majority of research conducted in Mexico is basic research. This is in line with the reward system of the SNI which favors publications.

MIEMBROS DEL SNI POR NIVEL DE ESTUDIOS
Members of the SIN by academic level
2010
Porcentaje / Percentage

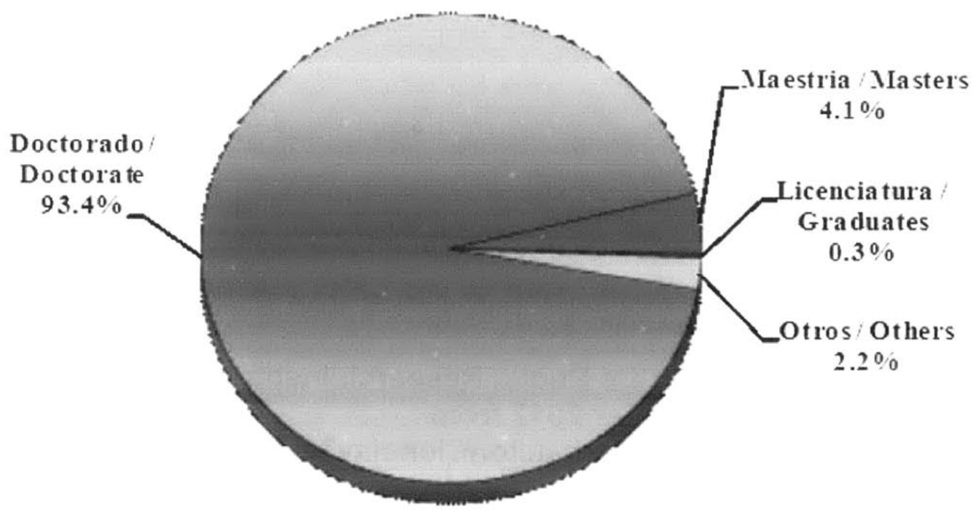


Figure 10: Members of the SNI by academic level in percentage 2010 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

CONACYT also manages a group of public research labs that consists of 27 institutions grouped in the following manner: 10 are focused on natural and exact sciences, 8 on social sciences and humanities, 8 specialize in innovation and development of technology and in financing postgraduate studies (CONACYT n.d.).

Dutrenit et. al. (2010) point out that in recent years CONACYT's public research centers have engaged in reducing their dependency on public funds by obtaining around 35% of funds from other sources (in 2006), this percentage varies by research lab with 3 labs that stand out in regards to obtaining private funding in 2006 (COMIMSA, INFOTEC and CIATEQ).

Table 5 below shows some basic data on CONACYT's public research labs.

INDICADORES DE OPERACIÓN DE LOS CENTROS PÚBLICOS DE INVESTIGACIÓN CONACYT, 2007-2010
Conacyt´s Research Public Institutions indicators, 2007-2010

Concepto	2007	2008	2009e/	2010 e/
Alumnos atendidos / Serverd students	4,466	4,673	4,950	5,375
Miembros del SNI / SNI members	1,232	1,307	1,392	1,422
Artículos publicados / Publications	1,820	1,694	1,981	1,958
Proyectos de Inv. C y T /Science and technology projects	3,134	2,647	2,683	2,682

Fuente / Source: CONACYT
e/ Datos estimados

Table 5: CONACYT's Public Research Institutions Indicators (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Other actors include:
The FCCT – Scientific and technological Consultive Forum

FCCT is a consultative agency to the president, senate, CONACYT and to the general council on R&D. It is an independent civil association composed of experts of R&D in Mexico from the private sector.

RNGCI – National network of groups and research labs

A civil association created in 1998 to decentralize R&D policies and development. It consists of representatives in all the states and is meant as a forum for dialogue and promoting technology at the state level.

RENACECYT – National network and state councils of Science and Technology

Members of RENACECYT oversee implementation of public policy for development of science and technology at the state level.

Universities and University Research Centers

The scale and complexity of the national innovation system in Mexico makes a complete description of the universities and research centers infeasible. This section will thus only point out select Higher Education Institutions (HEI's) considered important and relevant.

> "Mexico's higher education system consists of universities, technological institutes, state educational institutions, and normal schools (for the training of teachers). The system's foundations were put in place and consolidated during the era of import substitution. The most important public and private HEIs, such as the National University of Mexico (UNAM), the National Polytechnic Institute (IPN), the Technological Institute of Higher Studies of Monterrey (ITESM), the Metropolitan Autonomous University (UAM), as well as various state universities were established between 1930 and 1980. The number of HEIs grew from 26 to 84 from 1950 to 1980. However, it was during the latter part of the 20th century that Mexico experienced an unprecedented explosion in higher education in terms of the number and variety of institutions, students, faculty and research. By 2005, Mexico had 2 807 HEIs, of which 40% are public and 60% private, located all over the country. While fewer in number, public HEIs attracted nearly 68% of undergraduate and 58% of postgraduate students in 2006. The proportion of students attending private HEIs is on the rise, however, increasing from 18.5% of the undergraduate total in 1990 to 32% in 2006." (OECD 2009 pp. 139)
>
> Below is a description of the main Universities and Public Research Centers:
>
> "UNAM: Formally established in 1910, UNAM is the oldest and largest HEI in Mexico. UNAM's research centres and research institutes are distributed across the country, though most are concentrated in Mexico City. In 2007 these centres and institutes employed 2 337 researchers and 1 693 technicians. Scientific production consisted of 3 084 articles, 1 283 reports in internal yearbooks, 397 books and 948 book chapters. UNAM is the most important centre for training human resources at the postgraduate level. In the 2006-07 academic year, almost 21 000 were enrolled in different programmes and disciplines, with 17% of these accounted for by doctoral programmes.
>
> IPN: Founded in 1936, IPN is strongly oriented to technological research, although excellence in some scientific research areas is also well recognised. Research at IPN is mostly concentrated in its 19 research centres located across the country. In 2007, 1 579 researchers conducted 436 projects in all research centres. Between 1997 and 2006, its researchers published 5 536 articles in international journals. IPN offers

90 postgraduate programmes. In the 2006-07 academic year, a total of 5 199 students were enrolled in postgraduate programmes, with a little over 20% of these accounted for by PhD programmes.

UAM: Founded in 1974, UAM is the third largest HEI in Mexico, with practically all of its academic activities carried out in four campuses located in Mexico City. In 2006, 2 193 full-time researchers worked in around 140 research areas. During 1997-2006, UAM researchers published 5 708 articles in international journals. In the 2006-07 academic year, approximately 45 000 students were enrolled at undergraduate level, with a further 1 857 students enrolled in 21 postgraduate programmes.

CINVESTAV: Founded in 1961, CINVESTAV is organised into 28 academic departments located in 9 centres, two of which are in Mexico City. In 2005, its 549 researchers produced 904 scientific articles in international journals. CINVESTAV is the leading national academic institution in patenting and in transferring technologies to the private sector. It holds 105 national and 52 international patents, and 30 technologies developed by CINVESTAV researchers have been transferred. CINVESTAV offers several postgraduate programmes at the Master and PhD level, with around 3 500 students enrolled in the 2005-06 academic year.

BUAP: Formally founded in 1937, BUAP is one of the most important universities in terms of research outside Mexico City. In 2005, it had 534 researchers. During 1997-2006 a total of 2 680 scientific articles were published. The BUAP offers 58 postgraduate programmes, with around 15% of the cohort enrolled at PhD level.

UdG: Founded in 1925, UdG is the country's fourth largest HEI, located in the Guadalajara Valley. In 2006, nearly 3 000 academics (not all of whom are active in research, and around 500 registered in the SNI) worked at UdG. Its researchers published around 2 000 scientific papers in international journals over the ten years to 2006. Over the last decade, UdG has developed important linkages with the electronics sector, a major employer in the region. UdG offers a total of 147 postgraduate programmes, with 3 900 enrolled in 2006-07, around 8% of whom registered in PhD programmes.

ITESM: Founded in 1943 by a prominent entrepreneur in Monterrey, ITESM is the leading private HEI in Mexico and has 33 campuses across 21 states. In 2007, 2 787 full-time personnel were devoted to teaching and research activities, 235 of whom were SNI members. Around 11 000 students were registered in 53 Master and 9 PhD programmes in 2007."
(OECD 2009 pp. 142)

"Almost one-half of research activity in the HEI sector is concentrated in just four institutions, namely the National Autonomous University of Mexico, the Centre for Research and Advanced Studies (CINVESTAV), the Metropolitan Autonomous University and the National Polytechnic Institute. Outside of Mexico City, the University of Guadalajara (UdG) and the Autonomous University of Puebla (BUAP) are two of the largest state universities conducting research. The most prominent private HEI in this respect is the Monterrey Technological Institute for Higher Education (ITESM)." (OECD 2009 pp. 141)

Private Firms

Firms are an important part of a country's National Innovation System since the innovation process is mainly carried out inside profit seeking and risk taking firms. Universities and Research centers can provide human resources and knowledge to firms but it is essentially firms that create the innovations that are brought to market. In highly developed countries, the private sector funds a large part of the country's R&D.

In 2005, the private sector accounted for 41% of R&D spending in Mexico. This represents an increase from the 14.3% back in 1993 but is still not a significant number since the spending on R&D in Mexico as a percentage of GDP is one of the lowest among OECD countries (OECD 2009).

"At 25% of GDP, Mexico's inward FDI stocks are slightly above the OECD average (2006), and relatively larger than those of major emerging markets such as Brazil, China, India and Turkey. Between 1990 and 2006 Mexico's inward direct investment stocks increased more than tenfold (in USD)." (OECD 2009 pp. 72)

Mexico has grown a lot since 10 years ago and has advanced a lot in terms of science output and capabilities but the concern is that it has grown at a lesser rate than other economies that are developing particularly the BRIC countries (Brazil, Russian Federation, India and China). None the less Mexico in many areas has a very large market and is one of the largest economies in Latin America; qualitatively it is competitive with all the BRIC countries and has been ranked by many organizations as one of the top countries to investment in going forward. At the macro level, Mexico is not considered a contributor to global R&D because it lacks the critical mass (of researchers) to be able to compete globally in S&T.

GIDE POR SECTOR DE EJECUCIÓN
GERD by sector of performance
2009
Porcentaje / Percentage

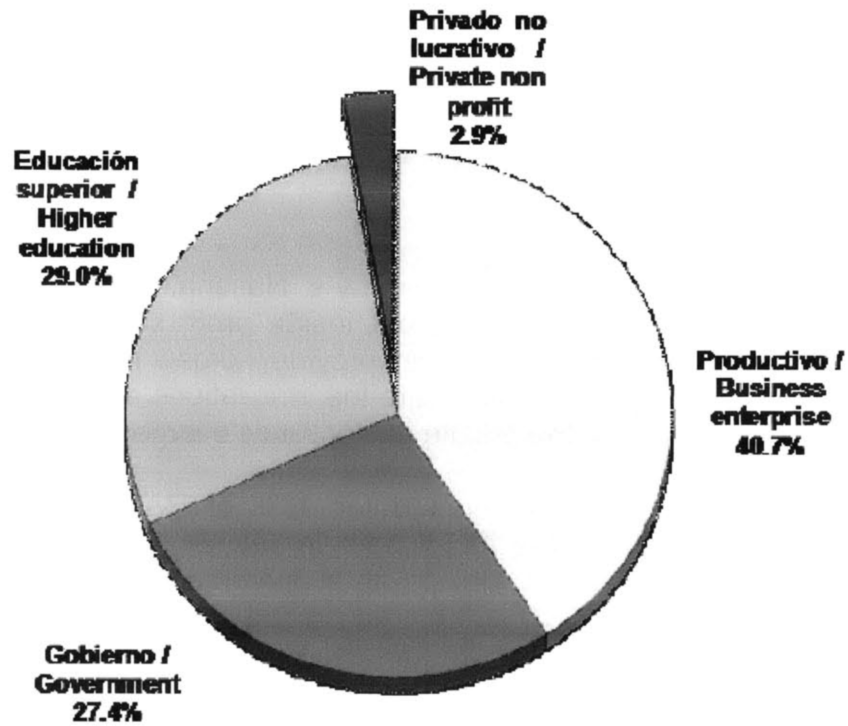


Figure 11: GERD by sector in percentage in 2009 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Figure 11** we can observe that the Business enterprise sector accounts for 40.7% of Gross Expenditure on R&D in 2009 in Mexico. In **Figure 12** we can observe that 38.7% of funds for R&D originate from the Business Sector. This means the government funds close to 60% of R&D in Mexico, in contrast to Mexico and for comparison, over 70% of R&D is funded by the private sector in Japan.

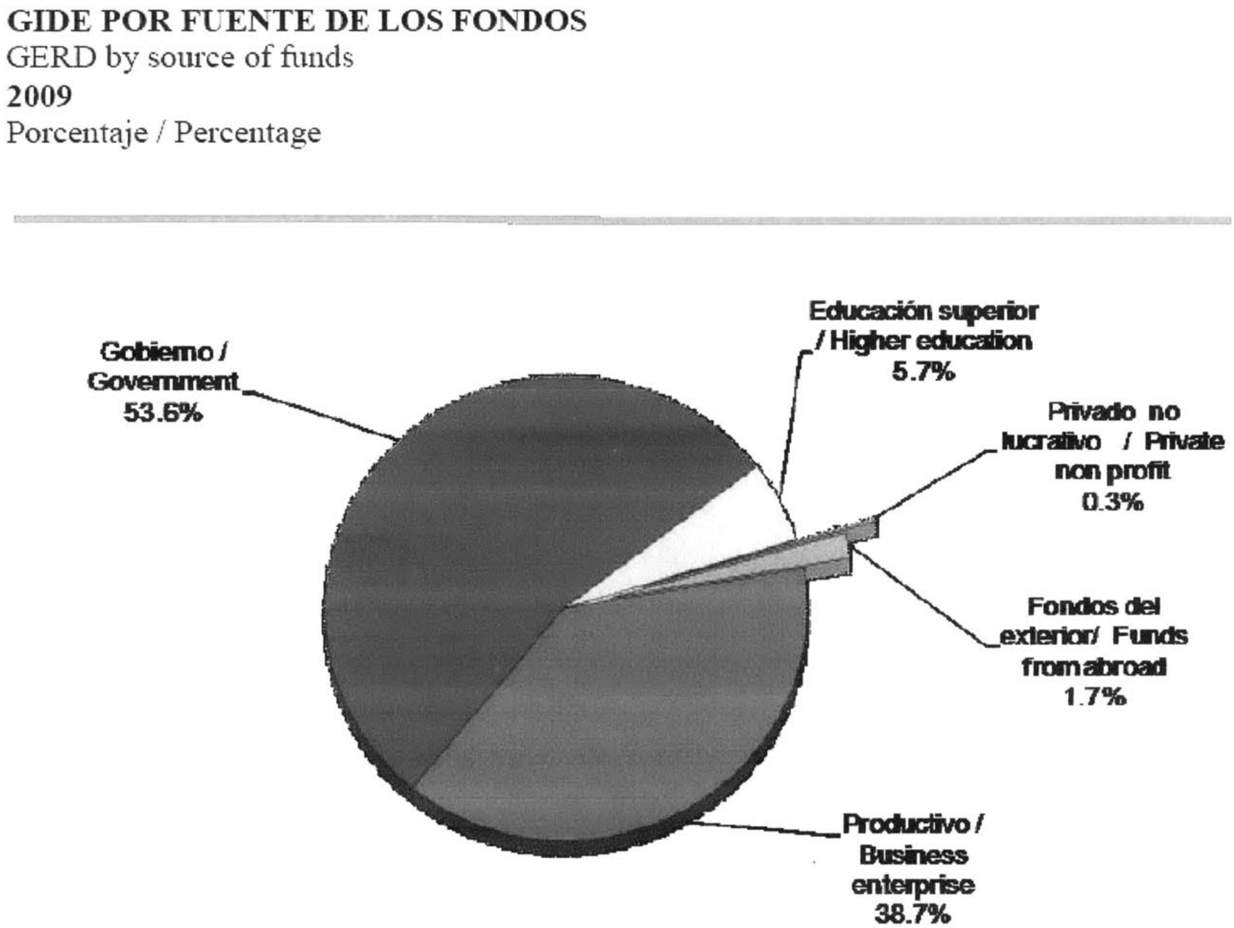


Figure 12: GERD by source of funds in percentage in 2009 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

R&D intensity is measured in a country by the GERD/GDP ratio and can be used by firms to decide whether that intensity level is adequate to establish R&D operations in a given location. Mexico scores very poorly in the GERD/GDP ratio but this is expected to some extent since Mexico is still a developing country and as such is not completely comparable to developed economies. Mexico has failed to achieve its long time target of 1 GERD/GDP with both government and private firms coming short of what is needed to achieve this target. An increase in spending alone will not achieve technological innovation but a sustained adequate budget may be necessary to transition to a knowledge economy. The low R&D spending as a percentage of GDP seems to be one of the largest negative factors firms face when considering establishment of R&D operations in Mexico. Funding varies by industry with a few strategic industries receiving more funding for R&D indirectly promoting formation of clusters.

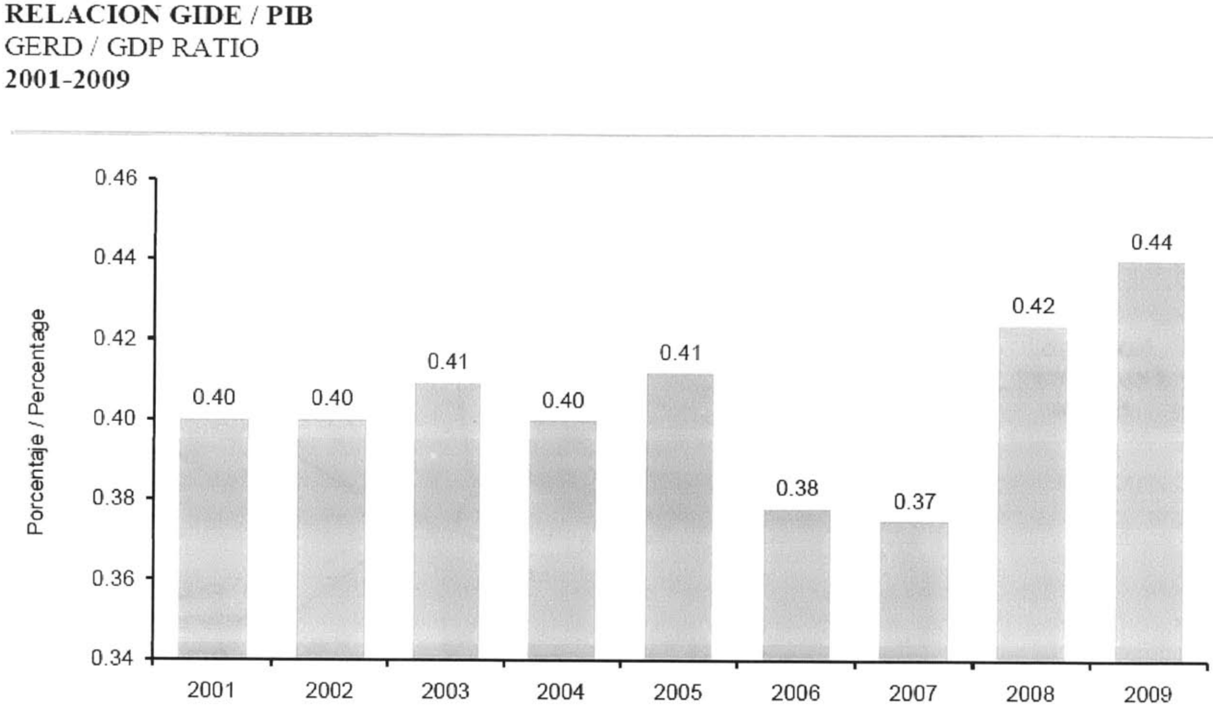


Figure 13: GERD/GDP ratio from 2001 to 2009 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Figure 13** we can see the gross expenditure in R&D (GERD) at .44% of GDP in 2009, one of the lowest among OECD countries and well short of the 1% target Mexico has had for about a decade.

Additionally in **Figure 13** we can observe a slowdown in R&D intensity in 2006 and recovery in 2008 but these numbers are still very low compared to OECD average and are particularly low for Mexico's potential. **Figure 14** shows a comparison of R&D intensity for 2008 with select countries showing Mexico's low performance in GERD/GDP also explaining the low quantity of R&D conducted with respect to Mexico's potential. The next section will examine Mexico's access to a large market, availability of skilled human resources, performance of universities and public research system, incentives aimed at R&D and clusters present in Mexico.

GIDE POR PAÍS CON RESPECTO AL PIB
GERD by country as a percentage of GDP
2008

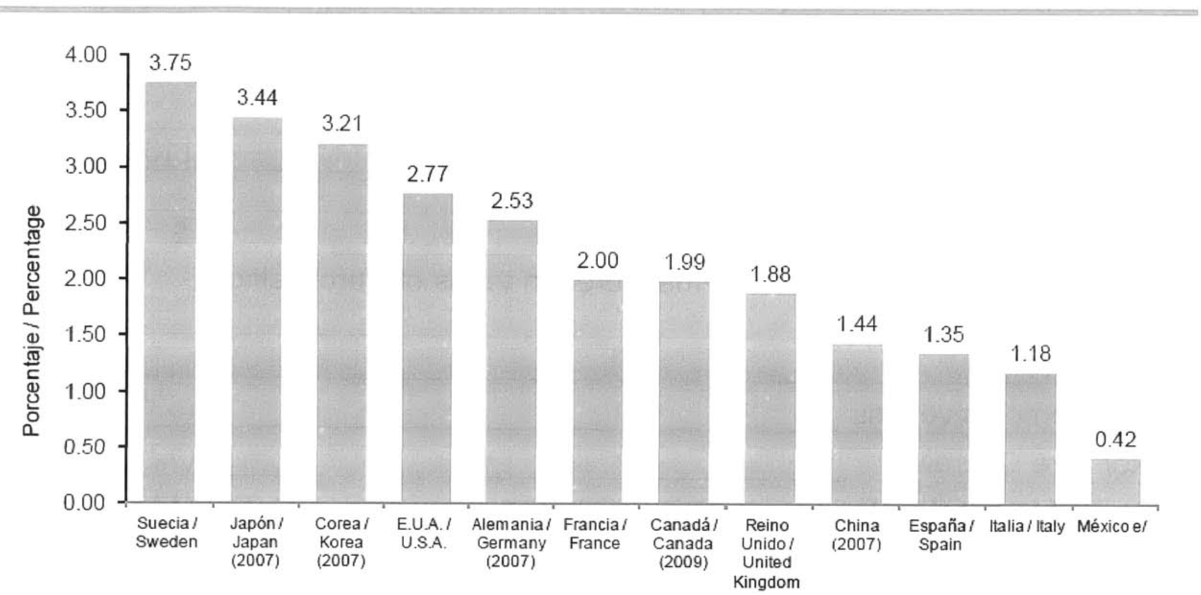


Figure 14: GERD/GDP ratio for select countries in 2008 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Performance of Mexico's National Innovation System

Access to a Large Market:

The World Economic Forum (WEF) 2012 -2013 Global Competitiveness Report ranks Mexico as shown in the following categories:

General Statistics:	
Population	116.4 Million
GDP (US$ billions)	$ 1,154.80
GDP per capita (US$)	$ 10,153.00
GDP as a share (%) of world total measured in terms of Purchasing Power Parity (PPP)	2.11%
Select factors	
Overall Competitiveness	(53rd place)
Market Size Overall	(12th place)
Domestic Market Size Index	(11th place)
Foreign Market size index	(15th place)
Innovation and Sophistication overall	(49th place)

Table 6: General Statistics and Select Factors for Mexico (created with information from WEF, Global Competitiveness Report 2012-2013)

Mexico is ranked 53rd total in the 2012 -2013 Global Competitiveness Report, moving up 5 places from the previous report with improvements in all 12 categories used in the study including Innovation. The report points out some of the competitiveness strengths of Mexico including its large and deep internal market (11th), a sound macroeconomic framework (40th), fairly good transport infrastructure (41st) and fairly sophisticated businesses (44th). The report also points out that the innovative potential is hampered by the low quality of education (110th) especially in math and science (124th), the low use of ICT (81st), and the low uptake by businesses of new technology to spur productivity improvements and innovation (75th) (WEF 2012, pp. 33). This population statistic ranks Mexico 11th largest in the world and 14th largest GDP giving Mexico a very large domestic market. Mexico is ranked by the World Bank as having an upper middle level income and according to De la Calle and Rubio (2012), Mexicans recently perceive themselves primarily as a middle class society. Data from the World Bank supports the noticeable increase in the middle class in Mexico in recent years (Ferreira et. al. 2013) and as such the purchasing power of Mexicans is on the rise. Additionally, Mexico is poised to have a demographic bonus in the next 25 years, this means more people in the work force and a primarily young population. It is yet to be seen if Mexico can take advantage of the demographic bonus (OECD 2009) but the demographic bonus also points attention to future consumers, particularly young buyers will be important in this market.

In addition to the WEF international market size rankings, Mexico has free-trade deals with 44 countries, more than any other nation. Mexico has one of the most open economies and internationalized trade economies in the world. Its geographical proximity to the US makes it particularly attractive for US FDI as well as exporting to the US. According to an article published in the Economist; the US will import more from Mexico than from any other country by 2018, overtaking China (The Economist 2012).

In conclusion, Mexico has one of the largest domestic markets in the world and also significant access to international markets. Access to a large domestic market and international markets is one of Mexico's biggest advocates of FDI in the form of establishment of production facilities and for conducting R&D. A large part of the nature of innovation is tacit knowledge and as such it is important to have innovation structures aimed at future growth markets. Mexico and South Korea top the next eleven list which is a list of eleven countries identified by Goldman Sachs as having high potential along with the BRICs to becoming the world's largest economies.

Availability of Skilled Human Resources in Mexico

"A qualified human resource base is a cornerstone of any innovation-based strategy for socio-economic development. Mexico has a pool of qualified scientists and engineers as a result of efforts over the past two decades, notably the scholarship programs... [Despite the huge growth in skilled human resources] it is insufficient in light of the country's size and economic potential. The bulk of the labour force is largely unskilled or low-skilled, and in a large majority of firms lack managerial skills which hinder their capacity to absorb technology and make them unwilling to take the risks associated with innovation" (OECD 2009 pp. 21). A pool of capable human resources is available for R&D, small and medium enterprises many times lack the managerial skills but an MNC has a large pool of qualified managers and experience to draw from.

"Mexico has the highest growth rate in human resources for R&D in the OECD in recent years. From 1996 to 2005 the average annual growth rate was 10.4% for researchers and 11.4% for total R&D personnel. Accordingly, R&D personnel grew from around 27 000 to 84 000 between 1993 and 2005, while the number of researchers more than tripled from 14 000 to 44 000. Mirroring shifting spending patterns, these increases can be mainly attributed to business enterprises and, to a lesser extent, higher education, whereas employment levels in the government sector have fallen slightly. The largest increases in numbers of R&D personnel and researchers have occurred since 2000, again reflecting increased spending levels on R&D." (OECD 2009 pp. 97)

Mexico has one of the largest pools of engineering graduates producing 130,000 engineers and technicians a year from universities and specialized high schools. Mexico competes with the United States in generating undergraduates in engineering (75,575 in 2010 and 83,000 in 2011 respectively) and is beating Brazil, a country with double the population in engineering graduates per year. The drawback is while the number of engineers has soared, engineering jobs have only slightly grown from 1.1 million in 2006 to 1.3 million in 2012 and Mexico has a low enrollment in higher education with less than 30% (The Washington Post 2012). Whether undergraduates will continue to higher levels of education (particularly PhD graduates still is low) or become researchers is unclear, but there is huge potential for growth in this area and the available pool is more than enough for the Ford of Mexico organization to find talent. The lack of high caliber jobs for S&T personal along with the high production of engineers seems to indicate there are large pools of underemployed or even unemployed qualified S&T personnel to draw from. Skilled personnel could be available for R&D positions for a fraction of the cost, 30-40% less than their US counterparts (Bloomberg BusinessWeek 2006).

Figure 15 below shows the number of researchers per 1000 labor force. This is still low for OECD standards and is to some extent linked with the low GERD/GDP ratio. The high pool of engineering graduates, potentially future researchers, could swing this statistic favorably as population growth stagnates and the Mexico enters it's demographic bonus, but in the meantime researchers per 1,000 labor force indicates Mexico is nowhere near its potential in regards to number of researchers. The low researchers per thousand does not necessarily indicate low availability of skilled human resources rather that Mexico lacks the critical mass in employed R&D personnel to compete globally in quantitative terms and that it has not reached its potential as it is developing. Interviews with researchers revealed that the availability of researchers seems adequate for the level of jobs available and also a large concentration of researchers in the Mexico City area where Ford of Mexico operates; the major obstacle seems to point not at researcher availability but availability of R&D jobs. Actually many skilled human resources emigrate to find R&D or high caliber jobs, "Mexico has the lowest proportion of highly skilled expatriates in the OECD area. Nonetheless, given the very large overall number of Mexican emigrants, the actual number of highly skilled migrants is one of the highest in the OECD area" (OECD 2009 pp. 154).

INVESTIGADORES POR CADA 1,000 DE LA PEA
Researchers per 1.000 labor force
2001 -2009

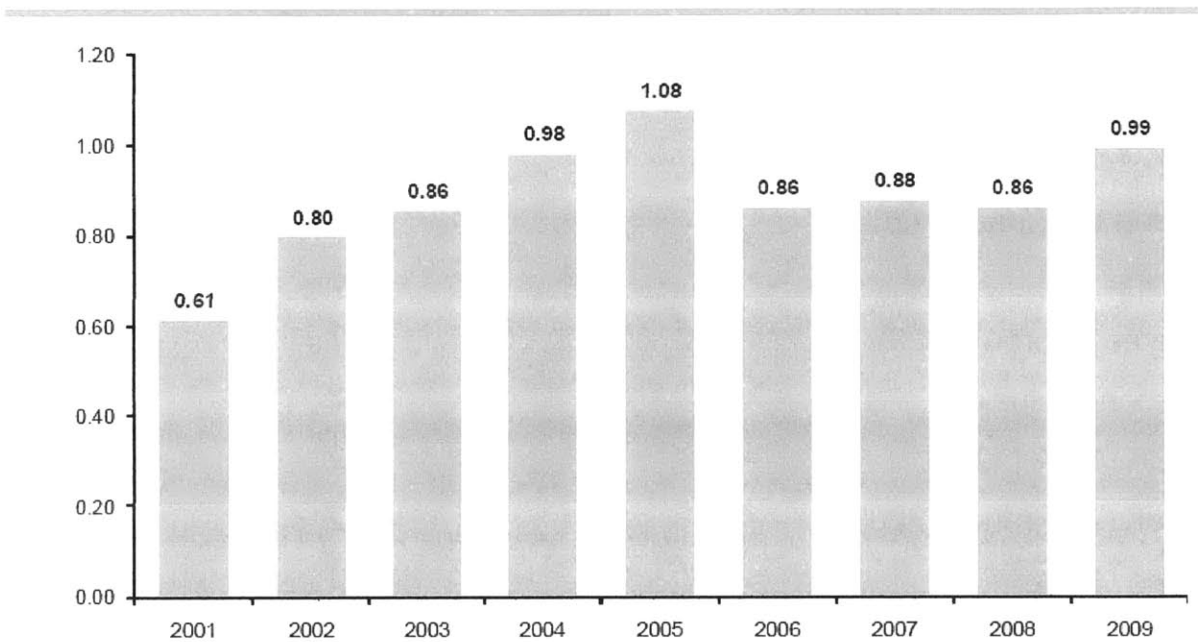


Figure 15 : Researchers per 1,000 labor force (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

INVESTIGADORES POR CADA 1,000 DE LA PEA, POR PAÍS
Researchers per 1,000 labor force by country
2009

País / Country	Inv x 1,000 de PEA / Researchers per 1,000 labor force
Alemania / Germany (2007)	7.5
Argentina (2008)	2.9
Canadá / Canada (2008)	8.2
China	1.5
Corea / Korea (2008)	9.7
España / Spain	5.8
EUA / USA (2007)	9.2
Francia / France (2008)	8.2
Italia / Italy	4.1
Japón / Japan	9.9
Mexico	**1.0**
Portugal	8.2
Turquía / Turkey	2.3

Fuentes / Sources: INEGI-Conacyt, Encuesta sobre Investigación y Desarrollo Experimental, 2010.
OECD, Main Science and Technology Indicators, 2011/1.

Table 7: Researchers per 1,000 labor force for select countries (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Table 7 above shows an international comparison of researchers per 1,000 labor force in select countries. As noted earlier, Mexico ranks low compared to other countries.

PERSONAL DEDICADO A IDE POR SECTOR DE EMPLEO
Total R&D personnel by sector of employment
2001 -2009
Número de personas en equivalente a tiempo completo / Full time equivalent

Sector de empleo / Sector of employment	2001	2002	2003	2004	2005	2006	2007	2008	2009
Productivo/ Business enterprise	8.901	13.697	18.608	35.041	42.329	31.882	34,474	32,408	39,635
Gobierno/Government	16.592	13.311	13.311	14.252	14.837	14.275	14,248	17,296	17,325
Educación superior/ Higher education	15.694	24.720	26.108	24.444	25.218	19.383	19,889	23,476	24,296
Privado no lucrativo/ Private non profit	206	1.651	1.848	1.373	1.299	1.518	1,781	2,190	2,386
Total	**41,393**	**53,379**	**59,875**	**75,110**	**83,683**	**67,058**	**70,392**	**75,370**	**83,642**

Fuentes / *Sources*: Conacyt-INEGI. Encuesta sobre investigación y Desarrollo Experimental 2002, 2004. 2006, 2008 y 2010.

Table 8: R&D personnel by sector of employment (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Table 8 above and **Figure 16** below show R&D personnel by sector of employment, we can observe most personnel reside in business enterprises followed by higher education institutions and then government.

PERSONAL DEDICADO A IDE POR SECTOR DE EMPLEO
Total R&D personnel by sector of employment
2009
Porcentaje / Percentage

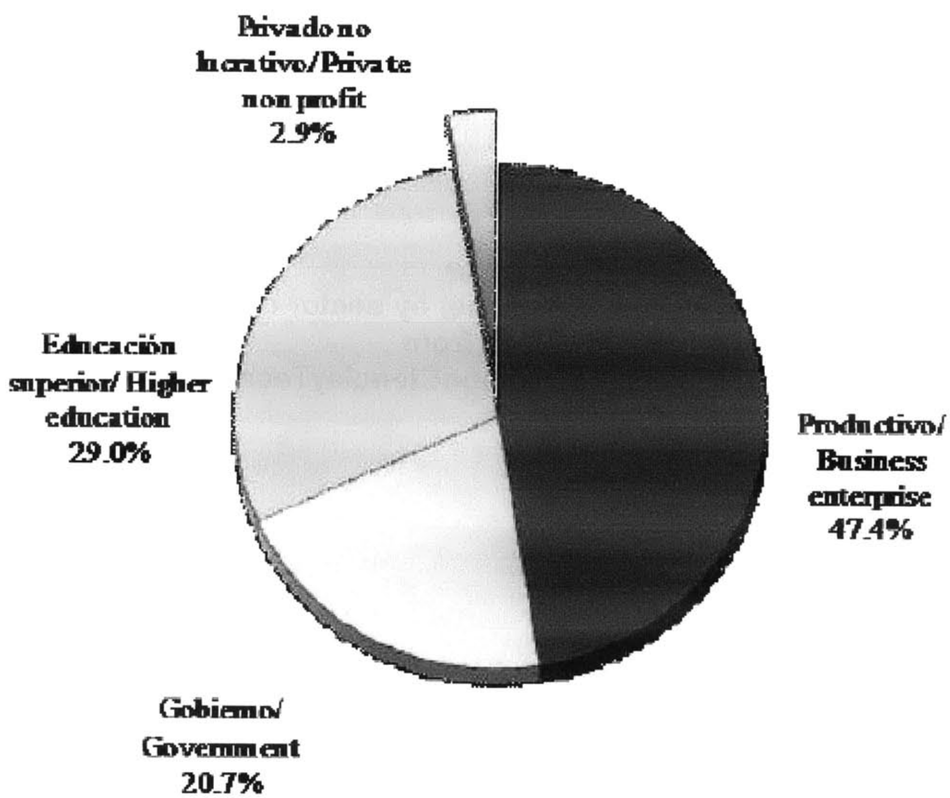


Figure 16 : R&D personnel by sector of employment (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

EGRESADOS DE PROGRAMAS DE POSGRADO
POR NIVEL DE ESTUDIOS Y CAMPO DE LA CIENCIA
Persons completing postgraduate studies by academic level and field 1/
2002-2010
Número / Number

Nivel de estudio/ Academic level	2002	2003	2004	2005	2006	2007	2008	2009	2010 e/
Especialización / Especialization program	10,307	10,099	13,158	13,251	14,844	16,092	16,790	16,903	19,541
Maestría / Master's degrees	26,253	26,840	31,840	33,127	32,591	35,647	39,183	40,927	44,885
Doctorado / Doctoral degrees	1,446	1,390	2,325	2,456	2,800	2,950	3,498	4,099	4,169
Total	**38,006**	**38,329**	**47,323**	**48,834**	**50,235**	**54,689**	**59,471**	**61,929**	**68,595**
Campo / *Field*									
Ciencias Exactas y Naturales / Exact and Natural Sciences	1,020	979	1,929	1,904	1,936	2,274	2,510	2,376	3,270
Ciencias Agropecuarias / Agricultural Sciences	715	889	1,189	1,064	1,238	1,114	964	1,239	1,384
Tecnologías y Ciencias de la Ingeniería / Engineering Sciences	4,979	5,417	6,555	6,007	5,764	5,537	5,733	5,957	6,984
Ciencias de la Salud / Health Sciences	3,764	4,077	7,162	6,590	7,465	8,354	8,142	7,938	9,634
Ciencias Sociales y Humanidades / Social Sciences and Humanities 2/	27,528	26,967	30,488	33,269	33,832	37,410	42,122	44,419	47,323
Total	**38,006**	**38,329**	**47,323**	**48,834**	**50,235**	**54,689**	**59,471**	**61,929**	**68,595**

e/ Datos estimados / Estimated data.
* No implica que el grado sea otorgado/ Does not imply that the degree is awarded
**Incluye los campos de ciencias sociales, administrativas, educación y humanidades/ Includes social sciences and humanities.
Fuente / Source: ANUIES, Anuarios Estadísticos de Posgrado, 2000-2010

Figure 17 : Persons completing postgraduate studies by academic level and field (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Figure 17** we can observe the increase in postgraduate studies over the years but note that most personnel reside in the social sciences and humanities with only a small proportion of postgraduates in Engineering Sciences. A lot of the postgraduate growth is attributed to the scholarship program sponsored by CONACYT but even this growth seems insufficient in light of the large population.

In **Figure 18** we can observe that the proportion of PhD's is low in Mexico in regards to total postgraduate studies, this is even lower when considering undergraduates as well.

EGRESADOS DE PROGRAMAS DE POSGRADO POR NIVEL DE ESTUDIOS
Persons completing postgraduate studies by academic level
2010 e/
Porcentaje / Percentage

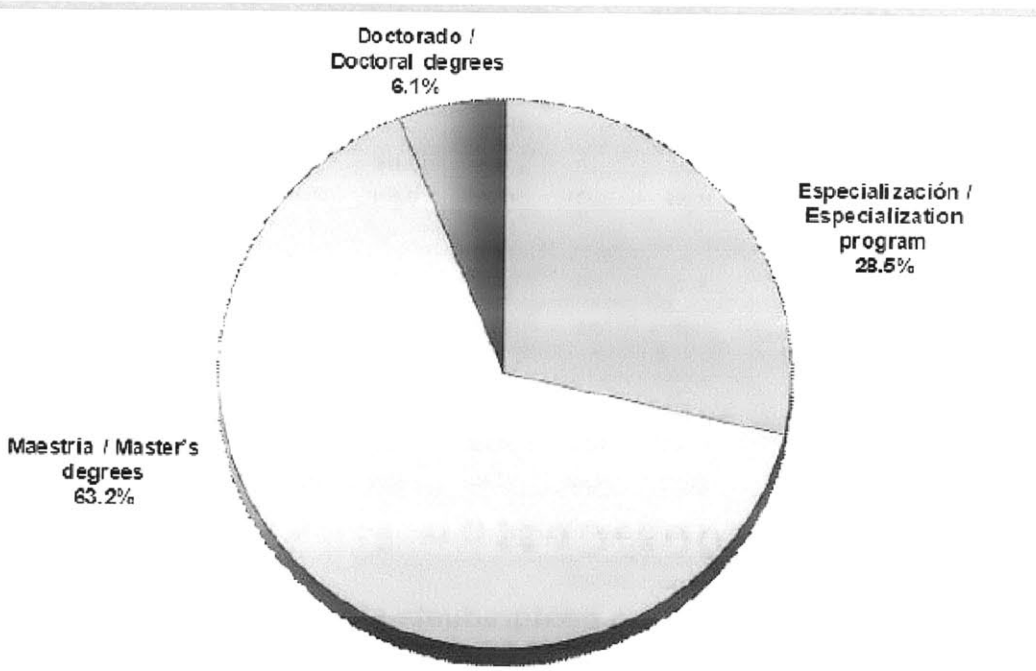


Figure 18 : Persons completing postgraduate studies by academic level (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In Summary, researchers per labor force is still low but there seems to be one of the largest pools of engineering graduates to draw from in Mexico. Availability of researchers also seems to be improving through government incentives, primarily the scholarship program, and industry matching R&D spending by the government. Mexico is far from its potential as indicated by low researcher per 1000 labor force but the sheer size of Mexico´s population accounts for a large pool of skilled personnel. There is a large concentration of personnel in the Mexico City area.

Universities and Public Research System

Even more important than the quantity of R&D personnel is the quality of their work. We will measure the performance of universities and public research system in number of publications, share of publications, citations and impact factor of publications and patent data. None of these indicators draw a perfect picture of the scientific quality of work in Mexico but all together give a reasonably clear broad conceptual understanding.

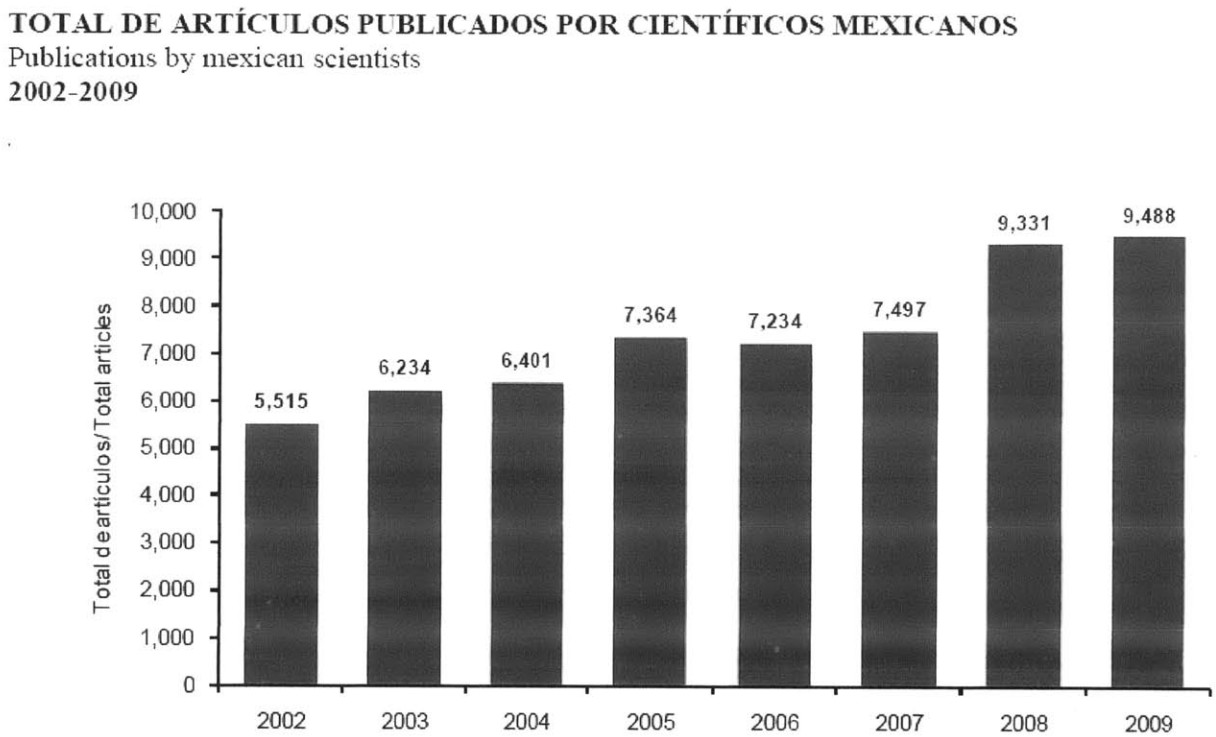


Figure 19: Publications by Mexican Scientists (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Figure 19 shows publications by Mexican Scientists where we observe an increase in publications through the years; this could be due to the increase in researchers year over year and partly to stimulus through SNI.

ARTÍCULOS PUBLICADOS POR PAÍS
Publications by country
2000-2009

País / Country	Promedio / Average 2000-2009	Participación mundial promedio/ International Average share 2000-2009	Producción/ Production 2009	Participación mundial/ International share 2009
Alemania / Germany	75,240	8.22	87,966	7.56
Argentina	5,350	0.58	7,121	0.61
Brasil / Brazil	18,232	1.91	31,603	2.71
Canadá / Canada	42,089	4.55	54,116	4.65
Chile	3,005	0.32	4,670	0.4
Colombia	1,100	0.11	2,364	0.2
Corea / Korea	24,720	2.62	38,183	3.28
E.U.A. / U.S.A.	290,636	31.73	331,298	28.46
España / Spain	30,844	3.31	43,285	3.72
Francia / France	53,816	5.87	63,898	5.49
Italia / Italy	40,223	4.35	50,807	4.36
Japón / Japan	76,253	8.41	78,551	6.75
México	6,913	0.74	9,488	0.82
Reino Unido / U. K.	77,832	8.51	89,378	7.68
Venezuela	1,128	0.12	1,330	0.11
Total Mundial / World Total	922,752	100.00	1,164,023	100.00

Fuente / Source: Institute for Scientific Information, 2010.

Table 9: Publications by Select Countries, International Comparison (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Table 9** above and **Figure 20** below we can see Mexico only marginally contributes to an international share of publications but slowly is starting to grow in this respect. If Mexico can increase the number of researchers and researchers per 1000 labor force, the potential for growth could be huge. As we have seen this task has proven difficult in light of low level of skilled employment yet the improvements in the past years for Mexico have been remarkable.

PARTICIPACIÓN DE LOS PAÍSES EN EL TOTAL DE ARTÍCULOS PUBLICADOS
Countries' share of published articles
2009

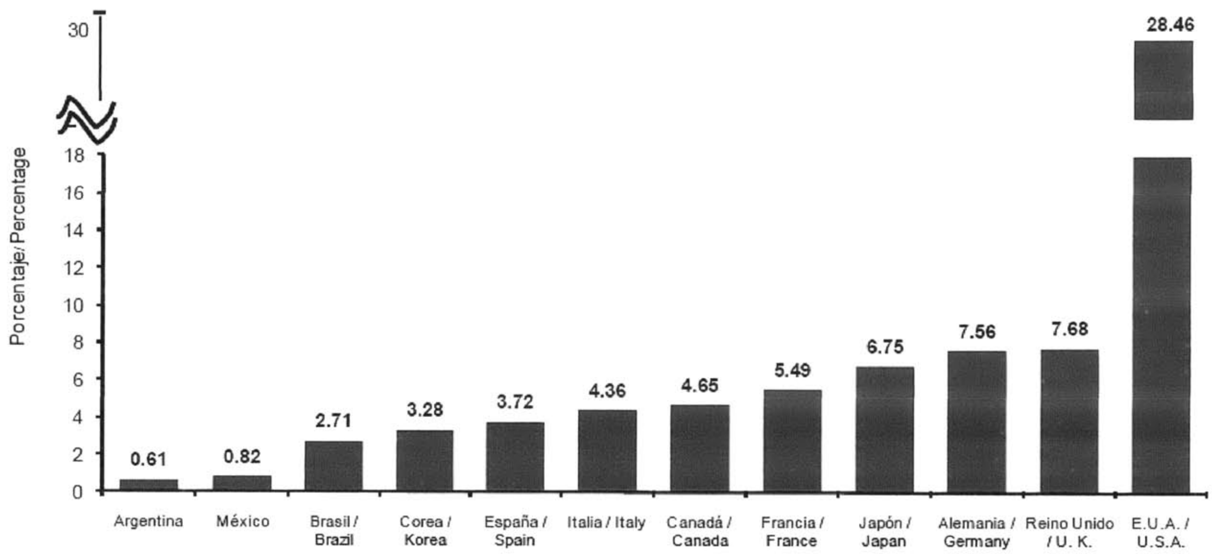


Figure 20: Select Countries´ share of Published Articles (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

CITAS E IMPACTO EN ANÁLISIS QUINQUENAL DE LOS ARTÍCULOS MEXICANOS
Five year overlapping period citations and impact for mexican publications
1996-2009

Quinquenio/ Five year period	Citas/ Citations	Impacto/ Impact
1996-2000	44.930	2.12
1997-2001	51.750	2.27
1998-2002	58.737	2.39
1999-2003	66.354	2.50
2000-2004	72.521	2.57
2001-2005	82.958	2.70
2002-2006	93.284	2.85
2003-2007	104.134	3.00
2004-2008	120.694	3.19
2005-2009	137.551	3.36

Fuente / Source: Institute for Scientific Information, 2010.

Table 10: Five year overlapping period citations and impact for mexican publications 1996-2009
(CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Table 10** above and **Figure 21** below, we can see an increase in citations year over year and impact factor. In **Table 11** and **Figure 22** we observe an International comparison showing Mexico´s research qualitatively competitive with developing countries and slowly catching up to the developed world.

CITAS EN ANÁLISIS QUINQUENAL DE LOS ARTÍCULOS MEXICANOS
Five year overlapping period citations for mexican publications
1996-2009

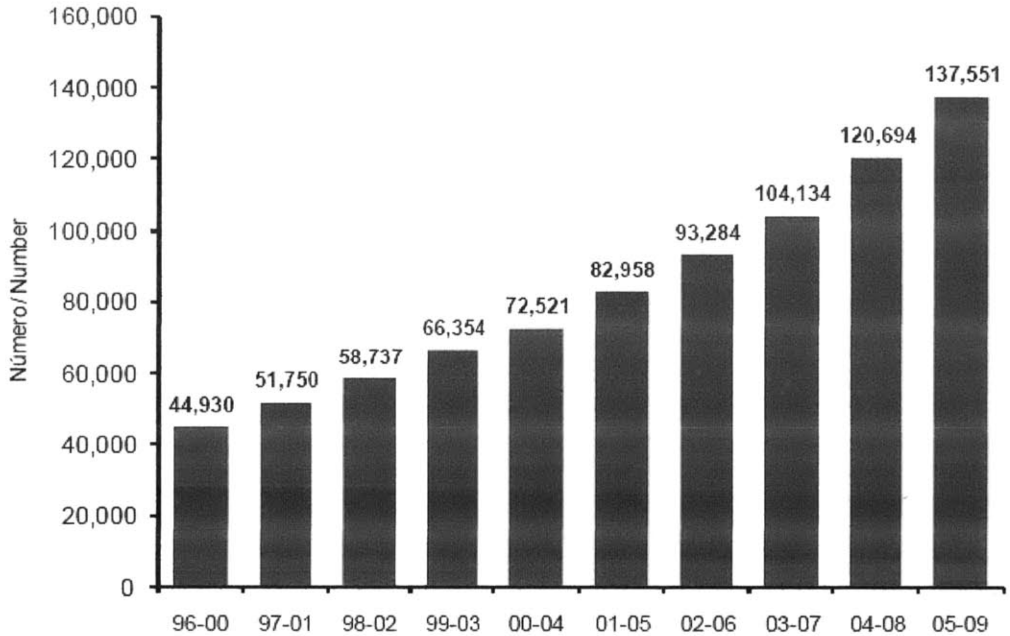


Figure 21: Five Year Ovelapping period citations for mexican Publications 1996-2009

(CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

IMPACTO POR PAÍS EN ANÁLISIS QUINQUENAL
Five year overlapping period impact by country
1998-2009

País/ Country	98-02	99-03	00-04	01-05	02-06	03-07	04-08	05-09
Alemania / Germany	4.74	4.98	5.10	5.37	5.56	5.76	6.06	6.40
Argentina	2.62	2.79	2.92	3.13	3.27	3.45	3.66	3.90
Brasil / Brazil	2.25	2.37	2.48	2.64	2.77	2.89	2.94	3.04
Canadá / Canada	4.92	5.05	5.09	5.21	5.32	5.52	5.78	6.10
Corea / Korea	2.30	2.50	2.62	2.79	2.93	3.11	3.29	3.49
E.U.A. / U.S.A.	5.90	6.08	6.15	6.38	6.51	6.65	6.85	7.08
España / Spain	3.69	3.88	3.94	4.14	4.34	4.56	4.84	5.10
Francia / France	4.47	4.61	4.74	4.94	5.07	5.24	5.50	5.82
Grecia / Greece	2.71	2.83	2.95	3.12	3.33	3.53	3.85	4.25
Japón / Japan	3.71	3.86	3.97	4.16	4.26	4.41	4.61	4.76
México	2.39	2.50	2.57	2.70	2.85	3.00	3.19	3.36
Polonia / Poland	2.47	2.60	2.68	2.86	3.00	3.21	3.30	3.40
Portugal	3.07	3.23	3.28	3.53	3.62	3.86	4.23	4.56
Reino Unido/ U. K.	5.11	5.33	5.49	5.75	5.96	6.08	6.39	6.75
Turquía / Turkey	1.48	1.56	1.64	1.79	1.95	2.11	2.28	2.44
Total Mundial/World Total	4.05	4.18	4.22	4.38	4.47	4.58	4.70	4.86

La suma de los totales puede no coincidir debido a que un artículo puede estar clasificado en varias areas de la ciencia. /Yearly total may not match with sum due to the articles be able to clasificaded in one or more fields.
Fuente / Source: Institute for Scientific Information, 2010.

Table 11: Five year overlapping period impact factor by Country 1998- 2009 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

IMPACTO POR PAÍS EN ANÁLISIS QUINQUENAL
Five year overlapping period impact by country
2005-2009

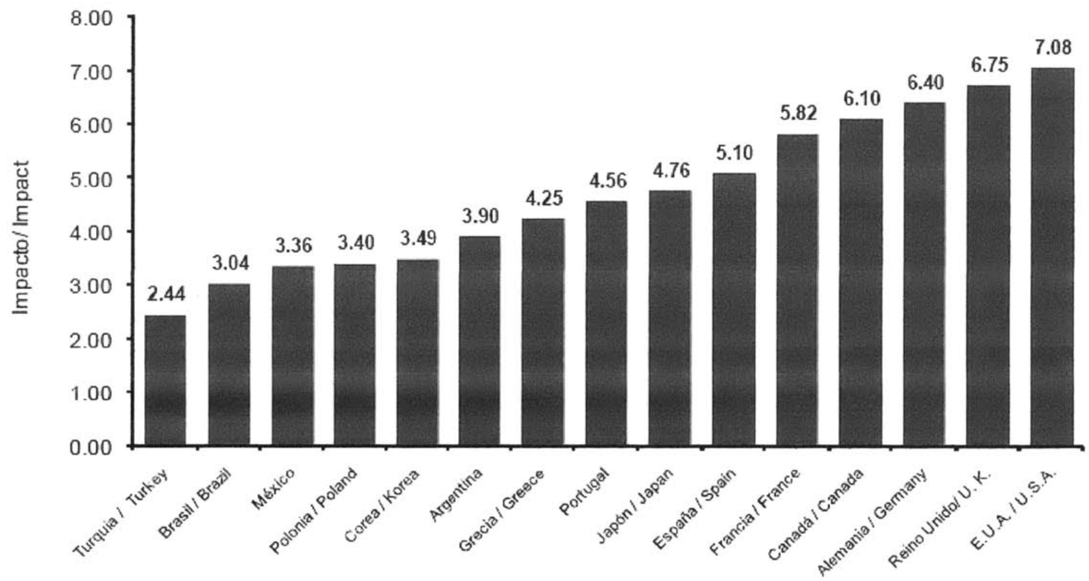


Figure 22: Five year overlapping period impact factor by country (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

PATENTES SOLICITADAS Y CONCEDIDAS EN MÉXICO
Patent applications and granted in Mexico
2001-2010
Número / Number

Año/ Year	Solicitadas/Applications			Concedidas/ Granted		
	Nacionales / Resident patents	Extranjeras / Non-resident patents	Total	Nacionales / Resident patents	Extranjeras / Non-resident patents	Total
2001	534	13.032	13.566	118	5.360	5.478
2002	526	12.536	13.062	139	6.472	6.611
2003	468	11.739	12.207	121	5.887	6.008
2004	565	12.629	13.194	162	6.676	6.838
2005	584	13.852	14.436	131	7.967	8.098
2006	574	14.926	15.500	132	9.500	9.632
2007	641	15.958	16.599	199	9.758	9.957
2008	685	15.896	16.581	197	10.243	10.440
2009	822	13.459	14.281	213	9.416	9.629
2010	951	13.625	14.576	229	9.170	9.399

Fuente/ Source: IMPI. en Cifras 2011.

Table 12: Patent Application and Granted in Mexico 2001-2010 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In **Table 12 above** and **Figure 23** below, we can observe Mexico´s Patent data and find an abnormally large number of non-resident patents, mainly MNC´s that patent in Mexico inventions created abroad. Mexico has a strong dependence of foreign research institutions and MNC´s to generate patents. Resident national patents granted are at 229 for 2010, and even though increasing year over year, is very low. MIT alone is granted over 100 patents per year in the US. Mexico´s inability to produce patents is not a good sign for R&D potential but is related more to the firms operating in Mexico than to the HEI. Poor patenting performance also highlights the low level of industry-university linkages.

PATENTES SOLICITADAS EN MÉXICO
Patents applications in Mexico
2001-2010

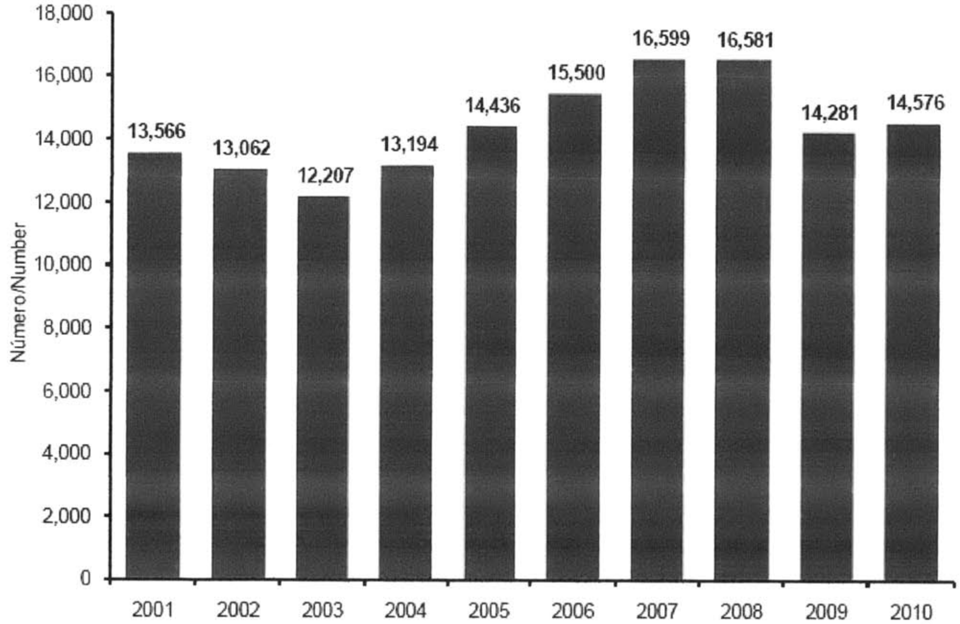


Figure 23: Patent applications in Mexico 2001-2009 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

Mexico´s patent generation is not significant in the world scene but it has increased a lot in recent years though far from being competitive. Over 90% of patents registered in Mexico were by foreign entities (mainly MNC´s) to protect their inventions in the Mexican market. Only a small fraction of patents registered in Mexico were from local entities/residents. Patents originating in Mexico but registered internationally have grown 14 times its size since 1995 (but even with this growth Mexico´s patenting activity is still one of the lowest among OECD countries).

PATENTES SOLICITADAS POR MEXICANOS EN EL EXTRANJERO. PRINCIPALES PAÍSES
International patent applications by mexican citizens.
Main countries.
2001-2009
Número / Number

País/ Country	2001	2002	2003	2004	2005	2006	2007	2008	2009
Alemania / Germany	3	0	2	0	0	0	4	3	4
Brasil / Brazil	19	21	25	31	26	31	27	0	0
Canadá / Canada	7	5	6	0	15	31	35	44	39
España / Spain	12	6	8	1	4	4	6	3	1
EUA / U.S.A	196	157	185	179	180	213	212	248	220
Francia / France	0	0	0	1	0	2	1	0	0
Reino Unido / U. K.	5	0	0	4	1	0	1	1	2
OEP / EPO*	5	5	3	23	28	47	30	63	51

*Oficina Europea de Patentes / European Patent Office
n.d. = Cifra no disponible / Not available data

Table 13: Internationl Patent Applications by Mexican Citizens 2001-2009 (CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

We can also observe in **Table 13** and **Figure 24** an abnormally large number of patent applications by Mexicans in foreign countries. Mexican researchers prefer to patent in more developed countries mainly the US. This indicates Mexicans prefer to patent abroad where the invention is more likely to be utilized to ensure protection and utilization of their IP. This also indicates that many MNC´s utilize Mexican researchers for their insight or to take advantage of lower wages but patent in their home country.

PATENTES SOLICITADAS POR MEXICANOS EN EL EXTRANJERO.
PRINCIPALES PAÍSES
International patent applications by mexican citizens.
Main countries.
2001-2009

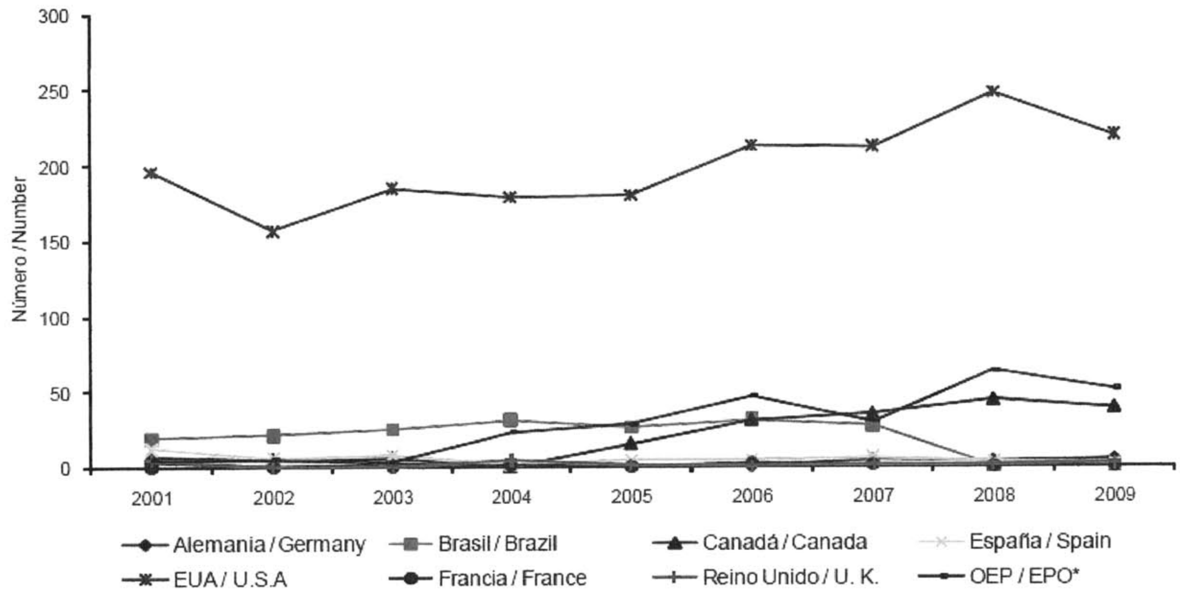


Figure 24: International Patent Applications by Mexican Citizens in Select countries 2001-2009
(CONACYT, retrieved November 2012 from http://www.conacyt.gob.mx/InformacionCienciayTecnologia/Documents/Indicadores_2010.pdf)

In summary, Mexico is beginning to appear as a player in publication share but its contribution is still insignificant largely due to the low quantity of researchers and low researchers per 1,000 labor force. Mexico is considered lacking in its ability to produce patents, even compared to BRICs. Qualitatively, Mexico is competitive with the BRIC´s in impact factor of publications.

Incentives and Policy

This section will highlight the types of incentives (mostly financial and fiscal) that the government has to develop R&D projects in Mexico. Funds may come from several sources but mostly CONACYT assesses the projects and grants the incentive (sometimes in conjunction with other institutes). Listed below are the main types of funds for R&D in Mexico.

Sectorial Funds for Education

Focused on basic science, these used to be aimed at individual researchers but now geared toward groups or networks. Sectorial Funds are geared towards strategic needs of the participating sectors and are generally given towards universities or research centers even though firms are not excluded from obtaining them.

Sectorial Funds for economic development

These are focused towards innovation and technology development to increase competitiveness of firms that operate in Mexico. Sectorial funds are operated jointly between CONACYT and sectorial ministries with highly defined selection criteria and typically high rejection rates. Typically firms that develop new products or processes participate and if large firms want to succeed obtaining sectorial funds their plan must incorporate small or medium enterprises as partners or suppliers (Dutrenit et. al. 2010 pp. 191)

Mixed Funds

Funds geared towards local demands (of states), to develop industry or regional capacities (Similar to sectorial funds but decentralized and targeted at region specific needs). Mixed funds are jointly administered and financed by CONACYT and state governments. Amounts allocated in mixed funds are generally quite small and do not have a good track record due to requirements not being well defined and a lack of coordination between stakeholders. (OECD 2009)

Institutional Funds

These are used for repatriation of scientists, AVANCE (startups, seed capital), SNI (cash incentives for researchers) and scholarships.

Fiscal stimulus:

The most widespread policy used in the past (mainly attracting manufacturing), provides a tax break for companies developing technology related products and/or having R&D projects, product development, production or commercialization of technology oriented products. Before 2008 Mexico gave huge tax incentives for R&D work to companies (the most than any other country), mainly large MNC´s took advantage of this but in 2008 the government changed the incentives scheme to give out cash incentives (direct investment) for R&D (funds geared to S&T halved but are considered more effective), fiscal stimulus has thus been removed from Mexico's incentives programs. (Dutrenit et. al 2010 pp. 194-196)

The Technological Innovation Fund

This fund replaced the fiscal stimulus after its elimination in order to continue stimulating R&D activity. It is jointly funded and operated by CONACYT and the Ministry of Economy and provides financial support to innovative projects proposed by individual firms or groups of enterprises. Selection is geared towards projects involving the development of new products, services or processes. Funding can cover up to 50% of the innovation-related costs and requires matching funds. Selection is made by administrative and expert committees who favor strategic sectors. The fund is distributed 1/3 for small and medium enterprises, 1/3 for firms collaborating with HEI's and public research labs and 1/3 for large enterprises. (OECD 2009 pp. 176; Dutrenit et. al. 2010 pp. 196).

The SME Fund

This fund is managed by the Ministry of Economy and is not primarily focused on fostering innovation and technological development. It has supported valuable initiatives owing to the role played by intermediary institutions in the design and submission of projects for funding, with matching resources from state and local governments and enterprises. Initiatives supported by FUMEC (the Mexico-United States Foundation for Science) for the development abroad of high-technology Mexican small and medium enterprises and the technological upgrading of supplier networks of firms in high-technology sectors dominated by multinationals are particularly noteworthy. The Monterrey Technological Institute for Higher Education (ITESM) and the State of Jalisco have developed high-technology clusters. In spite of limited resources, their leverage and economic impact have been quite high. (OECD 209 pp. 178)

AVANCE

This program is meant to help technology-based innovative firms (or other entities) to bring new products, processes or services derived from research to market. The program has been poorly endowed and the bulk of its resources go to relatively mature projects that are in the later stages of development. The financial components of AVANCE which is the provision of risk capital and guarantee funds are in principle co-financed by NAFIN (Mexico's Development Bank) in the framework of joint trust funds with CONACYT. These funds are new and their endowment is limited. (OECD 2009 pp. 178; Dutrenit 2010 pp. 196)

PROSOFT

The role of this program in innovation is indirect; the main objective is to provide support for the development of enterprises in the ICT sector. PROSOFT manages funds from three sources: the federal government, the state government and the companies that submit projects to the program through intermediary organizations that facilitate the review and management processes.

Its economic impact is quite positive in terms of job creation, firm creation, technological infrastructure, spillovers and cluster formation, and productivity. A positive side effect the program has had is promoting regional technological clusters and building linkages with the regional research base. (OECD 2009 pp. 178)

10 years of national strategy and policy have shaped a new focus in government policy and incentives. Interviews with government officials revealed that previously the main interest was attracting foreign direct investment, mainly manufacturing, this thinking still persists in many government institutions but there is a large change toward now gearing Mexico´s policy towards developing a knowledge economy. More than ever, the government is looking to develop an economy based on innovation, a knowledge economy by stimulating applied research with links to industry (less focus on basic research and more industry cooperation). New efforts focus on trying to remove stimulus from low cost strategy and putting it to innovation strategies that have value add to companies established in Mexico (R&D rather than low cost manufacturing). Historically the academic world and Industry have not had strong ties; a secondary objective the government has is to increase cooperation between universities/research centers and industry (largely due to OECD criticism of poor university-industry linkages). ITESM has been a good example of this, particularly in advanced manufacturing. Government strategy is now more focused on creating ecosystems for innovation through direct cash incentives. Financing still presents a problem (especially for small and medium companies), there is a lack of access to risk capital yet there are government initiatives for working with banks to improve this situation. MNC´s are well positioned to take advantage of incentives due to having skilled human resources (more so than most small and medium enterprises) and technological competencies already. These policy directions are clearly reflected in the more recent instruments introduced by the latest science and technology policy some of which are:

INNOVAPYME

This initiative is oriented to induce small and medium sized enterprises to carry out R&D projects in technology that are preferably undertaken in co-operation with universities and research centers to promote increased competitiveness and high value add. (KPMG 2012; OECD 2009 pp. 182)

INNOVATEC

This program supports technological innovation projects aimed at raising the competitiveness of enterprises regardless of size and preferably in co-operation with other firms or public research institutions. It also supports the development of research infrastructure, the creation of private R&D centers, the creation of new high-quality jobs and the stimulation of the country's economic growth. A link with universities and research centers is preferable. (KPMG 2012; OECD 2009 pp. 182)

PROINNOVA

This program is targeted at both small and medium enterprises as well as large companies that have innovation projects in frontier technologies and fields that stimulate knowledge flow among universities, research centers and the private sector. The link between the mentioned entities is mandatory in order to be eligible for this approach. (KPMG 2012; OECD 2009 pp. 182)

IDEA

IDEA provides scholarships for researchers to work on R&D in firms and thus stimulate linkages between the private sector and academia. This initiative looks to strengthen firm's capacity to innovate by placing R&D personnel in firms and provide professional development opportunities for SNI members. (Dutrenit et. al. 2010 pp. 200)

Sabbaticals in industry

Similar to IDEA and also geared towards strengthening private sector and university linkages, this program aims to place researchers in firms for specific projects that are requested by the firm. (Dutrenit et. al. 2010 pp.201)

Clusters and Centers of Excellence

"Although Mexico does not have an explicit technological cluster policy, policy initiatives at the federal, but perhaps more importantly at the state or municipal levels, have facilitated the emergence of technological and/or sectoral clusters in states such as Jalisco (electronics and high value added food and agro-industries), Guanajuato (biotechnology for agriculture and traditional industries), Nuevo Leon (software and electronics), Queretaro (machinery) and Baja California Norte (micro-electronics and biotechnology).

These clusters have benefited from support measures jointly funded at the federal (CONACYT and the Ministry of Economy) and state levels, often with matching funds from industry. However, a prerequisite for their success appears to have been strong participation of concerned business associations and intermediary organisations. Together with state and municipal authorities, these have fostered the development of technological infrastructure, human capital and knowledge transfers in collaboration with local higher education institutions and public research centres." (OECD 2009 pp. 188)

Aerospace Industry:

In Mexico, the aerospace sector is rapidly growing. The level of exports has tripled in only six years and, in 2011, the industry's exports reached 4.337 billion dollars. Imports, meanwhile reached 3.782 billion dollars in 2011, maintaining a positive trade balance. Foreign and national investment in the sector exceeded 1 billion dollars in 2010 and 3 billion in the last three years. According to estimates from the "Strategic Program of the Aerospace Industry 2010-2020," coordinated by the Ministry of Economy, the industry is expected to export 12.26 billion dollars in 2020, with a 14% average annual growth rate. Querétaro has the potential to specialize in turbine design, manufacturing, assembly and Maintenance, Repair and Overhaul (MRO) of complex fuselage parts, turbines and landing gears. As an important coordination mechanism between the industry and higher education and research institutes, the Aerospace Research and Innovation Network of Querétaro (RIIAQ) helps develop and strengthen research, technological development and innovation capabilities. Aerospace focused regions include: Baja California, Sonora, Queretaro, Chihuahua, Nuevo León, Tamaulipas, Jalisco, Coahuila and San Luis Potosí. Some of the companies established in Mexico include Bombardier, GE infrastructure, Eurocopter and Heroux Devtek. (ProMexico website)

Electronics Industry

Mexico has a solid installed capacity for manufacture of electronic products, which was valued at 62,775 million USD in 2011. In 2011, Mexico had an important share of global television and computer exports. It is the world's leading exporter of flat screens, ranking above highly competitive Asian countries. In addition, it ranked as fourth computer exporter globally. Some of the most important transnational companies of manufacturing services for the electronic industry operate in Mexico including Flextronics, Samsung, Lenovo, LG, Foxconn and Intel. Electronics industry locations include Baja California, Jalisco, Distrito Federal, Chihuahua, Sonora, Nuevo Leon and Mexico. (ProMexico website)

Automotive:

Mexico's automotive industry is mature, dynamic and in continuous growth. In 2011, the automotive sector accounted for approximately 4% of the Mexican GDP and 20% of Mexico's manufacturing GDP, according to the Mexican Association of the Automotive Industry (AMIA). The automotive and auto parts industries in Mexico have been pushed by the productive presence of the world's top ten vehicle (light and heavy) assembly companies, such as General Motors, Ford, Chrysler, Volkswagen, Nissan, Honda, BMW, Toyota, Volvo and Mercedes Benz. In total, there are nine light vehicle producers in Mexico, ten heavy vehicle producers and close to 1100 auto parts manufacturers, of which more than 300 are first tier suppliers. Most assembly companies in Mexico have auto parts companies located in the vicinity of their car plants to satisfy supply demands and delivery deadlines. In addition, according to the Automotive Aftermarket Suppliers Association (AASA), 84 of the 100 leading auto parts companies in the world have production presence in Mexico. Automotive presence persists in Mexico, Distrito Federal, Puebla, Coahuila, Nuevo Leon, Aguascalientes, Baja California and Jalisco. (ProMexico website)

Software and IT:

According to MexicoIT estimates, in Mexico there are almost 600 thousand professionals in the IT industry, including approximately 400 000 professionals specializing in software. In addition, each year 65 000 new professionals graduate specialized in the sector. Currently there are 121 universities linked with Prosoft the support of the government program. Among the most important companies of this industry in the country are: IBM, HP, Red Uno, Neoris, Unisys, Hildebrando, Softek, Bursatek and Mexis. The software cluster in Baja California is accessed by electronics, aerospace, medical and automotive industry (Toyota). (ProMexico website)

Other clusters found in Mexico include the Appliances, Renewable Energy, Food Innovation and Processed Foods, Mining, Medical Devices, Health, Electricity Equipment, Fashion and Decoration and Agriculture Industries.

Below is a brief list of some examples of success cases in firms conducting R&D:

- Probiomed – Pharmaceutical, biotechnology and combinatory DNA, genetics.
- Delphi – largest MNC producing automotive components in Mexico. Has a high level of R&D activity in Sensors and Actuators. Delphi works mostly with US universities rather than local research institutions.
- Tremec-Chrysler – manual and automatic transmissions, but highly supported by R&D organization from Chrysler located in Detroit area.
- Cemex – Is one of the largest cement companies in the world. It has world class R&D in cement and other technologies (support functions for its global operations such as IT). It has a small R&D presence in México; Cemex strategically located its main R&D center in Switzerland.
- Neoris – A subsidiary of Cemex is the largest IT and systems integration company in Mexico and second largest in Latin America.
- Skyworks – Does electronics development and semiconductors. Skyworks also has software capabilities and some aerospace related activities. This company has generated 5 spin-offs now providing it services (transferring risk).
- Intel – Electronics Industry, Intel has invested in a large product development organization and has an R&D operation with global reach in Guadalajara.
- GE Queretaro – largest turbine development center outside the United States for GE. There are large R&D efforts, potential for being leader in turbine development.
- Honeywell – Located in Mexicali, Baja California and is geared towards Aerospace, has an R&D center does a lot of product development including systems integration and validation.
- Goodrich – Aerospace in Baja California.
- Other success cases of firms conducting R&D include: Spicer, Condumex, Vitro and Cifunsa (Auto parts), which have some R&D in order to remain competitive on a global scale, mainly licensing technologies, alliances and co-development with international companies. Mastretta is a wholly Mexican owned startup designing a car; it is in seed capital stage looking for risk capital to launch its vehicle (entirely designed in Mexico).

Presence of clusters is one of the most influential factors for establishing R&D activities in a particular location for MNC's and the data shows Mexico has sufficient agglomeration of relevant industries to merit a positive review in this category.

Key Findings of Mexico´s National Innovation System

We observed that Mexico has a very large domestic market and access to very large international markets. Moreover the purchasing power of Mexico is growing as noted in the increase in the middle class and soon to have demographic bonus (more people in the work force and a young population). We also noted that Mexico´s R&D is still not significant quantitatively in the world in terms of publications and is especially lacking in patent generation largely due to one of the lowest R&D per GDP spending, a lack of critical mass in researchers and a low ratio of researchers per 1,000 labor force. Nonetheless, due to the large population of Mexico, researcher numbers is adequate for the needs of firms looking to conduct R&D; the low quantity of high caliber jobs also contributes to availability of underemployed or unemployed but qualified workers. Qualitatively, Mexican scientists' work is shown to be competitive against similar developing nations (the BRIC´s) and slowly closing the gap with the developed world. We also noted a set of competitive incentives in the form of direct cash rather than tax breaks which could make qualifying projects attractive to undertake in Mexico. Similarly we identified existing clusters which indicate the industries that are strategic to Mexico and have advantages due to concentration of skilled human resources, cost advantages, incentives and/or regional know how, these are: electronics, software, aerospace and automotive.

Discussion on Ford of Mexico

The case for a Global Ford Innovation Strategy

Five of the six identified decision factors were examined in the context of Mexico´s National Innovation system. One factor, strategy, has not been discussed due to the sensitivity of Corporate Strategy. This section is not to be misinterpreted assuming that Ford does not have a global innovation strategy but rather the details of corporate strategy are confidential and cannot be disclosed due to the secretive nature of such plans. This section will make a case for a Ford global strategy supporting a global innovation process utilizing Ford´s mission and vision as well as the very public ONE Ford plan:

Figure 25: One Ford Strategy

Source : http://corporate.ford.com/careers/careers-news-detail/employees?&ccode=US

One Team: As we can see, Ford´s mission and vision includes the idea of working together as a lean global enterprise. This is in agreement with the idea of a lean global innovation operation and as such a lean global R&D operation. This is not to say Ford should expand R&D everywhere, but analyze where it makes sense and will be part of a lean network contributing innovation to the company on a global scale.

One Plan: Part of the Ford ONE Plan includes accelerating development of new products customers want and value and lately customers want more technology and new features in their vehicles. Many new features as well as the integration of technology require R&D and innovation. Our analysis of the literature indicated that leveraging global centers of excellence can increase speed to market of innovations. Additionally the Ford plan includes working together effectively as one team which can be extended to the context of innovation work streams within Ford and its supplier network.

One Goal: A global innovation strategy both augments the home base operations as well as helps deploy home based innovations in regions. A global innovation structure that is adequately coordinated is able to support the company´s goals globally.

Foster Functional and Technical Excellence: The idea of demonstrating and building technical excellence globally should reinforce the notion of increasing technical capabilities worldwide through more R&D geared towards improving products and processes. Improving the capabilities of global operations can be supported through establishment of formal R&D structures and/or innovation work streams in subsidiaries and not just in headquarters.

Own working together: this statement extends on the ideas of inclusion, respect, believing in others, fostering great relationships and communicating effectively. All of these qualities are enablers of effective global innovation teams. Diversity promotes innovation efforts through different points of view and ideas which can only be garnered in an environment of respect for diversity and trust in other´s skills. To this statement is implicit the notion of working together globally.

Role Model Ford Values: innovation efforts imply showing initiative and are mainly geared towards significant product and process improvements which can be in the form of quality, safety and sustainability improvements. Adding global to the innovation efforts only makes modeling the ford values statement stronger and more universally applicable.

Deliver Results: The move to undertake innovation projects globally should be based on sound decisions using facts and data and can be used to set high expectations in all global Ford locations as a mechanism to inspire others. Innovation should be approached with an enterprise wide view, formal innovation structures support accountability for delivering results to customers worldwide.

As we can see the Ford Mission and Vision align and support the idea of global innovation practices. This alignment should not be misinterpreted with the notion that Ford should expand operations recklessly everywhere. R&D can be expensive and this expansion cannot negate the principle of restructuring profitably. Rather a sound strategy would be to consider locations based on facts and data, considering risks and benefits and execute in a way that could contribute to the company in significant ways as well as enable the ONE Ford plan.

Finally, even if Ford's innovation strategy is not as geographically widespread as assumed here initially, increasing Mexico's capabilities still makes sense. Ford of Mexico is different from other subsidiaries in that it is geographically, culturally, economically and operationally tightly interconnected with headquarters more than any other foreign subsidiary. Unlike some of the other regions operations, Ford of Mexico is considered an extension of the US operations (it has not historically operated independently) and has primarily focused on executing North American initiatives. Production and engineering in Mexico is primarily targeted towards the North American market primarily in the US and lead by headquarters. This interconnectedness between the US and Mexico makes the Mexico PD organization dependent on the North American headquarters (and vice versa) more than any other subsidiary, they are embedded in each other. There are also synergies in communication due to working in the same time zone (1 hour difference most of the year) as well as easy travel due to geographic proximity, advantages in language (the US has the second largest Spanish speaking population in the world behind Mexico and there is an adequate number of professionals that speak English in Mexico) and culturally/socially many Mexicans are accustomed to working with US companies due to their abundant presence in Mexico. It is argued here that strengthening Ford of Mexico's capabilities will increase efficiency in headquarters due to the tightly coupled nature with the US organization and given that the grand majority of FoM personnel report to US department heads already and work on programs led out of headquarters, the headquarters operations efficiency would also improve. Increasing Ford of Mexico's absorptive capacity will increase not just FoM´s ability to deliver, but contribute to improving how the company operates overall.

Current state of FoM

Ford of Mexico has several strategies already in place aimed at fostering relationships with universities, increasing capabilities and recruiting talent such as:

Master´s Degree Programs:

Ford negotiates study plans with universities and allows employees flexible time & career path selection. This strategy helps increase the technical capabilities of FoM´s workforce as well as build relationships with universities for cooperative work.

Equipment Donations:

Phased-out or obsolete but functional equipment is donated to universities in need. This also promotes a good standing with universities and willingness for further cooperative projects.

University Trainees:

A new program aimed at recruiting talent that began in 2012 and seeks potential new hires.

Technical Conferences:

FoM provides speakers for conferences as requested by universities.

Additionally, some ad-hoc R&D projects have been conducted in order to capture some of the government incentives for R&D work.

Intellectual Property:

In order to promote an innovation culture, the product development organization is encouraging employees to patent ideas and solutions that spring up from solving day to day problems. Key innovations & designs are protected with financial support from the Mexican government, up to 5k USD per patent (plus profits). In 2012, FoM filed for 5 patents.

CONACYT Innovation Program:

R&D projects with commercial applications are evaluated by government for grants with a maximum state budget of $12M USD/+100 companies. Every year employees are surveyed for potential projects to submit to CONACYT.

Specialized Training

Training is not considered R&D but does help build capability for R&D work. FoM employees are able to receive COMECYT-FOCACYTE grants for technical training in order to increase competencies.

Additionally, there are two initiatives that have not fully taken off but have been considered for some time:

The creation of Research Networks consisting on joint collaboration with national industrial parks and research centers.

A formal Research and Advanced Engineering department who´s focus would be on innovation, new technologies and patents.

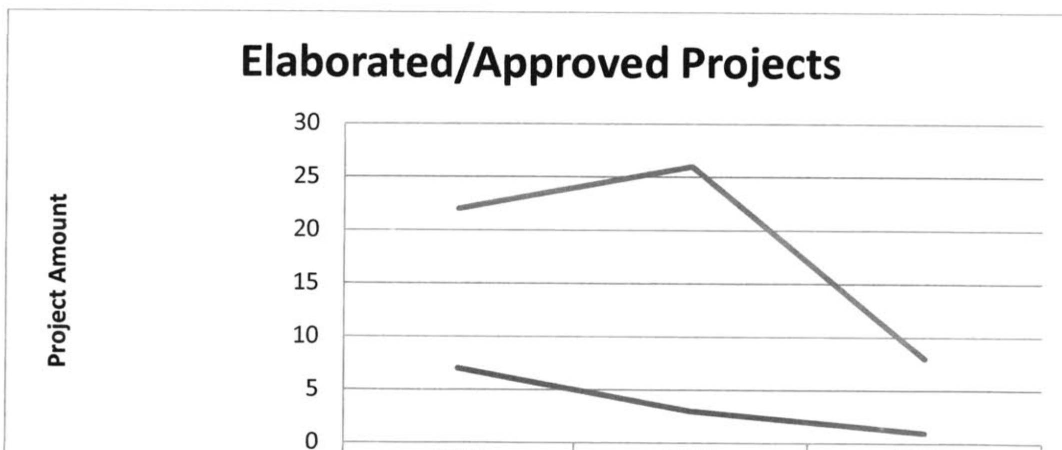
One concept is to hire highly skilled people from different institutions and have them not only conduct research in their specialty function but also become a liaison from the university or research center from which these workers proceed. It is unclear whether these researchers would really be in tune with other researchers in the same university but Mangematin and Nesta (1999) argue that highly educated employees engage with similarly competent employees outside the firm thus facilitating access to external networks. But even more critical than engaging with universities and research labs in Mexico is having highly educated employees with the ability to coordinate with researchers and advanced engineering activity within Ford globally.

As we can see, much has been done to foster university collaboration and promote a culture of innovation in recent years. Yet the potential for the FoM organization in regards to contributing to global innovation is just beginning.

Lessons learned and opportunities for R&D in FoM

FoM should continue the formidable work pertaining to recruiting talent and fostering university relationships and collaboration. Given that most incentives are now targeted at cooperative research, this area will need to improve in order to take advantage of those incentives.

The increase in headcount in FoM in the last few years now represents a significant portion of engineering resources in Ford globally. For example, one department holds 20% of its global headcount in Ford of Mexico. Previously, in the small organization a formal R&D group did not make sense, but now that there is a critical mass of engineering talent in FoM, the circumstances have changed. Ad-hoc innovation efforts have been less and less effective as the organization has grown and it is time to consider a formal R&D structure in Mexico. We can see in **Figure 26** that R&D projects aimed at capturing financial incentives, both elaborated and approved, has declined despite the huge growth in the organization (doubling in numbers from 2008 to 2010 and again from 2010 to 2012).



	2010	2011	2012
Projects Submitted	22	26	8
CONACYT Approved projects	7	3	1

Figure 26: Elaborated and Approved projects aimed at financial incentives

Many engineers, particularly application engineers focus on delivering their work to programs and as such, ignore ad-hoc initiatives for innovation due to the lack of time or interest. Many good R&D projects loose traction to the pressures of more immediate work such as product launches and program delivery, but this phenomenon is not specific to Mexico rather it is true for Ford globally. A more organized and formal approach to R&D and innovation would create some dedicated resources in FoM that can keep R&D projects on-track balancing out some of the pressure to deliver immediate results against the longer term nature and focus of R&D work. The R&D projects that have been successful recently in FoM are those when engineers identify that a solution to a problem they are working on as part of normal day to day operations is innovative or patentable. These "on the job" initiatives should be continued and a culture of innovation should be fostered across the organization but also a dedicated group to focus efforts on the longer term projects and collaborative projects would reinforce the innovation culture.

The primary duty of a formal R&D structure in FoM would be to contribute to the bottom line and global innovation efforts. This includes returns on investment by maintaining an R&D portfolio that reduces risk. None the less, a formal R&D structure can also bring some secondary benefits to FoM and Ford globally such as an increased balance between managerial and technical career advancement, motivation, talent attraction and retention, maintain employee satisfaction, increased efficiency, increased capabilities, etc.

Many engineers enjoy technical work, the reason they studied engineering in the first place was the passion to confront technical challenges. Allowing engineers to work in more research oriented activities can motivate engineers to use the skills they have in technical areas. Many PhD's and/or talented engineers have felt discouraged in application work since they feel their abilities are not fully utilized in those positions. Career advancement on the technical ladder is basically non-existent in Mexico. Promotions are through advancement in the managerial ladder and are typically geared towards high profile applications work such as positions in program management or project management roles. Even if an engineer is promoted because of technical prowess, promotion most surely means moving to a supervisory role in a less technical position since there is no possibility to move to a technical specialist role. In headquarters there is a more balanced career ladder with both managerial promotions and technical promotions (as mentioned, technical specialist positions do not exist in Mexico). An R&D function in FoM will help develop technical skills that may develop technical specialist positions in the future, it will also help balance the idea that the only way to get career advancement is through the managerial ladder in FoM.

Additionally, FoM has one the highest ESI (employee satisfaction indexes) in all of Ford globally. The ESI is around 90%, this means people are motivated and excited about working at Ford, and this is a big positive and something that an R&D work stream could keep building upon. Ford of Mexico has won the best place to work three years in CNN Espansion's survey "Super Empresas"; in 2011 FoM placed first place in the following categories.

- Leadership based on values
- Organizational cohesion
- Employees want to keep working for the company after several years of service.
- Work conditions
- Work-life balance
- Communications
- Growth of opportunities

Ford is not only seen as one of the best places to work in Mexico, Ford has one of the highest brand images as perceived by the public in Mexico (compared to the Ford brand globally). Ford was one of the first car companies to establish in Mexico and has had a reputation of selling reliable cars throughout the years. The positive image as a place to work in and favorable brand image perceived by the Mexican public helps attract and retain talent. An R&D activity will quickly gain notice and also contribute to attracting the talent in Mexico, particularly those with scientific or research backgrounds who previously had not considered Ford as a possible workplace.

According to Cohen & Levinthal (1990), absorptive capacity gives firms the ability to recognize the value of new information, assimilate and use it. Firms that have their own R&D are better able to use external information and opens up for better collaboration in R&D. A formal R&D department including formal R&D work streams can help increase FoM´s absorptive capacity. Increasing FoM´s absorptive capacity will benefit FoM´s ability to conduct higher level work in engineering and increase its ability to deliver advanced engineering work.

As FoM has taken a larger role in Ford's global product development organization, it finds itself mainly in an execution stage delivering top hats and supporting new model programs as well as supporting core engineering activities and local market adaptations. The move from an execution stage to an innovation stage will require a lot of effort, support from leadership and developing a well-structured plan to get there.

If FoM is to begin to get involved in the global innovation process then this starts by getting involved with the feature planning and R&AE planning groups. Identifying which projects can be undertaken (if any) in Mexico by taking advantage of the capabilities in FoM; cost advantages or efficiency advantages should be considered. Participating in the planning process will also give FoM representation in this forum to be able to provide input to planning giving a fresh perspective and possibly seeding new projects perhaps targeted at the Latin American region or Mexican market which has a young population. After all, developing Latin American countries have a growing middle class and will represent a larger market in the near future and the young population in these markets will be an important demographic in coming years.

FoM has began fostering relationships with universities and is just beginning to leverage them through the several channels aimed at cooperative projects such as the university research program. But there is potential for more cooperation between universities, research centers and even suppliers. Universities make good partners for basic research and applied research that is costly or further down the road since costs are shared and risk is reduced with partners. Also, many core engineering departments and research departments in the US cooperate with suppliers on innovation projects. A lot of times it is suppliers who generate technological innovations and are better partners than universities for such projects. With the auto-parts industry being heavily globalized and having a large manufacturing presence in Mexico, it makes sense to seek out which suppliers or SME's in Mexico have R&D capabilities that can be leveraged. In addition to the presence of clusters identified in this thesis, there is likely to be a good base of manufacturing knowledge and/or process knowledge in Mexico since these are intensive activities in the region.

The latest government incentives are geared toward promoting industry-university linkages and promoting innovation. FoM can tap into incentives to support collaborative projects with universities and/or suppliers. A particular interest from the government is forming innovation networks; where 3 or more firms and/or universities cooperate on innovation projects. FoM is well positioned to continue receiving incentives in the form of cash and or tax incentives and should continue to seek out these incentives with R&D projects. A formal R&D structure could generate a pipeline of projects that are well suited to compete for the financial incentives available. In many cases, the company's needs could be brought to universities and suppliers to gear the projects towards directions that benefit the company. An organized pipeline of projects would be more competitive than the previous ad-hoc process in order to obtain both, participation in the University Research Program that Ford sponsors and for obtaining financial incentives by government.

There have been some failed efforts in cooperative projects with universities in Mexico but there is a lot of interest for these types of projects for the three main stakeholders (government, universities and research centers and firms). Interviews with researchers and partners revealed some lessons learned for future projects which will be discussed: Collaborative projects between industry and universities have been scarce in Mexico in general and this has sometimes led to a failure of rapport. Neither the university nor the firms have a lot of experience doing collaborative work but these are professional relationships and as such should be carried out with seriousness and respect. Universities and suppliers should be considered partners in collaborative innovation projects. Effective communication is one of the clearest necessities voiced by researchers. This comes in several formats but essentially it means establishing expectations of the work early on. Having a clear idea on the objectives of the project and what the reporting mechanisms as well as timing will look like is desired. Having a well-defined budget and work plan and sticking to it. These are hard things to achieve in innovation projects due to the uncertainty involved but a better job can be reached through a more established process and with the gaining of experience.

Most of these issues arise from a lack of dedicated resources to collaboration and innovation projects and the ad-hoc nature with which they have been managed in the past. Delivery of new model programs has been the priority for FoM and for this reason the company has not put as much effort into the collaboration projects. Most of the time, the organization doesn't put the best or most adequate people on these projects since they do not have the highest priority due to their risk and their benefits cannot be seen immediately.

But collaborative work is only a small part of the equation. Even in headquarters, most R&D is conducted internally. FoM should seek out to have its own R&D capabilities geared toward the needs of the organization. As a branch of the US product development organization it should seek to support, in what it can, the global innovation strategy. This means serve as a partner with the US R&D organizations providing resources and know-how for projects that have origins in the US when Mexico possesses capabilities that make having the project executed in Mexico more efficient, lower cost or is strategic in nature (maybe the PD core responsibility is in Mexico). But also, FoM can contribute unique knowledge and support to the product development headquarters. R&D is meant to create new knowledge or apply existing knowledge in new ways so Mexico should seek to fill needs through R&D in the organization that are currently not being met. One of the most sensible ways to proceed with R&D work in Mexico is to apply it in areas or work streams that are done intensively in Mexico already. Below are identified four areas of opportunity for projects in which FoM can contribute:

Process Innovation:

Much innovation comes in the way of process innovation. Developing countries that have transitioned to an innovation stage or that have high levels of R&D began with process innovation particularly in manufacturing. Mexico has a large manufacturing footprint and one opportunity for R&D work lies in advanced manufacturing. This line of R&D work has the benefit that projects that are successful could have an immediate or short term return on investment. They may even be funded by the manufacturing plant itself and there are plenty of human resources in Mexico with experience in manufacturing. According to data published by INEGI, by December 2011, the automotive manufacturing sector had a pool of 661,649 individuals (Promexico n.d.).

Supporting Product Development needs:

FoM now has in house responsibility for global functions and some global lead design and release activities for commodities within product development. It makes sense to align product design responsibilities with R&D efforts conducted in Mexico as long as the expertise is present. Design and release engineers usually have little time to invest in innovation or research but a dedicated R&D department could coordinate such projects and keep them moving. Design engineers would still participate in projects because most of the requirement and customer input knowledge lies with the D&R engineers. R&D personnel could be co-located with applications but supervised and budgeted centrally.

Supporting Mexico's top hat development strategy:

It is Ford of Mexico's goal to be the best top hat delivery organization for Ford worldwide. Competition for top hat development is tough between all the Ford global product development centers and focusing research to improving the delivery of top hats could benefit the FoM organization in more ways than one. Establishing best practices or improving on delivery would make the FoM organization more attractive for top hat development and could support realizing its goal of being the best at delivering top hats. Improvements and research could later be cascaded to the rest of the organization benefiting the company as a whole while increasing Mexico's reputation as a center of excellence in top hat delivery.

In house core competencies and niche opportunities:

Ford is a very large and dynamic organization and as such there is always inefficiencies and room for improvement even in the best of processes. Lead firms in the automotive industry have witnessed a return of many activities which were previously outsourced to suppliers to be conducted in-house. It could be beneficial to identify which activities Ford can carry out in-house sustainably and more efficiently than suppliers and then analyze if Mexico is a good location for the activities due to cost advantages, competencies or efficiencies. Many times full service suppliers carry out activities that can be executed at a fraction of the cost if done in house or are better coordinated in house than through suppliers. Also, there are many niche's or gaps in the product development processes and identifying these niches could spring opportunities for FoM to do R&D or innovate. One example was identifying that electrical engineers often had to design and release brackets, the task was uncoordinated and usually ended up being done by a supplier. It was found that a small group specifically geared towards bracket design within the electrical underbody department could do the job for multiple commodities at a lesser cost of outsourcing to suppliers with the added benefit of owning the design and having more control over design parameters and manufacturing. The purpose of the niche opportunities is to create new work streams that benefit product development activities in delivering better quality and/or less cost.

Further work

This section provides a viewpoint of the analyzed system one layer up from the Mexico case study and sets the global innovation concept in context of a larger scope/scale.

The concept of global innovation encompasses a global innovation network and not just increasing the FoM R&D and advanced engineering capabilities. Analyzing the Mexico case study is only the first step of building a global innovation network. Further work suggests the methodology should be repeated in other regions where the company has product development offices and operations as well as where it makes sense strategically (although this may not be obvious). The BRICs (Brazil, Russia, India and China) make ideal candidates for further study since these countries represent a large part of the global market and have increasing technological capabilities. Innovation today is geared mainly toward the triad which are lead markets but soon developing nations will be increasingly relevant (particularly China). I predict that companies that learn to leverage global knowledge should have a competitive advantage over the ones that remain centralized in one or a few regions. This thesis also mainly discussed the startup of a formal R&D structure used to leverage local capabilities and centers of excellence in Mexico and augment the headquarters. In this larger context, innovation projects and capabilities would not only be leveraged and coordinated in cooperation with Mexican HEI's and with the home base but with the entire innovation network.

Establishing the global innovation network is only the first step in this larger context, the true challenge is coordinating and executing world class innovation in this global context. In order to execute a truly global innovation strategy, there must be innovative capabilities in several dispersed areas and these global innovation groups would have to excel at mobilizing all kinds of information between themselves and relevant stakeholders. Thus, there is much further research to be done in effective knowledge transfer considering there are different types of knowledge and sometimes tacit knowledge is very hard to transmit to remote locations.

Conclusion and Reflection

The results of this study are not in any sense a final conclusion but it has been a very rewarding exercise personally while hopefully delivering value to the Company. There is further analysis to be done on this topic and I hope that at a minimum awareness is raised in the organization towards pursuing a more global innovation strategy. Overall the feedback received from the Ford of Mexico leadership has been positive and the more I speak with researchers (internal or external) the more convinced I am that R&D is moving towards global networks of knowledge and I hope Ford is able to capitalize in innovation by tapping into the innovative potential of the world.

This thesis presented the challenges, opportunities and key themes of globalization of R&D from the point of view of a growing product development office in Mexico belonging to a large multinational automotive company. The review of the academic literature indicates that important trends and factors driving multinational corporations to localize formal R&D structures abroad are: access to a large market, availability of high caliber human resources, the quantity and quality of research produced by the national innovation system (universities and public research system), presence of clusters and/or centers of excellence and government incentives aimed at attracting R&D.

The study of Mexico's National Innovation System shows that:

- Mexico has a very large domestic market with a growing middle class and access to an even larger international market due to one of the most open economies in the world with over 40 trade treaties.
- Mexico has a growing pool of skilled human resources in S&T and is well positioned to keep growing the number of researchers in the near future. Even though the researchers per 1000 labor force is still low, the lack of high caliber jobs translates into there being a lot of qualified people available especially in Mexico City where a large number of researchers reside.

- The study also shows that even though the research in Mexico is not quantitatively significant in the world yet, it is qualitatively competitive with the BRICS and closing the gap with the developed world.
- The study also finds the presence of agglomeration and clusters in the aerospace, automotive, electronics and software industry which is a positive sign for establishing R&D operations.
- The incentives offered by Mexico make establishing R&D operations competitive with other countries and are aimed at university-industry linkages. Such incentives could make certain projects attractive to conduct in Mexico due to cost and/or efficiency benefits.

At the firm level the study finds that having a global innovation strategy can benefit the company as a whole by both, augmenting the innovation operations in the home base as well as increasing the absorptive capacity of Ford of Mexico. The study also shows that Ford of Mexico has several work streams that promote linkages with universities but these relationships have still not been exploited to their full potential, there is no dedicated function to R&D causing innovation projects to lose traction within the organization due to pressures of more immediate work and that the number of innovation projects aimed at incentives has declined in the past years even though the PD organization has doubled in size in the last 2 years. In order to increase FoM's ability to contribute to innovation it is recommended to have a small group of dedicated people to oversee and manage a portfolio of R&D projects in 4 areas of opportunity:

- Process innovations including manufacturing operations
- Product Innovations supporting FoM's core commodity responsibilities or targeted at commodities in which FoM has global design lead.
- Projects directly geared at improving FoM's ability to deliver top hats
- Building core competencies in niche areas currently not present in the company.

These activities, if adequately successful, could nucleate larger activities within an emerging Ford global innovation network.

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