Learning and Innovation Under Changing Market Conditions:

The Auto Parts Industry in Mexico

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by

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Summary

Learning and Innovation under Changing Market Conditions: The Auto Parts Industry in Mexico
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This research explores changes over time in the learning responses and innovation capacity of auto parts suppliers in Mexico, in the context of the confluence of market changes brought about by the North American Free Trade Agreement (NAFTA) regulations – which included labor, production and organizational requirements and consequent changes in the type of capacities that assemblers demanded from the auto parts suppliers.

The automobile industry is particularly relevant to an analysis of these learning and innovation processes because of its wide set of interrelations with other industrial activities. Its technological requirements have thus tended to stimulate technological development and upgrading in its supporting industries. However, the main subject of the dissertation is not the automobile industry *per se* but rather the institutional aspects affecting learning and innovation in a manufacturing sector that is located in a developing country and shaped by international organizational and technological standards.

The thesis combines elements from three strands of theory: the systems of innovation perspective, analytical tools from the interactive learning and capability building literature and the role of trade in learning and innovation.

The study was based on a unique panel dataset that tracked changes in learning modes for a set of 192 auto parts firms before and after the NAFTA agreement came into force. The results are complemented by two other empirical analyses comparing the technological efforts and firm-level characteristics of exporting auto parts firms with those of non-exporting firms.

The thesis points to the relevance of understanding the historical development of the industry and the role that traditional habits and practices play in shaping the development of the industry in order to understand the learning and innovation patterns followed by the auto parts suppliers. The research also considers how institutions (in the form of policies) can effect changes to (or reinforce) these habits and practices. The policy environment in the study was designed with the expecta-

tion that this policy regime (i.e., NAFTA) would encourage technological learning from international automotive manufactures and, in doing so, build Mexican capacity in this sector. However, the study showed that without purposeful intervention to support learning, the policy regime was not enough on its own to ensure that technological learning and capacity building took place. Therefore, building capacity locally and creating a policy and institutional regime that supports innovation appears to be the only way in which learning and capacity development processes can be enhanced.

Samenvatting

Leren en Innovatie onder Veranderende Marktomstandigheden. De Auto-Onderdelen Industrie in Mexico.
Bertha VALLEJO CARLOS

In dit proefschrift worden de veranderingen in leergedrag en innovatiecapaciteit van de auto-onderdelenindustrie in Mexico onderzocht in de jaren na de intreding van de Noord-Amerikaanse vrije handelsovereenkomst (NAFTA). De nieuwe economische context en met name de veranderende marktomstandigheden brachten een herziening van vereisten met zich mee voor toeleveranciers op het gebied van arbeid, productie en organisatie.

De auto-industrie in Mexico is in het bijzonder interessant voor het verkrijgen van inzichten in leer- en innovatieprocessen door de brede onderlinge samenwerkingsverbanden met andere industriële sectoren. De technologische vereisten in de sector en de afhankelijkheid voor onderdelen en componenten spoorde bijgevolg de technologische ontwikkeling aan bij de toeleveranciers. Echter, het onderzoek concentreert zich niet louter op de auto-industrie als sector, maar richt zich meer op de institutionele context van invloed op leergedrag en innovatie in een productiesector in een ontwikkelingsland, gestuurd door internationale organisatie- en technische standaarden.

Het proefschrift combineert inzichten uit 3 theoretische stromingen: innovatiesystemen, interactief leren in capaciteitsversterking en de rol van internationale handel in leer- en innovatieprocessen.

Het onderzoek gebruikte een specifieke set van panelgegevens die veranderingen volgde in leerwijzen van 192 auto-onderdelen bedrijven voor en na het van kracht worden van NAFTA. Het onderzoeksmateriaal is verder aangevuld met twee empirische studies die technische inspanningen en bedrijfseigenschappen van exporterende bedrijven vergelijken niet-exporterende bedrijven in de auto-onderdelen sector.

Het proefschrift toont de essentie aan van begrip van de historische ontwikkeling van de industrie – met name de rol van tradities, gewoonten en alledaagse praktijken in de vorming en ontwikkeling van de sector - ten einde het leergedrag en de gevolgde innovatiepatronen in de sector te begrijpen. Het onderzoek beschouwt

hoe instituties (in de vorm van beleid) veranderingen (of versterking) van deze rol kan bewerkstelligen. De beleidsomgeving (NAFTA) was destijds ontwikkeld met het idee het leergedrag uit de mondiale auto-industrie te stimuleren, en bijgevolg de Mexicaanse betrokkenheid in deze sector te bestendigen. Echter, de studie toont aan dat - zonder doelgerichte leerinterventies - de beleidsomgeving alleen niet voldoende is technologische leren en capaciteitsversterking te laten plaats vinden. Het proefschrift concludeert dat lokale capaciteitsversterking en het creëren van een gunstige beleids- en institutionele omgeving de enige manier is om leergedrag en capaciteitsontwikkelingsprocessen te verbeteren.

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Chapter 1

Introduction

Prior to the introduction of the North America Free Trade Agreement (NAFTA) in 1994, Mexico already had an established automobile industry. The first assembly plant was built by Ford in 1925, and the industry developed rapidly thereafter, nurtured by a series of automotive decrees that guided the industry according to different development strategies. The main underlying objective of these decrees was to improve the Balance of Payments (BoP) situation of the sector by requiring assemblers to offset their imports of parts and components through exports and to meet high local content requirements.

NAFTA's entry into force initiated a gradual liberalization of the auto industry over a period of 10 years. This brought on a dramatic increase in exports but also a sharp and sustained rise in imports. NAFTA not only opened the Mexican auto industry to foreign competition, but also exposed this industry to the production, organizational methods and quality levels followed by auto assemblers worldwide. Under these changed conditions, participation in this industry by the Mexican auto parts sector declined.

This thesis explores the learning and innovation responses of auto parts suppliers in Mexico to the new economic environment that was created by the confluence of market changes brought about by NAFTA regulations. These include labor, production and organizational requirements and consequent changes in the set of capabilities demanded from parts and components suppliers.

The hypothesis of this research is that the decline of the Mexican auto parts industry was not due to NAFTA alone, but to the historical shaping of the industry and to the industry's consequent inability to respond to the market conditions introduced under NAFTA. The thesis highlights the different learning processes (also referred to as mechanisms) adopted by auto parts firms before and under NAFTA, as well as factors within the firms that influenced learning and innovation.

1.1 Rationale of the Study

The automobile industry is characterized by a high level of globalization, with increasing investments by its main assemblers in overseas manufacturing activities. This thesis examines the changes over time in the learning responses and innovation capacity of the domestic suppliers of a global industry in a developing country context. The research focuses on how auto parts firms already operating in the pre-NAFTA period adapted to the new market conditions introduced by this agreement in 1994.

The main subject of this dissertation, however, is not the automobile firm *per se*, but rather the institutional aspects affecting learning and innovation in a manufacturing sector that is located in a developing country and shaped by international organizational and technological standards. The automobile industry is particularly relevant to an analysis of these learning and innovation processes because of its wide set of interrelations with other industrial activities. Its technological requirements and dependence for parts and components have thus tended to stimulate the technological development and upgrading of its supporting industries, even in the case of developing countries such as South Africa (Barnes and Kaplinsky 2000; Lorentzen 2005) and India (Parhi 2006).

In the case of Mexico, the automobile industry was chosen for its historical contribution to the Mexican economy since its establishment in the 1920s. It presents important lessons in its evolution through different phases of the Mexican industrialization process, as it progressed from a highly protected environment under the Import Substitution Industrialization (ISI) model to a totally liberalized sector under NAFTA.[1] It is, therefore, of particular interest to consider this industry when looking at economic policy decisions and their impact on learning and innovation.

Latin America, like many developing regions, went through a long ISI period – 1950s to late 1980s – in which the region focused its efforts on developing industrial activities and improving domestic competitiveness. It has been debated in academic and political circles whether or not ISI contributed to building technological capabilities in a deeper sense than simply learning to operate a plant efficiently and whether this constituted a foundation for later technological absorption, learning and innovation (Katz 1973; Mytelka 1978, 1985; Katz 1987; Mytelka and Ernst 1998; Katz 2000; ECLAC 2002). The Mexican case contributes further to these debates.

After the first automotive decree was instituted in 1962, the Mexican government promoted import substitution of automobiles and assembly components through a number of successive decrees. The objective of the 1962 Automotive Decree was to promote and modernize the automobile industry by encouraging national production and high local content integration. The government authorized the volume of production according to the degree of local content integration reached by each firm. In 1972, the earlier decree was modified to require auto firms to balance 100% of their imports of parts and components with an equivalent amount in exports. This objective was only realized in a single year, 1973.

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[1] Although Mexico does not have an explicit and formal industrial policy, the automobile sector is one of only two industrial sectors (the other being oil) for which there is a legal framework for its operation. That framework was formally institutionalized with the automotive decrees, which operated as a kind of sectoral policy (SEGOB, 1962; 2004).

In 1977, a new automotive decree extended the provisions of the 1962 decree to require that automobile firms also offset foreign payments they made, such as for technical assistance, expenses for replacements of parts, by the same value in exports. The decree also increased local content integration requirements from 60% to 80%. It is relevant to mention that these goals were never achieved and deficits in Mexico's BoP persisted.

In the early 1980s, Mexico implemented an International Monetary Fund (IMF) stabilization program that imposed trade liberalization measures.[2] A new auto decree in 1983 formalized the creation of two types of automobile manufacturing. The first type of manufacturing involved production for the domestic market, while the second included all production oriented towards foreign markets. Each branch of the industry was regulated by a different set of rules. The first was regulated by strong local content requirements, and the second had more relaxed, flexible operating conditions.

In 1989, the 1983 Automotive Decree was significantly modified. The new decree set the industry on a liberalization course that proposed to link Mexico to the global auto industry through exports and through the gradual elimination of protection from external competition. The 1989 decree, however, kept the distinction between production for domestic and foreign markets.

In 1995, the last automotive decree was issued in conformation with the requirements and regulations of NAFTA. This decree abolished the market orientation division established in 1983. Although not explicitly recognized in the literature, this unification of production into a single export-oriented industry was a very important structural change that was brought about by NAFTA. Consequently, since 1994 all auto parts suppliers have been required to gradually meet the global production and quality standards set by the assemblers.

The automobile industry is highly globalized. During the last several decades, the organizational and production strategies followed worldwide have undergone important changes, impacting product and process innovations in supplying industries and in the auto industry itself. These changes include the establishment of mass production in the 1920s, the internationalization of the industry in the 1980s, the introduction of lean production techniques in the late 1980s and modular production in the late 1990s[3].

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[2] The main modifications in the 1972 and 1977 automotive decrees were made with the objective of improving the BoP situation. However, the export and local content requirements were never achieved by the industry, and consequently no positive effect in the BoP was recorded.

[3] These changes will be discussed further in Chapter 4.

In Mexico, NAFTA lifted trade regulations and exposed domestic automobile suppliers to international production and quality standards. The convergence of the institutional changes brought about by NAFTA and the restructuring changes undergone by the industry worldwide mark the framework within which auto parts firms have had to perform. This research does not seek to determine which of these two conditions is more important, but rather explores how the organizational and production strategies became critical under the new market conditions faced by these firms – and even more importantly, how the institutional setting has shaped learning in the industry and influenced the building of innovation capabilities.

During the initial phase of the development of this thesis, two features of the Mexican automobile industry in the post-NAFTA period stood out. One was the increasingly important role of the automobile sector in the economy. Over the period 1994-2003, it accounted for about 3% of the GDP (INEGI 2003). Historically, the automobile sector has also played an important role in the Balance of Payments due to both its exports and its high levels of imports. In the post-NAFTA period, both production and exports increased, as illustrated by the data in Table 1.1.

Table 1-1 Automobile Industry (Production and Exports of Automobiles)*

	1994	1995	1996	1997	1998	1999	2000	2001	2002
Production	1097	931	1211	1339	1428	1494	1889	1818	1774
Exports	567	781	975	983	972	1074	1434	1404	1326

* thousands of units

Source: Elaborated by JETRO with data from the 3rd presidential annual report (Fox administration, 2003) and data from the AMIA.

A second notable feature was the persistently high level of imported inputs in the exports of the Mexican auto parts industry, despite the many automotive decrees designed to foster the development of local content in Mexican-produced vehicles.

Table 1-2 illustrates this for selected years in the post-NAFTA period.

Table 1-2 Imported Inputs in Exports of the Mexican Auto Parts Industry*

	1995	1996	1998	2000	2003
Exports	21,712,913	55,927,746	67,286,386	74,080,462	61,655,812
Imported inputs	14,129,045	24,978,160	40,259,366	47,561,205	34,978,397
% of imported inputs in exports	65.07%	44.66%	59.83%	64.20%	56.73%

* millions of Mexican Pesos – current pesos

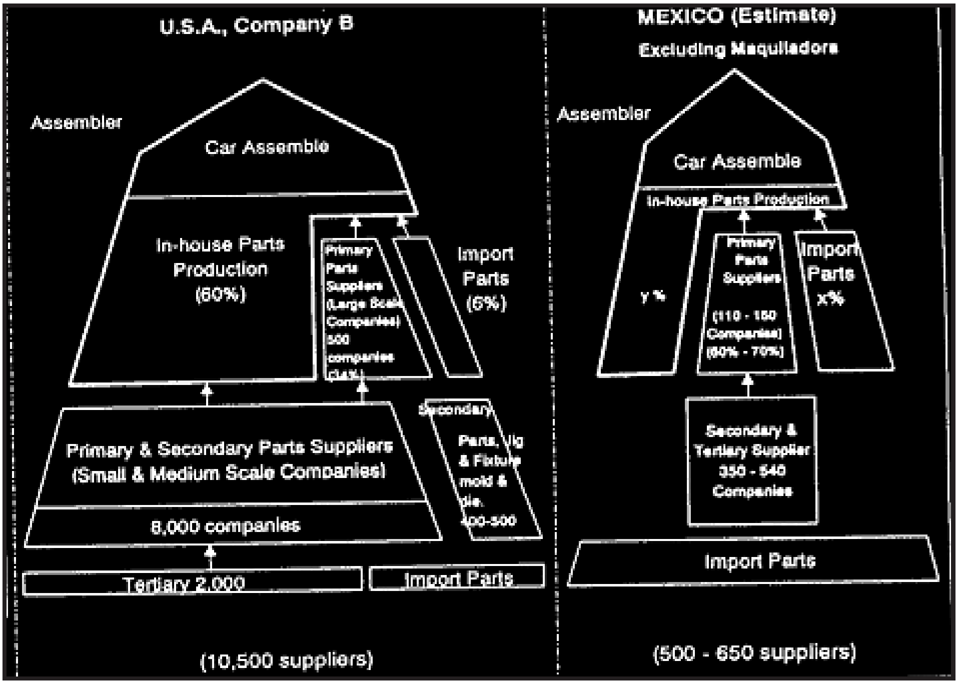
Source: Elaborated by the author with data from (Bancomext 1999, 2000, 2004) and the internal database of the Ministry of Economy, Automobile Sector Department (1995, 1997, 2000, 2003).

In the initial search for an explanation, a key source of information was a study by the Japanese International Cooperation Agency (JICA) titled *Fundamental Technology Transfer in Mexico*[4]. This report contained a technical assessment of the Mexican auto industry and included several Mexican auto parts firms (JICA 1996). The assessment covers the 2 years just after NAFTA came into force (1995-1996). The results of the report – presented in Chapter 4 – illustrate the technical level of the auto parts industry in Mexico at that time.

Figure 1-1, drawn from the JICA report, illustrates how the Mexican automobile industry resembles an umbrella rather than the traditional pyramid that characterizes the industry in developed and new industrializing countries. In the latter, the second and third-tier suppliers represent the base of the pyramid and the assemblers the top (JICA 1996).

[4] The full report of JICA (1996) on *Fundamental Technology Transfer in Mexico* was facilitated by the Mexican Development Banking Institution (Nacional Financiera) office in Tokyo, Japan.

Figure 1-1 Graphic Representation of the Automobile Industry by Integration Between Assemblers and Auto Parts Providers



Source: JICA (1996).

The following sections introduce the research questions and offer a brief discussion of the literature that informed the theoretical and analytical approach taken in this thesis. It concludes with an overview of the chapters and their contribution to the arguments developed in the thesis.

1.2 The Research Objective and Approach

The objective of this study is to analyze the innovation and learning responses of Mexican automotive firms under the new economic conditions brought about by NAFTA in 1994. The central questions in this dissertation are: *What have been the innovation and learning responses of Mexican auto parts firms to the new economic conditions brought about by NAFTA? How have state policies and established habits and practices affected these responses?*

The research questions explored in this thesis are implicitly based on the role that traditional habits and practices of firms, reinforced by policies and their implementation, can have in shaping industry learning and innovation capabilities. In a series of case studies across different industries and in different country contexts, Mytelka has shown how state policies can influence firms in an industry to replace local technological capabilities with technology imports, discourage the development of technological capabilities within the firm or influence firms to engage in a process of technological mastery (Mytelka 1978, 1985, 1998). In the Mexican case, we argue that changes in the competitive environment and in public policies have had a major impact on the production capabilities needed by firms in the auto parts sector. In the absence of technological efforts to stimulate learning and technological capabilities building, this has resulted in imported expertise and the replacement of domestic inputs with imports.

As primarily a micro-economic learning study explaining firm-level learning and innovation performance, this thesis draws on three bodies of literature. First is the systems perspective, which focuses on the actions taken by the main actors in the system (i.e., firms, government, knowledge centers), their orientation, the changes in their internal structures and external networking, as well as their responses to market changes and pressures. This is understood in the innovation systems literature as taking place in an institutional context that consists of traditional habits, practices, norms and laws. (Freeman 1988; Lundvall 1992; Edquist and Johnson 1997; OECD 1997; Mytelka 2000; Oyelaran-Oyeyinka and Barclay 2002). Second is the use of interactive learning and capability building theories that provide the analytical tools for analyzing and understanding the processes by which firms develop the knowledge and skills needed to acquire, assimilate, change and create their technology (Dahlman and Westphal 1982; Bell 1984; Katz 1987; Dosi 1988; Lall 1990; Bell and Pavitt 1993, 1995; Ernest, Ganiatsos and Mytelka 1998; Mytelka 1999; Oyelaran-Oyeyinka and Lal 2004). Third are elements drawn from development literature – in particular, the role that the literature assigns to trade (i.e., exports) as a factor in learning and innovation processes. Combining these three conceptual approaches allows us to go beyond national boundaries in the research problem at hand and provide a better understanding of the fragility of the sector's structure in the context of a globalized industry.

1.3 The Data

The empirical analyses presented in Chapters 5, 6 and 7 are based on three different national databases and a number of internal reports by the Mexican Trade Commission (Bancomext) dealing with the automobile Industry.

The first, and main, database used in this study is the National Survey on Employment, Salaries, Technology and Training (ENESTyC). Chapter 5 uses a set of 192 auto parts firms and analyzes their behavior in 1991 (our reference year before the implementation of NAFTA) and the years 1994, 1998 and 2000 (under NAFTA). The empirical results obtained from this dataset illustrate changes in trends in the adoption of different learning mechanisms among firms in this sector, before and after the implementation of NAFTA. The results obtained provide useful insights into the learning mechanisms and learning efforts of firms operating under the pressures of a changing economic environment. The database also enables an analysis of the institutional networks created by firms for training and innovation activities before and after the implementation of NAFTA. The results allow us to establish a pattern of the existing interactions and communication between firms and other actors over time, an area that has not been explored much in the Mexican context.

A second source of data used in this study is an electronic database collected annually by the Manufacturing Industry National Chamber (CANACINTRA) and the Ministry of Economy and administered by the Mexican Entrepreneurial Information System (SIEM).[5] This is a public database with wide coverage at the firm level in Mexico. Unfortunately, since the objective of the SIEM is merely informative, no historical records of data are kept and the data obtained was only for one year, 2002. Nonetheless, after screening out auto parts firms that are involved largely in commercial activities and those registered as "sole proprietorship," we obtained a sample of 257 firms.[6] The analysis of these firms sheds some light on the internal structure of auto parts firms that export and on their innovative capabilities in comparison with non-exporting firms. The results establish a clear differentiation between firms oriented to the domestic market and those whose production is oriented to the export market.

The third database used in the analysis was compiled internally by the Auto Parts Department of the Ministry of Economy. It consists of about 350 firms, with an annual sequence from 1995 through 2002. Simple statistical tools illustrate the evolution of local content in both local and export-oriented automobile production. The study found increasing integration of imported inputs into the production process.

The empirical data are supplemented by a set of interviews conducted with Mexican policy-makers and regulators in the automobile industry during 2003-2004. Their extensive explanations, data and comments, as well as a comprehensive visit to the Nissan Assembling Plant in Puebla, Mexico and to the DAF Manufacturing Plant in Eindhoven in The Netherlands helped the author enormously in understanding the underlying institutional environment in which this industry operates.

[5] The SIEM is a dependency of the Ministry of Economy. The data are collected by CANACINTRA.

[6] The set of firms oriented to commercial activities and those with "sole proprietorship" status constituted about 55.9% of the total population of automotive firms registered in 2002.

1.4 Research Contribution

Although there is an extensive body of literature focusing on automobile assemblers and their main auto parts suppliers and OEM firms (Jasso and Torres 1998; Barnes and Kaplinsky 2000; Quadros 2002; Lara Rivero, Trujano and Garcia Garnica 2004; Lorentzen 2005), few studies have used firm-level data to analyze the auto parts supply industry (including all the tiers involved) across time.

This thesis contributes to the intra-firm capability building literature, and this explains in a sense the study's importance and relevance. The main econometric analysis takes into consideration the heterogeneity of firms in the auto parts sector and illustrates the trends and characteristics of changes in the firms' capability building and performance overtime. By looking at the pre- and post-NAFTA period, it also provides evidence of changes in firms' learning and innovation patterns under the new market and organizational regulations implemented as a result of this trade agreement, thus contributing to the scant firm-level literature on the manufacturing industry in Mexico.

The use of apparently competing analytical frameworks is a novelty employed in this thesis. On the one hand, the research is based on the capability building literature, which largely focuses on case studies whose point of departure is the firm, and in which the environment around the firm is mainly seen as "context." On the other hand, it also uses the systems of innovation approach, which considers the relationships and interaction of the whole system to be a key element in explaining performance in firms.

The use of the principles of the systems approach to understand the results obtained in the empirical analyses, based on the techniques provided by the capability building literature, allows us to go beyond the firm dimension and understand sector performance. Through the use of these two methodological approaches, the conclusions and findings attained in this thesis contribute to understanding firms' learning behavior in a changing market environment in developing countries. Questioning the role of trade in learning and innovation complements this analysis and enriches it with insights into how industrial development outside a national system affects learning and innovation in domestic firms.

1.5 Thesis Outline

An extensive review of the relevant theoretical and empirical literature in Chapter 2 allows us to formulate the research topic in a way that situates it in a cross-national setting extending far beyond the Mexican context. The chapter concludes by presenting the general principles of the literature supporting the research and the conceptual framework adopted in this study.

Chapter 3 presents an overview of the Mexican economy, automotive policies and the emergence of the automobile industry. The chapter contains a historical description of the general evolution of the Mexican auto industry. It describes the environment in which traditional habits and practices were developed and how they were reinforced by public policies (e.g. the automotive decrees and NAFTA) over time. This lays the basis for an analysis of the impact of these habits and practices on the learning practices adopted by firms, their technological efforts and their interaction with other actors in the system.

Chapter 4 describes the adaptation of the Mexican auto parts industry to the changing organizational and production strategies of the global automobile industry. It provides an extensive review that covers general aspects of the automobile industry, its structure and dynamics as well as its production and organization strategies worldwide. The chapter also presents empirical findings of other studies of the Mexican auto parts sector during 1993-2003 and descriptive statistics of the three databases that are used in this analysis.

Chapter 5 is the main empirical chapter of the thesis. It shows how the adoption of learning mechanisms in a panel of 192 firms changed as a result of the different economic environment brought about by NAFTA. The main pillar of the systems of innovation approach is the importance of learning as a basis for sustainable development.

A central concept in this thesis is that of *learning mechanisms*. We understand this concept as the diverse channels through which firms build and strengthen their capabilities. Firms engage in different technological efforts and learning mechanisms in order to learn and upgrade their capabilities. This thesis explores five types of mechanisms, namely learning by training, by innovating, by searching, by using and by exporting.

The econometric analysis presented in Chapter 5 estimates firms' probability of learning through the above-mentioned five mechanisms, assuming that they do not operate in isolation, and that when faced with a choice of knowledge acquisition mechanisms, the adoption of one type of mechanism will influence the probability of adoption of the others. The econometric estimation used a multivariate probit model to explain the effect and relevance of critical firm-level characteristics on the firm's probability of adopting the learning mechanisms analyzed. We found that the learning mechanisms that firms engage in over time changed as a response to changes in market environment.

Chapter 6 illustrates the internal structure of exporting and non-exporting auto parts firms and their innovative capabilities. First, an analysis of variance (ANOVA) comparing means of productivity shows higher productivity in exporting firms compared to non-exporting ones. Second, assuming that export capabilities depend on the firm's own structural characteristics (i.e., size, experience), we use a probit model to explain the effect and significance of basic firm-level characteristics on firms' probability of exporting their main products.

The empirical exercise conducted in Chapter 7 helps us to establish the pattern of the industry's integration with domestic firms. This was derived from a database internally constructed for the Ministry of Economy's Automobile Industry Department. The information includes about 350 firms for the years 1995-2002, and it is presented in simple descriptive statistics and ANOVA tests.

The research proceeds analytically from the micro level to the meso level. Chapter 8 presents the empirical results found in the above-mentioned firm-level analyses, reviewing and analyzing those results from the systems of innovation perspective. The use of this approach is vital in analyzing and understanding the dynamics behind learning and innovation performance at the meso level. The principles of the systems of innovation approach allow for a clearer view of the interaction and behavior of the entire system.

Chapter 2

Analytical Framework

Abstract

This chapter presents elements from the three bodies of literature upon which this thesis draws. It describes the main principles of the systems of innovation perspective, its characteristics, its diversity of approaches and its importance as a tool of analysis. The chapter also covers interactive learning and capability building theories, which establish diverse mechanisms through which firms learn. It emphasizes the relevance of interactive learning and the construction of technological capabilities, providing us with the methodological insights to build the models used in the empirical part of this research. The chapter then briefly reviews the trade-led development literature that helps to establish a linkage between industrial developments outside the national system of innovation and the learning choices of domestic firms. The last section of the chapter presents the conceptual framework of the thesis, summarizes its approach and introduces its research questions, its variables to be examined, the interrelationships between them and the indicators used. Some methodological problems faced in this research are also discussed.

2.1 Introduction

The research undertaken in this thesis combines elements from three strands of theory. First, it presents the systems perspective, with its focus on the actions taken by the main actors of the system, their orientation, their changes in internal structures and external networking, as well as their responses to market changes and pressures (Freeman 1987; Lundvall 1992; Edquist and Johnson 1997). Second, it introduces analytical tools from the interactive learning and capability building theories that allow us to understand those processes by which firms acquire the knowledge and skills they need to acquire, assimilate, change and create their technology (Dahlman and Westphal 1982; Katz 1987; Dosi 1988; Lall 1990; Ernest, Ganiatsos and Mytelka 1998; Mytelka 1999; Oyelaran-Oyeyinka 2003a; Oyelaran-Oyeyinka and Lal 2004). Third, the role of trade in learning and innovation in firms is briefly discussed. This third element gives the research a perspective on the international dynamics of the automobile industry (e.g., the influence of global automotive practices in local auto parts production requirements), which is highly relevant for a study of an extensively globalized industry like automotives.

2.2 Systems Perspective

The systems of innovation (SI) approach is rooted in the institutional and evolutionary economics literature. SI, like evolutionary theory, focuses on the interaction between economic development agents, highlighting the role played by learning in the innovation process (Lundvall 1992; Nelson 1993a; Nelson and Rosenberg 1993; Lundvall, Johnson, Sloth et al. 2002).

In contrast to the neoclassic economics focus on profit maximization and market variables, evolutionary theory – as well as SI – shifts attention to interaction among the system's actors (e.g., knowledge producers, knowledge users, producers of basic research and users of applied research) and understands innovation as the application of knowledge resulting in social, economic and developmental outputs (Lundvall, Johnson, Sloth et al. 2002). It offers a new approach for understanding the innovation concept in a more dynamic way (Mytelka 2000).

The major relevance of SI consists of highlighting the *interactive linkages* among its components and the notion that *dynamic learning* plays a key role in innovation and economic performance (Freeman 2002). Systems are seen as sets of interconnected elements[7] interacting with their environment and exhibiting their own internal

[7] These elements are defined by Carlsson, Jacobsson, Holmen et al. (2002) as the building blocks of the system. They present a useful review of the analytical and methodological issues of the systems of innovation literature. They describe systems of innovation as constituted by components, relationships

dynamics (Von Bertalanffy 1968; Niosi, Saviotti, Bellon et al. 1993; Carlsson, Jacobsson, Holmén et al. 2002).

Innovation systems have three fundamental characteristics. They are *open* to other systems and in *constant evolution* due to transformation pressures from the outside and from within the system, as a result of which specific actors in the system are not equally important in different historical times. They are *social system*s that are constantly shaping – and being shaped by – human action (Lundvall 1988; Johnson 1992; Lundvall 1992). The system actors are shaped by the particular historical, political and national trajectory of the geographic or sectoral area of interest. In other words, the system's components play different roles in different national contexts over time.

The concept of systems of innovation is an analytical tool developed to provide a useful framework for analyzing the dynamics of innovation. SI recognizes the importance of knowledge in the economic development of a country, as well as the nature of the institutions involved in its generation and the relevance of the system approach (OECD 1997). The SI concept rests on the premise that understanding the web of interactions among the agents involved in innovation is essential to improve technology performance and national competitiveness (Lundvall 1988; Johnson 1992; OECD 1997), with the institutional set-up as the core factor explaining innovation in the system (Edquist 1997; Johnson and Nielsen 1998).

SI is an analytical approach with no formalized methodology, manuals or best practices for its application. It has only a set of basic principles that operate in their own context and the characteristics of the system being analyzed (Edquist 1997; Lastres and Cassiolato 2002).[8] Due to this flexibility, diverse authors have conceptualized SI in narrow and broad terms.[9]

A narrow definition emphasizes primarily the role of organizations and institutions, thus defining SI mostly in institutional terms. Among the most traditional definitions in this category are those of Freeman and Nelson. Freeman (1987) defines IS as "the

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and attributes. *Components* are the operating parts of the system, consisting of individual actors, organizations, physical or technological artifacts, and most importantly the system institutions. Inter-organizational networks or linkages among the system components constitute the system *relationships*; and the system *attributes* are shaped by the properties and characteristics of the relationships among the system components.

[8] For arguments see Edquist and Johnson (1997) Section 3.9.

[9] Outlines of some IS definitions can be found in OECD (1997) and in Niosi (2002).

network of institutions in the public and private sectors whose activities and interaction initiate, import, modify and diffuse new technologies." Nelson (1993) defines it as "a set of institutions whose interactions determine the innovative performance … of national firms" (4).

In broad terms, SI conceptualizations address all habits, routines, practices, rules, norms and laws that regulate the behavior and interaction of the system's agents, as well as all interrelated institutional actors that create, diffuse and exploit innovations. Within this type of definition, we find Lundvall (1992) defining SI as "the elements and relationships that interact in the production, diffusion and use of new, and economically useful, knowledge." Lundvall, Tomlinson, Andersen et al. (2002) emphasize the role of institutions, domestic market and policy efficiency and add variables such as environmental sustainability. Niosi, Saviotti, Bellon et al. (1993) define systems of innovation as the system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of science and technology within national borders. Interaction among these units could be technical, commercial, legal, social or financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new science and technology. ECLAC (2002) defines it as the set of agents, institutions and norms in which the process of technology adoption is supported. The system determines the rhythm of the generation, adaptation and diffusion of technological knowledge to all the productive activities in the economy. Hall, Yoganand, Sulaiman et al. (2004), understand IS as "the system of all the actors and their routines and habits that, in a given policy context, produce, use, diffuse and adapt knowledge in socio-economically significant ways" (4).

In addition to the distinction between narrow and broad definitions, work from an innovation systems perspective has been extended beyond the national system of innovation, with its initial focus on developed countries (Freeman 1987; Lundvall 1992; Nelson 1993b), to encompass sectoral innovation systems (Malerba 2004) including innovation systems in agriculture (Hall 2005), local and regional innovation systems (Cooke 1998; Cassiolato and Lastres 1999; Mytelka 2000; Mytelka and Farinelli 2003) and innovation systems in developing countries (Mytelka and Ernst 1998; Oyelaran-Oyeyinka 2003a; Mytelka 2004).

A. Institutions and Organizations

The systems of innovation idea is an institutional concept *per excellence* (Nelson and Nelson 2002). Therefore, it is important to establish a distinction between institutions and organizations. *Organizations* are bodies such as firms, research institutes, government, non-governmental organizations (NGOs) or universities;

whereas *institutions* are a set of habits, routines, rules, norms and laws regulating the relations between people and shaping social interaction (Johnson 1992; Mytelka 1999). Institutions are defined as the rules of the game of a society, or more formally the man-made constraints that structure interaction. They consist of formal rules and informal constraints and the enforcement characteristics of both (North 1990, 1996).

Mytelka's various studies emphasize the role that laws and policies play, as formal institutions, in setting the parameters that shape the investment and innovation choices made by a system's actors. Her work also describes informal institutions (e.g., habits, practices, norms, corporate culture) as developed by actors' own experiences of being part of a community and shaped by the characteristics of the system in which these actors perform. Mytelka (2000) emphasizes the need to take into account the habits and practices of the actors whose behavior policies target, as these affect policy dynamics and hence the varied outcomes of policies in different contexts. Across a number of different industries, times and places, Mytelka has shown how state policies can influence firms in an industry to replace technological capabilities within the firm with technological imports, as took place in the petrochemical and machine tool industries in the Andean Group during the 1970s (Mytelka 1978). Her work on textiles in the Ivory Coast and Korea during the 1980s illustrates how domestic policies can discourage the development of technological capabilities within the firm, making continued competitiveness more difficult (Mytelka 1998), but how in other instances they can influence a move towards technological mastery. In the 1990s, changes in telecommunications policy in Korea led to the development of in-house research on digital switching, replacing earlier practices of reliance on public sector research and technology transfer to local firms (Mytelka 2000). Case studies of the textile industry in the Ivory Coast (Mytelka 1985), the natural gas industry in Trinidad and Tobago and the integrated circuit industry in Costa Rica (Mytelka and Barclay 2004) illustrate how the efficiency with which technology is transferred to developing countries, and the extent to which it forms the basis for continuous learning and innovation in its host environment, is strongly affected by the set of institutions, formal and informal[10], shaping the system of innovation of that particular country.

Mytelka (1985, 2000, 2003) and Mytelka and Barclay (2004) illustrate in several of their case studies how formal institutions in the form of industrial or national policies shape the choices, behavior and interaction patterns (i.e., linkages and relationships) followed by the system's actors.

[10] Long-established practices (i.e., foreign managers in decision-making positions, reliance on expatriate personnel and on imported inputs) combined with public instruments to attract and promote foreign direct investment (FDI) without seeking incremental technological capability building.

Habits and practices are marked by the historical specificities of a particular system and time frame. A set of dynamic policies can collectively change (or reinforce) these habits and practices and accelerate (or slow down) the needed changes in traditional behaviors that would allow the actors in the system to learn, link and interact with each other, favoring the innovation process (Mytelka 2000; Lundvall 2001; Mytelka 2004).

The failure of the state to provide the policy and formal institutional environment necessary to stimulate and support innovation (i.e., gaps in knowledge and information, lack of critical organizations, policy discontinuity, favoritism to foreign firms, lack of networking among public organizations and lack of policy coherence) is a common feature in all the above-mentioned case studies. This highlights the relevance of the role of the state as facilitator and designer of strategic policy-making that promotes long-run technological capability building, an important aspect covered in this research and underlying our findings.

The relevance of government regulation and support for the evolution of existing user-producer relationships is a key element in facilitating the shift towards new technological paradigms characterized by [radical] innovations (Lundvall 1988).
Transforming the existing network of relationships among the system's actors and breaking up the *inertia*[11] of their interactions is a difficult task and one in which the government plays a key role. The lobbying and political influence of parties whose interest is in the already established structure creates tremendous inertia (supported by the organization of the prevailing market) that can only be broken by establishing new ways of interaction among existing actors in the system, as well as bringing in new actors and creating new relationships (Lundvall 1988). This is a long-run commitment that should be characterized by consistency and knowledge of the goals that are pursued and the tasks that are necessary to achieve these goals.

The role of the government in the adjustment process is relevant, as many of the system's rigidities are produced within the market itself. For example, there may be resistance to technological change because it might alter the existing socio-economic institutional set-up, including the interaction between the system's actors (Freeman and Perez 1986). In the long run, technological transitions bring radical changes in the rules of the game and the power weight of the actors involved.
Developing countries could miss the opportunities brought by the technological transition if they act under the inertia of past experiences and implement and

[11] Defined in Lundvall (1988) as "a general resistance to change [in which] risk aversion is combined with rational motives in reinforcing existing relationships."

continue policies following old practices, without fully understanding the new conditions and rules created under the new paradigm (Perez 1985).
The flexibility of the SI approach in incorporating different kinds of interactions that contribute to innovation into the institutional settings and the prevailing habits and practices allows us to explain why Mexican auto parts firms respond they way they do. In addition, the characteristic institutional perspective of the IS framework allows us to understand how national policies have shaped the habits and practices of actors in this industry over time.

B. Interaction

In the innovation systems approach, firms improve their innovative performance through interaction and collaboration with other actors in the system (OECD 1997). The new competitive environment brought about by globalization requires that firms interact, compete and innovate with more complex articulation than in the past. Firms in the business sector play a fundamental role in economic and technological development (Galli and Teubal 1997).

Firms require certain knowledge bases or learning capability to achieve the benefits of interaction and to be able to produce new forms of knowledge and achieve higher levels of innovation (Ernest, Ganiatsos and Mytelka 1998; Mytelka 2000; Oyelaran-Oyeyinka 2002; Oyelaran-Oyeyinka and Barclay 2002). This cumulative knowledge capability of the firm defines the *technological paradigms*[12] within which the firm is able to achieve further innovations (Dosi 1988). The codified and/or tacit knowledge that the firm has accumulated will allow it to continue along a certain *technological trajectory*[13] (Dosi 1988; Oyelaran-Oyeyinka 2002).

Innovative activities are not a natural product of interaction. They involve high degrees of uncertainty about the consequences and results of the innovation. Innovations rely on scientific knowledge and integrated research activities (e.g., among firms and their departments, between industries, with universities or research centers). They depend on firms' absorptive capacity (Cohen and Levinthal 1990) and their already accumulated technological and research capabilities (Dosi 1988).

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[12] Defined as "the needs that are meant to be fulfilled, the scientific principles utilized for the task, the material technology to be used… [They are] a pattern for solution of selected techno-economic problems based on highly selected principles derived from the natural sciences … A set of exemplars … and a set of heuristics" (Dosi 1988, 224-225). Exemplars are "basic artefacts which are to be developed and improved" (Dosi 1988, 224).
[13] Defined as "the activity of technological progress along [a path] … defined by a paradigm" and accompanied by "economic and technological trade-offs" (from Saviotti and Metcalfe 1984; cited in Dosi 1988, 225).

Interactions among firms (or industries) are not a sufficient condition for innovation to occur. There are other agents in the system (e.g., universities, research institutes and governments) contributing to the way interactions take place. These other agents constitute important parts of the environment in which the firms perform.
The two main channels of interaction are: i) through networking – as innovation involves the process in which information and knowledge flows between different actors of the system; and ii) through various types of supplier-client (i.e., user-producer) relationships. This wider network of interaction among the IS actors plays a fundamental role in the innovative activity of the economy, increasing or decreasing the firms' opportunities to improve their technological capabilities (OECD 1997; ECLAC 2002).

There is also networking among agents with different orientations, purposes and natures, which brings more complexities to the system. Linkages among the business sector, research institutes and universities promote knowledge generation by diffusing and linking the different kinds of knowledge generated in each agent involved.
Each actor in the R&D performing sector executes a specific function in knowledge generation. Universities generate basic and generic knowledge; R&D institutes are mission-oriented knowledge producers; and finally, applied research and technology development is the competence of the business sector (Galli and Teubal 1997; OECD 1997).

Closer links between customers and suppliers are essential to the innovative activity of the firms (OECD 1997). The *user-producer interaction* is a critical parameter for innovative success and an essential micro-level principle of the systems of innovation approach (Lundvall 1992; OECD 1997). In this process, the producer has an incentive to follow the needs, tastes and preferences of users. Also, users require (general and specific) information and use-value characteristics of the products they consume. Interaction between users and producers takes place at diverse phases, in which both parties interchange information on their needs and the technicalities of the product (Lundvall 1988). A more expansive view of users' and producers' needs allows firms to learn from their clients and suppliers and fosters technology transfer (or diffusion) at the consumption and production level (Müller 1999).

Relationships between users and producers develop in the long run and always require elements of hierarchy and mutual trust (Lundvall 1988). These relationships are influenced in many simple, sensitive ways by existing habits, practices and traditions, which also affect the criteria used in judging decisions and [new] ideas (Andersen 1992; Mytelka 2000).

Other channels of knowledge diffusion among firms are technical collaboration between firms (e.g. R&D collaborations and strategic technical alliances), equipment procurement, joint ventures, (cross) patenting, mergers and acquisitions, licensing, joint technology projects, joint research activities, specific research contracts, market transactions, unilateral flows of funds, skills and knowledge and financing staff and researchers (Galli and Teubal 1997; OECD 1997). Informal channels such as contracts or social relationships are also important in relation to knowledge flows and access to technical networks. These kinds of interactions induce knowledge and technology diffusion among firms and promote improvement in firms' organizational routines, product and process innovations and diversification, vertical integration and horizontal diversification (Mytelka 1978; Teece 1988; OECD 1997; Johnson and Segura-Bonilla 2001; Oyelaran-Oyeyinka 2002).

C. Examples of SI Classifications

1. National Systems of Innovation

Without any doubt, the most commonly utilized concept in the systems literature is the National System of Innovation (NSI). It is seen as a system that creates and uses innovation and competencies. Its analysis addresses not only industries and firms but also other actors and organizations, primarily in science and technology (S&T) – including government's roles in technology policy.

Analysis of NSI is carried out within national boundaries and fits both with the focus on technological capability and with the focus on institutions. Although science communities appear to be becoming global and the national level seems to be losing relevance in this era of globalization, "as long as national states exist as political entities with their own agendas related to innovation, it is useful to work with national systems as analytical objects" (Lundvall, Johnson, Sloth et al. 2002, 215).

2. Sectoral Systems of Innovation

After the national perspective of IS, the sectoral perspective has been perhaps the next most widely diffused. It is based on the idea that different sectors or industries operate under different technological regimes that are characterized by particular combinations of opportunity and appropriation conditions, different degrees of cumulativeness of technological knowledge, and different characteristics of the relevant knowledge base (Carlsson, Jacobsson, Holmén et al. 2002; Malerba 2004).

A Sectoral System of Innovation (SSI) is defined as "a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products" (Malerba 2002, 250). It is formed by organizations (e.g., firms, universities, industry associations) and individuals characterized by specific learning processes, competences, objectives and organizational structure (Malerba 2002).

3. Local Productive Systems and Arrangements

In 1997, the concept of Local Productive Systems and Arrangements (LPSA) emerged from a research network team based in Brazil. The objective of the network was to understand local processes of learning and capability accumulation.

Local Productive Systems are defined as systems for any productive agglomeration in which economic, political and social actors are localized in the same geographic area performing related economic activities and presenting consistent linkages, interaction, collaboration and learning processes (Cassiolato and Lastres 1999). They are called *arrangements* when in the productive agglomeration there are no significant linkages among the actors (Cassiolato and Lastres 1999). The LPSA includes firms, associations, chambers and public and private organizations performing training, R&D, engineering and financing (Cassiolato and Lastres 1999).

D. Elements from SI Used in This Research

The research understands *systems of innovation* as the set of actors, institutions (including routines, practices and habits) and norms in which the process of technology adoption is supported (Mytelka 1985; ECLAC 2002) and the policy context in which the system produces, uses, diffuses and adapts knowledge in socio-economically significant ways (Mytelka 2000; Hall, Yoganand, Sulaiman et al. 2004).

The research topic analyzed in this study covers the auto parts industry; therefore, the sectoral level of the system of innovation seems the most appropriate framework to use. In order to allow for the inclusion of the role played by national and international policies, foreign and national actors and other relevant components shaping the development of this industry, our conceptual framework is not confined to the sectoral level but rather works at the interface between the national and sectoral systems of innovation. By working at this interface, we can apply a more flexible approach to SI and obtain a deeper insight into how national, international, industrial and sectoral policies interact with the prevailing habits and practices of the industry over time, allowing us to understand why Mexican auto parts firms respond the way they do.

R&D activities in the innovative performance of firms, industries and countries are of undeniable relevance. This is an activity mostly concentrated in large firms and high-tech industries, particularly in developed economies (Dosi 1988; Acs and Audretsch 1990; Shefer and Frenkel 2005). Nevertheless, innovative processes can be developed in many other ways, depending on the context and the particular characteristics of firms or industries. In developing countries, not many firms have

the resources to engage in this type of formal R&D activities. A substantial part of firms' learning in this type of economies is not carried out in the form of formal R&D activities but through informal and incremental problem solving and experimentation on the shop floor (Albaradejo and Romijn 2000). Many incremental innovations are made by production engineers and shop-floor workers without any reference to explicit R&D activities (Hollander 1965).
This research is framed within a developing country context, in which R&D *per se* is not a common practice within firms (particularly SMEs). Therefore, we adopted a definition of *innovation* based on Ernst, Mytelka and Ganiatsos (1998), who define it as "*the process by which firms master and implement the design and production of goods and services that are new to them, irrespectively of whether or not they are new to their competitors – domestic or foreign"* (13).

Institutions are a key element of the systems of innovation. Therefore the research puts emphasis on the role that prevailing habits and practices play in the development of the auto parts industry, since they shape and determine the routines and institutional learning of the system. Understanding the historical development of the industry helps us to establish the sort of experiences shaping the characteristics of the system in which actors perform and the role that public policies have in influencing the actors' habits and practices (Mytelka 2000). Understanding the historical effect of policies influencing firms in an industry (e.g., the automotive decrees in the Mexican case) helps us to analyze how these policies influence or discourage learning and capability building within firms in the system (Mytelka 1978, 1998).

To sustain their competitiveness in domestic and international markets, firms need to engage in a process of continuous innovation and undertake conscious and explicit learning efforts by interacting with other actors in the system (Mytelka and Farinelli 2003). The thesis also explores the interactions and networks built in the industry over time, particularly those with knowledge centers. And for the study's core analysis, it explores the learning mechanisms (and their evolution) adopted by the industry over time.

The SI is the core theory behind the analysis presented here. Therefore, the thesis pays attention to processes of interaction and learning; the role played by formal and informal institutions; the openness of the system, which helps to understand the international factors affecting sectors; and the specific needs for learning and innovation that this openness engenders. All these factors are mentioned in our analytical framework and developed in the following chapters to support the final conclusions presented in Chapter 8.

2.3 Interactive Learning and Capability Building Theories

The systems of innovation approach is rooted in interactive learning and stresses the relevance of knowledge production and knowledge transfer and diffusion. Understanding the roles performed by different actors in a system and their interactions helps us to locate and analyze the different mechanisms that shape relationships within the system and its impact on firms' learning and innovation.
The interactive learning and capability building literature is strongly based on empirical analysis of case studies and considers the firm as the departing point for analysis. The main theoretical features used by both theories explore mechanisms through which organizations and firms learn and accumulate the necessary knowledge and skills that contribute to strengthen, build and accumulate their technological, learning and innovation capabilities.
The following sections present the features of the capability building literature used in this research.

A. Organizational Learning

Learning is "the process involving repetition and experimentation which enables tasks to be performed better and quicker, and new production opportunities to be identified" (Teece, Pisano and Shuen 1997, 320). It "takes place inside individual human heads, [and contributes to organizational learning] in two ways: (a) by the learning of its members, or (b) by ingesting new members who have knowledge the organization didn't previously have" (Simon 1996, 176).

Organizational learning is a process of generating new competencies and improving existing ones (Marengo 1992), and it requires a corporate culture able to identify, support and reward learning (Teece, Rumelt, Dosi et al. 1994). "Although organizational learning occurs through individuals, it would be a mistake to conclude that organizational learning is nothing but the cumulative result of their members' learning" (Hedberg 1981).

What an individual learns in an organization is very much dependent on what is already known to (or believed by) other members of the organization and what kinds of information are present in the organizational environment. Human learning in the context of an organization is very much influenced by the organization, has consequences for the organization, and produces phenomena at the organizational level that go beyond anything we could infer simply by observing learning processes in isolated individuals (Simon 1996, 176).

Simon (1996) adds, "Individual learning in organizations is very much a social, not solitary, phenomenon" (176), where the traditional habits and practices and the "memory" of the organization play a determining role (Mytelka 2000; Oyelaran-Oyeyinka and Barclay 2002).

B. Technological Capabilities

The concept of *technological capabilities* (TC) emerged in the late 1980s and early 1990s. Authors such as Westphal, Kim and Dahlman (1985); Dahlman, Ross-Larson and Westphal (1987); Lall (1990, 1992); Mowery (1993) and Bell and Pavitt (1993, 1995) made important contributions to the definition of this concept.

Westphal, Kim and Dahlman (1985) defined TC as "the ability to make effective use of technological knowledge in production, investment and innovation" (171). Dahlman, Ross-Larson and Westphal (1987) understood TC as abilities to use existing technology to produce more efficiently and to use the experience gained in production and investment to adapt and improve the technology in use.

Lall (1987, 1990, 1992) – drawing on Dahlman and Westphal (1982), Katz (1984, 1987) and Dahlman, Ross-Larson and Westphal (1987) – presents a pioneering learning taxonomy where he refers to TC as the capabilities needed to execute all technical functions entailed in setting up, operating, improving, expanding and modernizing a firm's productive facilities. Lall's taxonomy (1990, 1992) refers to three main groups of technological capabilities (i.e., production, investment and linkage) of the firm, divided by their technical functions and different degrees of maturity, as well as the types of activity undertaken in each function. Production capabilities cover all the skills needed to run a plant efficiently and to improve it over time, and they involve three broad types of engineering functions: process, product and industrial. Investment capabilities are understood as the skills required to identify, prepare, design, set up and commission a new industrial project (or an expansion of it). And linkage capabilities are the skills needed to transfer technology from one firm to another, from service firms to manufacturers and from the S&T infrastructure to industry (Lall 1990).[14]

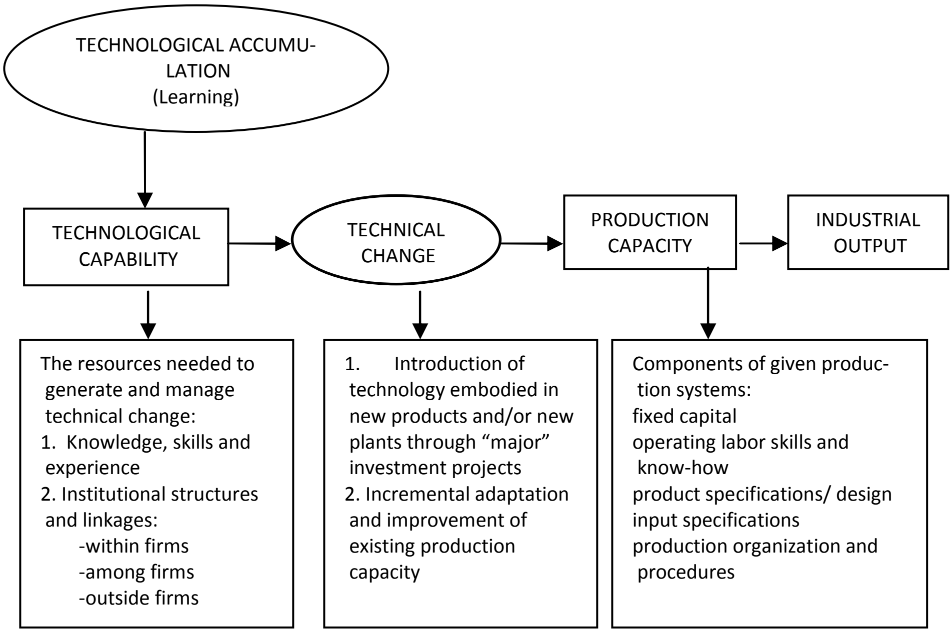
Bell and Pavitt (1993) add to Lall's taxonomy (1990, 1992) a differentiation between production capacity and technological capabilities. Defining the former as those "resources used to produce industrial goods at given levels of efficiency and [with] given input combinations" (163)[15] and the latter as "resources needed to generate and manage technical change, including skills, knowledge and experience, and

[14] An illustrative matrix of Lall's technological capabilities can be found in Lall (1990, 22-23) and in Lall (1992, 167).

[15] Equipment (e.g., capital-embodied technology), labor skills (e.g., operating and managerial know-how and experience), product and input specifications, and organizational methods and systems used.

institutional structures and linkages" (163). The authors define technical change as the process by which new technologies are incorporated into a firm's production capacity.[16] Figure 2-1 illustrates the basic concepts and terms of Bell and Pavitt's taxonomy (1995).

Figure 2-1 Technological Accumulation: Basic Concepts and Terms



Source: Bell and Pavitt (1985, 78).

More recently, Ernst, Mytelka and Ganiatsos (1998) introduced explicitly the concept of knowledge to technological capabilities, defining them as the *"variety ... of knowledge and skills which firms need so that they can acquire, assimilate, use, adapt, change and create technology"* (17).

Ernst, Mytelka and Ganiatsos (1998) classified TC into six types of functions, which can be organized as follows:

a) Production capabilities: knowledge and skills used in plant operation. They are divided into three broad types of activities: i) production management, ii) production engineering and iii) repair and maintenance of physical capital.

b) Investment capabilities: knowledge and skills needed to undertake the functions of identification, preparation, design, setting up and commissioning of new industrial projects, or the expansion and/or modernization of existing ones. This

[16] For an illustrative framework of Bell and Pavitt's industrial technological capabilities (see Bell and Pavitt 1995, 84).

category has two main elements: i) pre-investment capabilities and ii) project execution capabilities.

c) Minor change capabilities: a firm's ability to adapt and continuously improve its products and processes. It includes: i) reverse engineering, ii) analytical design and iii) system engineering capabilities.
d) Strategic marketing capabilities: include the knowledge and skills required for collecting market intelligence in the development of new markets, the establishment of distribution channels and the provision of customer services.
e) Linkage capabilities: ability and organizational competences to transfer technologies within the firm, among firms, and between firms and domestic scientific and technological infrastructures.
f) Major change capabilities: knowledge and skills required for creating new technology, designing new features of products and processes and applying scientific knowledge in developing patentable ideas.

Even though these different taxonomies seem to be competing among themselves due to the different definitions and classifications adopted by their authors, all of them refer to knowledge, skills and experience as core elements of technological capability. They build on one another. One important difference among them, especially in the context of developing economies, is the inclusion of marketing capabilities as a separate and essential aspect for successful innovation activities between firms.

On the one hand, Ernest, Mytelka and Ganiatsos (1998) include this capability explicitly; Westphal, Kim and Dahlman (1985) and Lall (1990, 1992) only do it implicitly; Westphal, Kim and Dahlman (1985) include it under the umbrella of production capability; and Lall (1990, 1992) includes it under linkage capabilities by remarking about firms' needs to identify potential suppliers and help them develop by providing technical and other forms of assistance[17].
On the other hand, Bell and Pavitt (1993, 1995) focus mainly on TC leading to production capacity and do not include marketing capabilities in their taxonomy.

B.1. Building and Strengthening Technological Capabilities

The notion of technological capabilities attempts to capture the great variety of knowledge and skills needed to acquire, assimilate, use, adapt, change and create

[17] Lall and Wignaraja (1994) emphasize marketing as one of the necessary technological capabilities of the firms. For firms exporting from developing countries, marketing in the sense of finding or attracting customers and persuading them to place orders or buy products is almost inseparable in practice from building up the firm's supply capabilities (Keesing and Lall 1992). This applies especially to textiles and clothing.

technology. It goes well beyond engineering and technical know-how to include knowledge of organizational structures and procedures as much as knowledge of behavioral patterns (e.g., of workers and customers). Firms need certain complementary assets and capabilities in order to relate, mobilize, and improve their technological capabilities, among which may be noted organizational flexibility, finance, quality of human resources, sophistication of the support services and of the information management and coordination of capabilities (OECD 1992).

Technological capability accumulation and its underlying learning processes have been broadly addressed in the literature. Two main strands of literature are identified within the evolutionary technological literature. The first strand of theory considers technological capability in technological frontier firms. It is based on the way a firm builds its core and strategic capabilities at the international technological frontier, where a certain level of TC has already been accumulated. The second strand of literature analyzes technological capability in latecomer firms. It is based on technological accumulation and the creation of capability building (possibly for the first time) in firms mainly located in developing countries.

B.2. Technological Capability at the Technological Frontier

This strand of literature is constructed by conceptual approaches to a firm's main competencies and/or organizational capabilities (Nelson and Winter 1982; Dosi 1988; Dosi and Marengo 1993; Teece, Rumelt, Dosi et al. 1994; Teece, Pisano and Shuen 1997) and based on empirical studies carried out in multinational corporations (MNC). Its main concern is to analyze in what way or under what conditions firms that have already accumulated a significant base of knowledge are able to maintain, train, modify, rebuild, renew and strengthen their main existing capabilities, focusing mainly on technological knowledge and organizational issues. It is mainly based on case studies analyzing the combination of different knowledge specialization patterns in firms in terms of technological, organizational and managerial dimensions (Prahalad and Hamel 1990; Leonard-Barton 1992; Miyazaki 1994; Leonard-Barton 1995; Granstrand, Patel and Pavitt 1997; Patel and Pavitt 1997). The research conducted within this strand of literature assumes that the firm has already accumulated a certain level of capabilities and identified its core competencies. The analysis is oriented towards the organizational capabilities required to strengthen and renew the technological knowledge base already existing in the firm and does not explain the processes and activities by which TC and the firm's knowledge base are identified, built or created.

The literature on technological frontier firms tries to answer fundamental questions of how firms achieve and sustain their competitive advantage and what their sources of wealth creation and capture are. It offers limited insights to the literature of latecomer firm capability building, which focuses on the process of building an essential knowledge base to survive in the market, under the assumption that the firm lacks this basic technological knowledge. However, in an industry like automotives, prior capability building was necessary to be able to move ahead in the 1990s. In Brazil, for example, such capability building succeeded, while Argentina failed to do enough (Katz and Ablin 1987).

B.3. Technological Capability in Latecomer Firms

The focus of analysis of technological capabilities studies in developing countries has been in constant evolution. In the early 1970s, it was mainly shaped by the influence of neo-classical economics and dependence theories and thus focused on costs, suitability and effectiveness problems associated with technology transfer from developed to developing countries (Cooper 1973; Vaitsos 1975). In the early 1980s, the attention shifted to processes involved in the adoption, adaptation and mastering of imported technologies by developing countries (Katz 1973; Lall 1987). In the 1990s, the analysis focused on the learning processes and mechanisms needed to build a base of technological knowledge not yet existent, the renewal of the existent knowledge base and its alternative uses.

The technological capability in the literature on latecomer firms is mainly represented by Jorge Katz (1987), Lall (1990, 1992), Martin Bell (1984), Westphal, Kim and Dahlman (1985) and Bell and Pavitt (1993, 1995). It is focused on the process of transferring and building up technological capabilities in firms located in developing countries. The literature on latecomer firms is built on case studies presenting different scenarious and conditions than those covered by the literature on TC at the frontier. Comparison between case studies, as well as the analysis itself, is even more difficult due to the different macro and meso environments in which firms in developing regions perform.

In the late 1970s, Jorge Katz from the United Nations Economic Commission for Latin America and the Caribbean (UN-ECLAC, hereafter referred to as ECLAC) directed a major research program within this focus of analysis. This pioneering project on scientific and technological development in Latin America was carried out under the sponsorship of IDB/ECLAC/UNDP, and it deserves special attention for being the base of posterior work in the region. The project included individual firm and industry studies on six Latin American countries, namely Brazil, Argentina, Mexico, Chile, Peru and Colombia.[18] The results shed some light upon a) the rate and

[18] A partial summary of the results of the project can be found in Katz (1987).

nature of the domestic technology generating efforts carried out by diverse firms and manufacturing industries, b) macro and micro variables affecting knowledge generating efforts and c) consequences of local technological efforts (Katz 1987; Katz, Gutkowski, Rodrigues et al. 1987).

Regarding the rate and nature of technical change and the type of innovations and productivity advances in a firm, the project found that it depends strongly on: i) strictly microeconomic forces emerging from the specific history of the firm, ii) market variables describing the competitive environment in which the firm operates, iii) macroeconomic forces characterizing the broad parameters of the system in which both the firm and the industry are immersed and iv) the evolution of the knowledge frontier at the international level.

The limited size of the domestic market and shortages in the supply of engineering and entrepreneurial skills are two important reasons that force manufacturing firms in developing countries to settle for a manufacturing and organizational technology with a higher degree of vertical integration, resulting in highly idiosyncratic technological packages. Other important factors found are: a firm's size, lack of domestic subcontractors, policy inducement and autonomous substitution effects, as well as the inability to properly replicate technical information.

An important lesson supported by these case studies is that the technological path of a given industrial plant is "evolutionary" or time-dimensional and should not be analyzed as a state or condition (Katz 1987).
In the early 1980s, Dahlman and Westphal (1980) directed another major research project, financed by the World Bank, called *The Acquisition of Technological Capability* (RPO-672-48). The results of this project enriched the conceptualization of technological capabilities in four developing countries – India, South Korea, Mexico and Brazil – and inspired the development of another pioneering learning taxonomy published in 1982 by Dahlman and Westphal.[19]

Inspired by these two pioneering projects, a large body of research following the same case study methodology has emerged. All of it focuses on identifying key characteristics of learning and technology transfer processes, as well as relevant factors that stimulate and hamper innovation in firms from developing countries. Representative case studies have been conducted for East Asia (Westphal, Rhee and Pursell 1984; Westphal, Kim and Dahlman 1985; Kim 1998), Indonesia (Jonker, Romijn and Szirmai 2006), Sub-Saharan African countries (Mytelka 1985, 1999; Oyelaran-Oyeyinka and Barclay 2002; Oyelaran-Oyeyinka 2003a, 2003b, 2004b;

[19] See Dahlman, Ross-Larson and Westphal (1987) for details on the project findings.

Oyelaran-Oyeyinka and Adeya 2004a, 2004b; Oyelaran-Oyeyinka and Lal 2004, 2005, 2006), Central Asia (Dahlman and Westphal 1982; Dahlman 1989; Romijn 1997, 1999) and Latin America (Katz 1973; Mytelka 1978; Katz 1984, 1987; Katz and Ablin 1987; Katz, Gutkowski, Rodrigues et al. 1987; Katz 2000; Tan and Lopez-Acevedo 2003).

These case studies were the basis for the empirical work in this thesis (i.e., Chapters 5-7), providing important insights into factors that influence trends and changes in learning, innovation and capability building in firms located in developing countries.

C. Technological Efforts and Learning Mechanisms

While learning can be influenced by doing, it is not an inevitable consequence thereof (Nelson and Winter 1982). It is an active process that requires the explicit use of resources to facilitate firms' learning, and most importantly, it is a long-run explicit process and not a one-time event.

In order to acquire the necessary *technological capabilities* (TC) to compete, firms need an intensive process of *technological efforts* (TE). TE are understood as the explicit and deliberate investment in activities aimed at technology learning and mastery (Dahlman and Westphal 1981, 1982; Katz, Gutkowski, Rodrigues et al. 1987; Lall 1987; Romijn 1997; Jonker, Romijn and Szirmai 2006), and they are carried out through diverse channels, which are referred to in this research as learning mechanisms. Not all these empirical studies make an explicit distinction between TC and TE, although TE are the fundamental elements for capability building and strengthening.

Katz, Gutkowski and Rodrigues (1987), Romijn (1997) and Jonker, Romijn and Szirmai (2006) do make an explicit and deliberate distinction between, on the one hand, the activities through which a firm engages in learning mechanisms aimed at technological learning and mastery (TE) and, on the other hand, the technological capabilities (TC) achieved by the firm.

Romijn's (1997) study on the acquisition of technological capabilities in small-scale metalworking firms in Pakistan makes use of the process indicators through which TC are built. Some of the proxies used in her analysis are the education level of the owner-manager of the firm, levels of technical education among the workforce, prior working experience of the owner-manager and internal efforts to assimilate and improve products.

Jonker, Romijn and Szirmai (2006) analyze TE in their study on the paper manufacturing industry in West Java, Indonesia. They measure TE with variables related to the formal education and experience of the workforce and the number of checks conducted per paper machine.

C.1 Technological Efforts Within the Firm

Within the case studies of the capability building literature, special attention is paid to firm-level variables. Based on those variables used further on in this analysis, we present here two main categories of TE at the firm level.

a) Training and Workforce Skills

The level and nature of workforce skills is key to firms' learning and innovation potential. The individuals within the firm are the leading actors in the process of [organizational] learning (Kim 1997). Employees play a relevant part in the learning process in the firm.[20] The most common sources of formal skill creation are universities and technical schools, which supply individuals with scientific and technical knowledge. Firms' demand for a better educated, skilled workforce has increased as a consequence of technological change. The introduction of information and communications technologies (ICT) has accelerated the tendency towards skill intensity in employment (Howell and Wolff 1996; Autor, Katz and Krueger 1998).

A skilled workforce is more amenable to learning complex technologies. The workers' experience gained in the process of operating a given technology increases efficiency (Piva, Santarelli and Vivarelli 2003).

Howell and Wolff (1996) find that in US industries between 1970-1985, expenditures on computers were associated with increasing demand for skilled workers. However, cases studies of Pakistan's capital goods industry (Romijn 1997), the paper manufacturing industry in West Java (Jonker, Romijn and Szirmai 2006) and diverse SMEs from Uganda, Nigeria and India (Oyelaran-Oyeyinka and Lal 2006) find no statistically significant evidence of the association of university-educated managers with the adoption of more complex learning mechanisms or with higher technological capabilities in firms.

Biggs, Manju and Pradeep (1995) argue that "the simple existence of trained managers … does not guarantee high firm specific productivity if individuals with formal credentials do not possess the production and engineering skills to improve the total factor productivity" (49). Romijn (1999) reaches a similar conclusion for the capital goods industry in Pakistan, arguing that "apparently, [the education of the

[20] The user-producer approach highlights the role that workers [and consumers] play in relation to innovation (Lundvall 1988).

managers] is too abstract and theoretical to be of much value" (373). Romijn (1999) emphasizes that "it is important for the skills and knowledge imparted to be of a higher level than those already mastered by the industry" (373).

Oyelaran-Oyeyinka (2004b) shows in his case studies of African firms that internal training contributes to increased labor productivity, influencing the technological trajectory of these firms, particularly in SMEs. Similar results were found for case studies in Uganda and Nigeria, where firms consider in-house training more important than learning by doing as a mechanism of knowledge accumulation (Oyelaran-Oyeyinka and Lal 2006).

A case study on the Mexican manufacturing industry (Padilla and Juarez 2007) and a broader study on Latin American firms (Labarca 1999) show how SMEs find it increasingly more attractive to benefit from their employees' prior learning than to invest in the formation of basic skills and knowledge in their workforce, concentrating training efforts in subjects more specific to the needs of the firm.

b) Managerial and Organizational Practices

Empirical studies on French manufacturing firms (Greenan 2003) and firms in Northern Britain (Freel 2005) show relevant associations between organizational aspects and innovative activities in firms. Greenan (2003) analyzes process innovation in a panel of French manufacturing firms, distinguishing between firms that use robots or Numerically Controlled Machine Tools (NCMT) and those that do not.

Firms with advance manufacturing technologies increased their technical expertise and are moving into the model of flexible enterprise based on the Toyota (lean production) model implemented in Japan in the early 1980s.[21] The results also suggest complementarity between technological and organizational changes (Bresnahan, Brynjolfsson and Hitt 2002; Greenan 2003) and between organizational changes and changes in skills/competencies required by the firm (Caroli and van Reenen 2001; Greenan 2003).

Empirical studies conclude that firms that invest in technological changes combined with proper organizational changes are more capable of facing market competition and have a higher survival rate (Caroli and van Reenen 2001; Bresnahan, Brynjolfsson and Hitt 2002; Greenan 2003; Freel 2005)

[21] Aoki (1986) formalized the main theoretical features of this organizational model. Chapter 4 in this thesis presents its main structural characteristics.

The interaction between departments and functions within the firm in search and problem solving activities (Gjerding 1992; Freeman 1997) as well as in-house and contractual R&D activities (Teece 1988) are other important channels for knowledge transmission between firms. In a formal sense, R&D refers to those knowledge search activities primarily treated in science-based industries. The presence of a formal R&D department in the firm indicates the concession of great importance to this activity and the dedication of effort to its organization. R&D expenditure is considered in diverse studies as a significant variable related to firms' propensity to innovate (Dosi 1988; Freeman and Soete 1997), to productivity growth and to total revenue in firms (Shefer and Frenkel 2005).

Table 2-1 in the appendix to this chapter summarizes the data, variables, techniques and results with respect to TC, TE and the relationship between firm-level characteristics and learning in developing countries. These studies provided important inputs in the selection of variables used in Chapters 5 to 7.

The adoption of learning mechanisms lets firms learn to adapt and develop organizational efficiency by improving their use of the broad skills of their workforce and by incorporating knowledge into their operating activities (Cohen and Levinthal 1990; Dodgson 1993).

Learning mechanisms most commonly identified in the literature are: the classic learning by doing (Arrow 1962; Cohen and Levinthal 1990); learning by R&D (Katz 1973; Cohen and Levinthal 1989); learning by interacting (Lundvall 1988); learning by changing (Figuereiro 2001), which includes learning by innovating – including research and development (Katz 1973; Cohen and Levinthal 1989) – and learning by searching – involving external upgrading through technology contracts with foreign consultants or equipment suppliers to engage in technology transfer or technological packages acquisition (Bell 1984; Dahlman and Fonseca 1987); and learning by exploring (Teubal 1984). Acquisition and upgrading of TC are also achieved through mechanisms such as: learning by hiring (Katz and Ablin 1987; Katz, Gutkowski, Rodrigues et al. 1987); learning by producing (Johnson 1992); learning by imitating and by licensing (Mytelka 1978; Erber 1986); learning by using the technology embodied in their machinery and equipment (Rosenberg 1976); and learning through training (Dahlman and Fonseca 1987; Figuereiro 2001).[22]

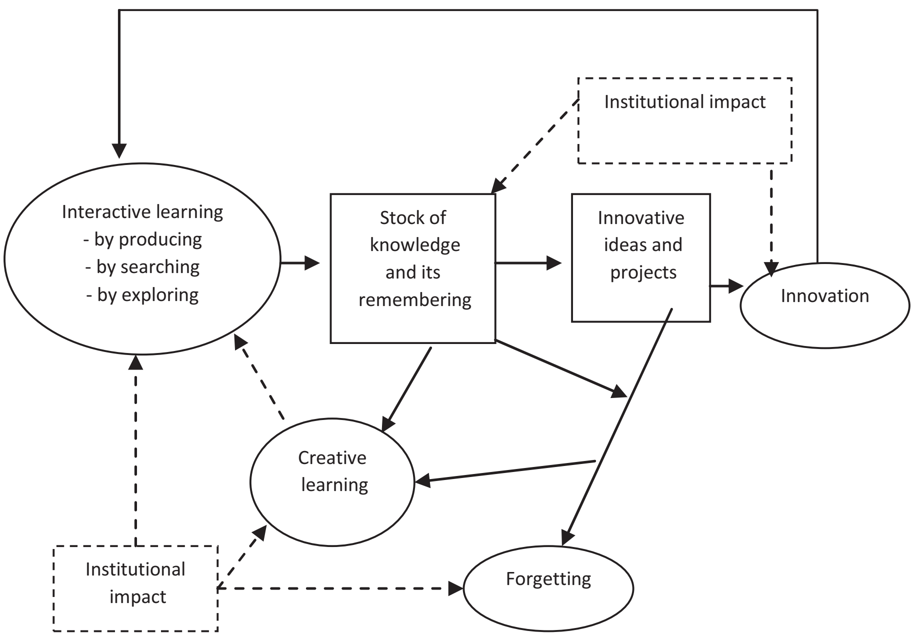
Integration of external knowledge into the firm's capabilities is commonly carried out through mechanisms such as vendors, national laboratories or research insti-

[22] The empirical analysis presented in Chapter 5 analyzes four of these learning mechanisms; the results are complemented by the analysis of one more mechanism, learning by exporting, analyzed in Chapters 6 and 7.

tutes, customers, consultants, suppliers, competitors, technological alliances, joint industry activities, public/private interactions (e.g., joint research activities), technology diffusion (e.g., through machinery and equipment) and personal mobility (Leonard-Barton 1992; Garvin 1993; Leonard-Barton 1995; Huber 1996).

The interface of these mechanisms creates a process of interactive learning within the firm, which serves to increase the stock of economically useful knowledge, as well as to decrease old knowledge by adaptation and forgetting (Johnson 1992). Figure 2-2 exemplifies this interface among diverse learning mechanisms favoring the innovation process.

Figure 2-2 The Relations Between Learning, Growth of Knowledge and Innovation



Source: From Johnson, (1992, 33).

D. Innovation Capabilities

The acquisition and mastering of technological capabilities are undoubtedly of vital importance for successful industrial development. They constitute a necessary condition for competing and keeping firms in the market. However, the acquisition and mastering of TC alone is not a sufficient condition. In order to succeed in the unpredictably changing modern environment, firms should be able to put into use their knowledge and skills and, most importantly, they should also be able to adapt, rearrange and modify this knowledge constantly and dynamically in response to changing and evolving conditions, situations and demands. This is conceptualized by the term *Innovation Capacity* (Mytelka 2000; Hall 2005), a concept rarely used *per se* in the literature but whose relevance represents the utmost goal of learning and innovation objectives in the system. It is a concept also embedded in the earlier Nordic literature on learning and forgetting. Innovation capacity can be defined as "the context specific range of skills [scientific and of other types] held by actors [e.g., individuals, firms, organizations], practices, routines, [patterns of interaction], institutions and policies needed to [create and] put knowledge into productive use in response to an evolving set of challenges, opportunities and technical and institutional contexts" (Hall 2005, 625).[23]

Innovation capacity should be understood as a system capacity that cannot be achieved by firms in isolation. It requires that firms and the system actors with which they interact evolve in a similar and complementary direction. It requires the adoption of learning as a continuous process, and one that necessitates a constant understanding of the surrounding settings in which firms or organizations operate.

The interactive learning and capability building literature provides the analytical insights for the analyses presented in this study. Diverse methodologies and variable selection used in case studies from the literature on capability building in latecomer firms provide the basis for the empirical analysis conducted in this research. This strand of literature also contributes to explaining empirically the critical firm-level characteristics and technological efforts that contribute to technological capability building in Mexican auto parts firms.

2.4 Learning by Exporting

In the late 1990s, the World Bank emphasized the relevance of exports in facilitating countries' abilities to obtain knowledge from abroad. It argued that exporting firms increase their productivity through learning from participating in international markets (World Bank 1998; Galina and Murat 2004). It is assumed that exporting firms learn by changing their production, distribution and managerial procedures, as well as by upgrading their technological capabilities, in order to respond to competitive pressure at international levels (Macario 1999; Bonelli 2000; Macario 2000a; Macario, Bonelli, Ten Kate et al. 2000).

[23] Comments in square brackets reflect adaptations to the definition taken from a later project proposal titled "The Andean Rural Innovation Dynamo" (Hall, Dijkman and Saravia 2007).

By signing Free Trade Agreements, countries not only agree to engage in the purchase and sale of products with other countries; they institutionalize their entrance into the global market. In other words, they open their borders to international requirements and production standards, as well as to new actors and relationships in the international arena that will influence and possibly determine the development and strategies of their industries, as in the case of the assemblers engaged in global auto parts production.

Globalization also implies that the national actors are no longer in charge of the decision-making for all processes, as foreign firms begin to play relevant roles in the direction of industries. As Dicken (2003) indicates, globalization entails not only a set of new economic processes, but also political and technological ones which are driven by the actions of multinational corporations and states with uneven effects across space and time.

Chapter 4 presents some important features and patterns of the increasing globalization of the automobile industry, enabled not only by technological progress in information and communication technologies but also by the increasing liberalization of trade, ownership requirements and foreign direct investment. Chapter 4 also presents the main organizational changes undergone by this industry globally and how local firms in Mexico have coped with those changes. The chapter also discusses global integration among the main firms of the auto sector, allowing for a better understanding of how globalization has had an effect [an important one] on the learning and innovation trends of Mexican auto parts firms.

The empirical literature on innovation, exports and learning by exporting considers the firm as the entity that engages in efforts towards capability building. The role of the firm's size as an important factor in dynamic performance has long been a source of debate in the literature. Industrial organization theorists argue that in achieving competitiveness with a certain level of efficiency, the size of the firm is an important variable to consider (Pratten 1971). In the case of the automobile industry, the size of the firm is considered to play a significant and positive role in firms' exporting capability (Bhavani 2002; Rasiah 2003).

Exports of long-produced but lower-technology products (i.e., more standardized products) are associated with countries that have industries less experienced in foreign trade, and that have a low degree of openness and intra-industry trade (An and Iyigun 2004). As this seems to be the case in the Mexican auto parts industry, we classified firms industrially according to their main product. Exporting firms learn by changing their production, distribution and managerial procedures, as well as by upgrading their technological capabilities, in order to be competitive at the international level. Firms that export are found to have significantly greater learning opportunities than non-exporting ones (Macario 2000a, 2000b; Macario, Bonelli, Ten Kate et al. 2000). To remain competitive in international markets, however, they must upgrade their capabilities. Therefore they should continuously engage in technological efforts to upgrade their learning and innovation capabilities (Ernst, Mytelka and Ganiatsos 1998). One TE considered in this analysis is the use of Information and Communications Technologies (ICT), which does not stand alone and is often associated with the establishment of networks. It facilitates firms' exposure and communication with foreign markets. Training is also an important learning effort (and a learning mechanism itself) that enables firms to acquire external knowledge (Dahlman and Fonseca 1987; Figuereiro 2001).

2.5 Approach of This Thesis

This section presents the perspective, the theoretical elements, their relationship to the research objective and the methodology adopted by this thesis. It draws on three bodies of literature.

First is the systems perspective, which focuses on the actions taken by the main actors in the system (i.e., firms, governments, knowledge centers), their orientation, the changes in their internal structures and external networking, as well as their responses to market changes and pressures. This perspective establishes the setting and institutional framework in which firms operate.

Following the innovation systems approach, the research undertaken in this thesis is based on the premise that innovation is shaped by both formal institutions (e.g. national automobile policies/decrees and NAFTA) and the informal institutional context, consisting of traditional habits, practice and norms that have evolved historically overtime (Freeman 1988; Lundvall 1992; Edquist and Johnson 1997; OECD 1997; Mytelka 2000; Oyelaran-Oyeyinka and Barclay 2002). The study pays particularly close attention to the role played by institutions in affecting the learning and innovation responses of firms in the auto parts sector in Mexico.

The Mexican case study is also framed in a developing country context. It thus adopts a definition of innovation that goes beyond a focus on formal R&D activities to include "the process by which firms master and implement the design and production of goods and services that are new to them, irrespectively of whether or not they are new to their competitors – domestic or foreign" (Ernst, Mytelka and Ganiatsos 1998).

Second is the use of interactive learning and capability building theories that provide the analytical tools with which to analyze and understand those processes by which firms develop the knowledge and skills needed to acquire, assimilate, change and create their technology (Dahlman and Westphal 1982; Bell 1984; Katz 1987; Dosi 1988; Lall 1990; Bell and Pavitt 1993, 1995; Ernest, Ganiatsos and Mytelka 1998; Mytelka 1999; Oyelaran-Oyeyinka and Lal 2004).

Third are elements drawn from the development literature, in particular, the role that it assigns to trade (i.e., exports) as a factor in learning and innovation processes. By combining these three conceptual approaches, it is possible to go beyond the national boundaries in our research problem and provide a better understanding of the fragility of the automobile sector's structure in the context of a globalized industry.

The unit of analysis is the auto parts industry. The research analyzes changes in innovation and learning responses of this industry in an environment characterized by rapid changes in market and formal institutional settings (i.e., NAFTA). This study considered only those firms manufacturing auto parts and components classified into the following categories of the Mexican Classification of Productive Activities (CMAP)[24]:

- Manufacture and assembly of bodies (384121)
- Manufacture of engines and their parts (384122)
- Manufacture of power train systems, parts and components (384123)
- Manufacture of suspension systems, parts and components (384124)
- Manufacture of brake systems, parts and components (384125)
- Manufacture of other [main] parts and components (384126)

The thesis implements an innovative research approach that focuses on the sustainability of the Mexican auto parts industry as reflected in conscious learning processes and technological capacity building as elements to build innovation capacity, rather than on traditional economic indicators, sector exports, entry/exit of firms and the growth in the number of firms. The research questions posed in the study are: *What has been the innovation and learning response of the Mexican auto parts firms to the new economic conditions brought about by NAFTA? How have state policies and established habits and practices affected these responses?*

The research is structured around six statements that provide us with a progressive set of different sources of evidence that, when put together in an integrated way,

[24] All acronyms of Mexican organizations in this paper are based on the Spanish name, unless otherwise noted.

explore the research questions of the study. These statements are independently tested in the various chapters of this thesis and only discussed in an integrated way in Chapter 8. The following paragraphs present the six statements that provide the analytical base for the arguments made in the thesis. They are presented in the order in which they are explored in each chapter of the thesis (see Table 2-2 at the end of this chapter).

1) The innovation support system for automotive firms has been inadequate under circumstances of market change.
This statement is explored in Chapters 3 and 4, which describe the institutional setting in which the industry developed. Chapter 3 presents the historical role of policy in shaping the habits and practices of the actors in the system. It describes the position of the government and the promotion of policies targeting explicitly employment and the BoP rather than the learning and building of technological capabilities.
Chapter 3 also describes the sector response to these policies and the way in which these policies affected the parameters within which the firms made decisions about learning, investing and innovation. Although Chapter 3 does not aim to define the composition (i.e., actors, institutions, organizations, processes) in the innovative support systems for automotive firms, it presents evidence largely based on historical facts that discuss changes in ownership structure, lack of local content integration and limited exporting capacity. And although these specific factors are not discussed as part of an innovative support system, they provide the impression that such a system was not very developed in the pre-NAFTA period, and also that the situation did not improve when NAFTA came into force.
Chapter 4 complements the national context presented in Chapter 3 and gives a general view of the evolution of the auto industry globally. It presents the context of a changing global automobile sector (emphasizing the introduction of lean production) and the new requirements brought about by these changes to the local industry (e.g., an increasing need to meet international standards).

2) Networking among Mexican auto parts firms has been weakened by the convergence of factors brought about by NAFTA.
Linking and networking among actors is essential in improving technological and innovation performance and is an important pillar of the SI approach (Lundvall 1988). Chapter 3 presents a historical description of the development of the auto industry in Mexico. This provides insights into the relationships between the auto parts suppliers and the terminal firms, as well as the poor involvement of the auto parts firms in strategy planning and policy design affecting the auto industry. This statement is explored in Chapter 4, where *networking* is understood as the interac-

tion among auto parts firms and universities, research centers and other knowledge centers (e.g., training centers).[25]

Chapter 4 provides a descriptive comparison of changes in the number of firms conducting innovation activities in collaboration with knowledge institutions – universities, training centers, firms' subsidiaries and consultants – before and after NAFTA (we used the same set of firms for two different years).

3) Domestic innovation and learning mechanisms in the auto parts industry are correlated with firm size, ownership structure and supplier tier level.

Case studies from the capability building literature suggest that firm-level characteristics, such as firms' size, growth and ownership structure and the technological efforts engaged in by these firms are positively related to the firms' TC (Gregersen 1992; Rasiah 2003; Jonker, Romijn and Szirmai 2006).

In Chapter 5, we assume that firms' choice of what learning mechanisms to adopt in their search to build or strengthen their capabilities is positively correlated with firm-level characteristics, as size and ownership are important factors in innovation success (Oyelaran-Oyeyinka 2003a).

We consider ownership structure to be an important factor influencing learning and innovation in the industry, since both foreign and domestic firms carry out their own sets of habits and practices. On the one hand, foreign firms are more "obligated" to follow the strategies of their parent firms. On the other hand, domestically owned firms do not have this sort of obligation and carry out a set of habits and practices that were developed as a result of various policies – and their implementation standards – over time. These habits and practices have an important influence on firms' adjustment to the new learning and innovation requirements that came about as a result of NAFTA.

This is a particularly important point in discussing the impact of the intersection between the historically shaped habits and practices of the auto parts firms and the requirement to meet market changes introduced by NAFTA.

4) The nature and direction of the innovation and learning mechanisms adopted by automotive suppliers have changed since the introduction of NAFTA in 1994.

Based on a sample of 192 firms established before 1994, we run a multivariate probit model in Chapter 5 to explore changes in the learning mechanisms that these same firms have experienced after the entrance of NAFTA.

5) The domestic supply chain has not been strengthened under NAFTA, and an important proportion of imported parts and components is significantly preferred in

[25] It is only in Chapter 4 that we conduct a statistical test to compare changes in firms' interaction with knowledge centers over time.

production over those that are domestically supplied, thereby weakening the domestic supply chain.
Having an automobile industry in a developing country is attractive in the sense that it fosters the development of auto parts suppliers and other related supporting industries. However, when domestic output is not competitive with the international standards required in production, assemblers and large auto firms are inclined to substitute this production with imports, and consequently, there is a slowdown in local learning, capacity building and innovation in the sector. This statement is explored in Chapters 6 and 7.

6) The production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms, and these firms differ widely in their internal knowledge, size and technological efforts.
Free Trade Agreements (FTAs) change the market environment in which firms operate. FTAs institutionalize new competitive, commercial, environmental, social and economic conditions, to which firms in developing countries have to adapt by building, strengthening and upgrading their TC.
In Mexico, as well as in other Latin American countries, exports were viewed as one mechanism by which trade liberalization would improve performance and stimulate economic growth (Pack 1988; Ten Kate 1992). It was assumed that private actors, in contrast to the state-owned firms that predominated during the ISI period, would take advantage of the labor-abundant resources in the region (Krueger 1983). In order to survive the new competitive economic environment, domestic and foreign firms would have to undergo substantial changes and investments in a short period of time (Macario 2000a).
Internal firm characteristics (e.g., size, ownership structure, experience) and technological efforts (e.g., adoption of quality control, skilled workers, etc.) are explored from Chapters 4 to 7, looking at the same aspects – based on different databases – to see how they changed over time. Chapters 6 and 7 present two empirical analyses on how firm-level characteristics and technological efforts differ between exporting and non-exporting firms under NAFTA.

Table 2-2 in the appendix to this chapter presents the organization of the analytical work in different chapters of the thesis. The table shows the main statements explored in each chapter and the databases used as empirical support. It indicates how each of the three empirical chapters (i.e., Chapters 5, 6 and 7) are contextualized by not only the history of the auto industry in Mexico and its institutional background (presented in Chapter 3) but also the global strategies followed by the industry and the previous technological efforts and capabilities already achieved by the Mexican auto parts industry (presented in Chapter 4).

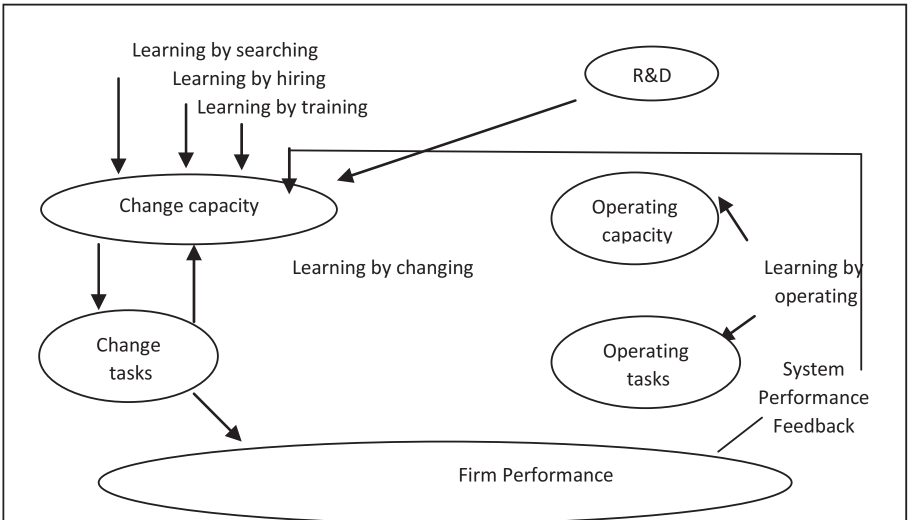
Methodology

This thesis introduces the concept of *learning mechanisms* as the diverse channels through which firms build and strengthen their capabilities. These mechanisms are understood as the specific ways by which firms learn, and which contribute to improving the skills of the workforce and upgrading firms' technological capabilities (Arrow 1962; Young 1991, 1993; Benarroch and Gaisford 2001).

The thesis analyzes changes in the type of learning mechanisms adopted by firms over time as an indicator of how learning, technological efforts and innovation have adapted to the new market conditions brought about by NAFTA based on the habits and practices already existing.

Figure 2-3 presents Bell's (1984) illustration on how firms' performance is influenced by the adoption of diverse learning mechanisms. It shows that learning mechanisms do not work in isolation from one another. They influence learning and performance in the firm interactively.

Figure 2-3 Interaction Among Different Learning Mechanisms



Source: Bell (1984)

The following paragraphs describe how these variables are composed and divided into three broad classifications (i.e., learning mechanisms, firm-level characteristics and technological efforts).

1. Learning Mechanisms

a. Learning by training. In our analysis we divided this type of mechanism according to the type of training given to the workforce.

b. Learning by innovating. The question capturing this variable asks whether or not the firm conducted any of the following three activities: a) design of new products, including increasing the variety of products; b) process and product quality improvement, including the adoption of new (or improved) productive processes that contribute to increasing productivity and quality control; and c) design, improvement and manufacture of machinery.[26]

c. Learning by searching. This mechanism involves external upgrading through technology contracts with foreign consultants or equipment suppliers to engage in technology transfer or technological packages acquisition (Bell 1984; Dahlman and Fonseca 1987). Due to the nature of the data, we could not separate this variable into two components, so we created a dummy variable with value 1 when firms buy technological packages and/or receive technological transfers from their headquarters, and 0 otherwise.

d. Learning by using. In 1976, Nathan Rosenberg talked about firms learning by using the technology embodied in their machinery and equipment. We constructed this variable based on whether the firm reported having used *new* machinery and equipment that year.

e. Learning by exporting. This variable explores how the internal structure and technological efforts engaged in by auto parts firms influenced their propensity to export. The variable includes all direct exports of the firm but also the part of production sold to firms that would later export these products. In our analysis, we only consider this variable in the period under NAFTA, due to the lack of available data prior to 1994. The analysis assumes that exporting firms have stronger innovative capabilities and higher marginal factor productivities than non-exporting firms (Feder 1982).

[26] The Enestyc survey only separated this question in different components in the year 2000. Therefore, for comparison reasons we constructed a variable that reflects if the firm conducts any of these three activities or not. Due to this aggregation, we are not able to specify which of these three activities was realized by the firm, and consequently we cannot declare if the firm is conducting R&D *per se* (i.e., as referred to in components a) and c) of this question). We thus labeled this variable "learning by innovating," which, according to our definition of innovation, covers a wider range of activities (including point b) than the three aspects explored by this question.

2. Firm-level Characteristics

One of our research statements explores firm-level variables related to size, ownership, age and tier supplier level as important factors determining learning and innovation in the auto parts industry.

a. Size of the firm

The research adopts its size classification from the official classification of the Mexican Industrial Sector published in 1991. According to this classification, we considered as small those industrial firms with less than 100 employees, as medium those firms with 100 to 499 employees and as large those firms with more than 500 employees (SEGOB 1999). As in other empirical analyses, we used the natural logarithm of the total number of employees to measure the size of the firm (Biggs, Manju S. and al. 1995; Yasuda 2005).

b. Ownership structure

The roots of historically established routines and institutional learning are fundamental conditions in understanding firms' learning patterns. In the 1970s, the terminal industry underwent a process of denationalization, and the auto industry engaged in an export-led strategy based on the compensation of imports by a similar percentage of exports (e.g., 1972 Automobile Decree). The study explores the influence that ownership structure plays in firm's adoption of diverse learning mechanisms. The research assumes that firms with a higher percentage of foreign equity are more likely to engage in more demanding learning mechanisms (e.g., learning by innovating, learning by searching).

To maintain the scale of the variables used, we calculated ownership of the firm by dividing the percentage of foreign equity by 100. In the case of the analyses presented in Chapters 6 and 7, this variable was obtained as a binomial variable with value 1 if the firm has more than 51% of foreign equity participation, and 0 otherwise.

c. Experience of the firm

Learning is a process strongly linked to firms' environment. Their business culture, habits and practices are shaped by the relational interaction of the agents in the system. Industrial and national policies shape the interaction patterns of the system actors. Informal institutions (e.g., ways firms interrelate to others and to their environment) are framed and influenced by the historical specificities of their system (Mytelka 2000; Lundvall 2001; Mytelka 2004). The thesis analyzes how firms established in the period before trade liberalization evolved and adopted different learning mechanisms in order to keep operating under new market conditions than those established under this period.

Following other empirical studies, to measure the firm's experience, we use the natural logarithm of the number of years since the firm began its actual manufacturing activity (Oyelaran-Oyeyinka and Barclay 2002).[27]

d. Tier supplier level

An important characteristic of the automobile industry is the set of interrelations it has with other industrial activities in the economy. This set of interrelations favors technological upgrading in the different auto parts sectors and supporting industries. The first-tier suppliers are mainly large multinationals using their own production technologies[28] in the manufacture of complex sets of automotive systems and sub-systems. They possess the knowledge and technology involved in the design and production of functional parts and components (modules). First-tier suppliers are in constant and direct communication with the assemblers, although they do not necessarily have all the technical information on every part and component used in their models. The assemblers place great importance on the technological development and upgrading of their first-tier suppliers and not necessarily on the development of lower tiers in the chain (Lara Rivero, Trujano and Garcia Garnica 2004). Due to the constant technological demand from the terminal industry, we expect that first-tier suppliers adapt to this requirement by adopting more dynamic and up-front learning mechanisms and TE.[29]

Firms selected for this analysis belong to the core economic activities of the industry (marked in bold in the table). The research presented here only analyzes firms from the following six CMAP categories:[30]

- Manufacture and assembly of bodies (384121)
- Manufacture of engines and their parts (384122)
- Manufacture of power train systems, parts and components (384123)
- Manufacture of suspension systems, parts and components (384124)
- Manufacture of brake systems, parts and components (384125)
- Manufacture of other [main] parts and components (384126)

[27] This indicator is our proxy for the firm's memory of the environment in which it started to operate in that specific manufacturing activity. It indicates how long the same firm has been conducting that specific activity over time. The study analyzes the same group of 192 firms over time, and changes in their manufacturing activities are partially reflected in this variable.

[28] Sometimes the assemblers have some of their subsidiaries producing "key" parts – inside or outside their production plants – such as engines and body panels.

[29] The author created a dummy variable for first-tier suppliers under the guidance of Raul Alfaro, Mexican Trade Commissioner for the Benelux 2001-2006 and based on internal information from the Ministry of Economy and Bancomext, Automobile Industry Department. Mr. Alfaro is a Mexican expert on the automobile industry and has actively participated in many of the policy processes the industry has undergone.

[30] Due to confidentiality reasons, the author does not disclose the number of firms by economic activity or by CMAP code.

3. Technological Efforts

Several empirical studies from the TC literature show how different firm-specific characteristics influence the acquisition of TC in the firm (Biggs, Manju S. and al. 1995; Romijn 1999; Cameron G. 2005; Jonker, Romijn and Szirmai 2006; Oyelaran-Oyeyinka and Lal 2006). Following case studies done by Katz, Gutkowski and Rodrigues (1987), Romijn (1997) and Jonker, Romijn and Szirmai (2006), we include explicit variables indicating TE – the inputs to learning that in turn are the activities required to build, accumulate, strengthen and improve the firm technological capabilities – carried out by firms in our sample.

Though the conceptual distinction between technological capabilities and technological efforts seems logical and straightforward, empirically this differentiation is not easy to apply. The differentiation between proxies capturing technological efforts as distinct from technological capabilities is in many ways subjective to the researcher and to the data available.

Although the learning mechanisms selected for our analysis could equally well have been viewed as proxies for technological efforts, we selected them as independent variables based on their similarities to those learning modes mentioned in the literature (Arrow 1962; Katz 1973; Mytelka 1978; Bell, Ross-Larson and Westphal 1984; Dahlman and Fonseca 1987; Lundvall 1988; Cohen and Levinthal 1989; Figuereiro 2001) and on the fact that we considered in a straighter way a mode of learning.

The selection of proxies representing technological efforts was done by the author based on examples of the capability building literature (Katz 1984, 1987; Katz, Gutkowski, Rodrigues et al. 1987; Biggs, Manju S. and al. 1995; Howell and Wolff 1996; Romijn 1997, 1999, 2001; Piva, Santarelli and Vivarelli 2005; Jonker, Romijn and Szirmai 2006). These variables reflect activities that are executed within the firm and that, with repetition and time, bring learning to the firm in an indirect way.

In our analysis we chose our proxies for technological efforts based on the type of information provided by the data. Three types of efforts were considered:

- Automation
- Organizational Processes
- Linkages with Knowledge Centers

These variables and their proxies were classified as technological efforts and not as technological capabilities based on global automobile production tendencies (presented in Chapter 4). As presented in Chapter 4, transcendent technological and organizational changes in the industry originated in Japan in the early 1980s and

1990s. The adoption of these changes (such as lean production techniques – involving JIT and TQC) was uneven between firms and countries hosting this industry. The time and extent of their adoption also differs.

In the case of Mexico, changes in the terminal industry's ownership structure in the early 1970s (i.e., before NAFTA) influenced the structural changes that took place in the industry. With a wholly foreign owned terminal industry, the adoption of production and organizational methods was determined by the global industry rather than by the local industry situation (a point discussed at greater length in Chapter 3).

The following variables are the proxies used by this research in representing the technological efforts carried out by the sector in the transition to NAFTA:

A. Automation
A.1. Adoption of mechatronics in the production process
Mechatronics is the coupling of electronic functions with traditional mechanical engineering routines; it results in relatively complex machinery with routines that tend to demand higher and more specialized skills. Its implications for firms are two-fold. First, additional learning efforts are required to master the new electronic functions embedded in mechatronics. Second, a reorganization of the workplace function is often required, because digital-based technologies do not stand alone and often work within networks. The research assumes that firms introducing mechatronics into their production processes have better capabilities than those using simpler technologies. This variable is measured by the proportion of Computerized Machine Tools (CMT) and robots in the total machinery and equipment used in the production process.[31]

A.2. Adoption of statistical process control (SPC)
The adoption of statistical process control exemplifies the use of advanced manufacturing techniques involving the use of computerized systems such as CAPC (Computer-Aided System of Production Control). A binary variable for computer-aided programs used in production takes the value 1 if the firm uses statistically or computerized process controls, and 0 otherwise. This variable is expected to have a positive relationship with the firm's probability of adopting the learning mechanisms analyzed.

[31] Robots are understood as reprogrammable multifunctional manipulators, designed to move material, parts, tools or specialized devices through variable re-programmed motions for the performance of a variety of tasks (definition adopted from the Robot Institute of America).

B. Organizational Processes

B.1 Adoption of lean production techniques

Lean production techniques – based on the Toyota Production System (TPS) – are strongly supported by three fundamental tools: just-in-time inventories, standardization and quality control. Taking advantage of the data available in the comparative analysis of changes before and under NAFTA, we constructed a variable with value 1 if the firm has adopted in its organizational management either JIT or TQC.

a. Just-in-time (JIT)

The just-in-time (JIT) system lets firms minimize the stockpiling of parts and components along the assembly line or in any part of the production processes, thereby saving inventory costs. In the words of Mr. Minoura, Toyota Production Manager, JIT "is about producing only what is needed and transferring only what is needed" (TMMK 2003). The implementation of JIT involves securing a constant flow of work and reducing the lead time for making things in the production line, as well as enforcing high standards of quality control. JIT also implies the adoption of visual control tools (e.g., information cards, display boards and error prevention mechanisms) that could not be implemented without the adoption of appropriate microelectronic systems and information technologies.

b. Total Quality Control (TQC)

Establishing quality control (QC) in a firm implies that the firm has already achieved quality consistency in its production steps (Schmitz and Knorringa 2000).

TQC requires training for middle level managers in QC techniques, as well as the need to link shop-floor processes to higher level management policies (Sako 2004). In order to meet quality control standards, the firm would already have undergone learning processes that allow it to establish standard processes and production outputs. For the analysis presented in Chapter 6 (analyzing the industry for the year 2002), TQC is represented by the following two explanatory variables:

c. Quality control certifications

The adoption of global quality standards (e.g., ISO quality assurance norms, QS9000, VDA, EAQF) has important implications for local producers, especially those located in developing countries. These types of certifications are seen as indicators of firms' capability to assume further responsibilities in the supply chain, lowering transactions and governance costs with other tier suppliers (Nadvi and Waltering 2002; Quadros 2002).

With the globalization of the industry, the acquisition of QC certifications by local firms becomes an important requirement to supply multinational firms and to access government programs and credits (Quadros 2002). In Mexico, MNCs are increasingly demanding that their local suppliers acquire international quality certifications in order to keep serving as their suppliers (Jasso and Torres 1998; Carrasco 2005).

The adoption of QC certifications is not an easy task. It demands that firms internalize other sets of skills, techniques and organizational methods and develop the ability to implement them consistently. In the empirical analyses of this research, we consider the adoption of QC certifications as a mechanism by which a firm makes an explicit learning effort towards the achievement of technological capabilities.

B.2 Adoption of ICT

There is no doubt that the new computerized and Information and Communication Technologies (ICT) play a key role in the production of automobiles. Emerging from previous mechanical paradigms, the incremental introduction of ICT in production, organizational and managerial processes brought a complete re-definition of the production system, relationships and networking among firms in this industry (Lung 2001; Mytelka 2003).

B.3 Learning by hiring

A model of production that emphasizes mechatronics, lean production techniques, total quality control and the adoption of ICT clearly requires a skilled workforce that facilitates firms' efforts and investments in upgrading and provides the capabilities needed to keep TPS working efficiently.[32]

Based on some case studies from the capability building literature (Jasso and Torres 1998; Oyelaran-Oyeyinka 2003a), this analysis uses the following two indicators to test these earlier findings:

a. Workforce with university studies

The proportion of white- and blue-collar workers with a university education and postgraduate education is expected to have a positive and significant effect on the dependent variables analyzed.

b. Managers with graduate studies

As all decision-making is concentrated in a firm's management, we included a variable measuring the number of managers with post-graduate education divided by the total number of managers in the firm.

[32] See Sako (2004) for more on organizational capability enhancement and transfer in Japanese automobile suppliers by Honda, Nissan and Toyota.

B.4 Use of imported main inputs

This variable is analyzed in Chapters 6 and 7, with the assumption that as local content requirements are lifted and imports of parts and components with embodied knowledge take the place of investment in new skills and capabilities, domestic technological and learning efforts are reduced (see Figure 1-1). When allowed by the data, as in Chapter 7, we divided this variable in two items:

a. Share of imported inputs in gross sales (constant values)

b. Share of imported inputs in exports

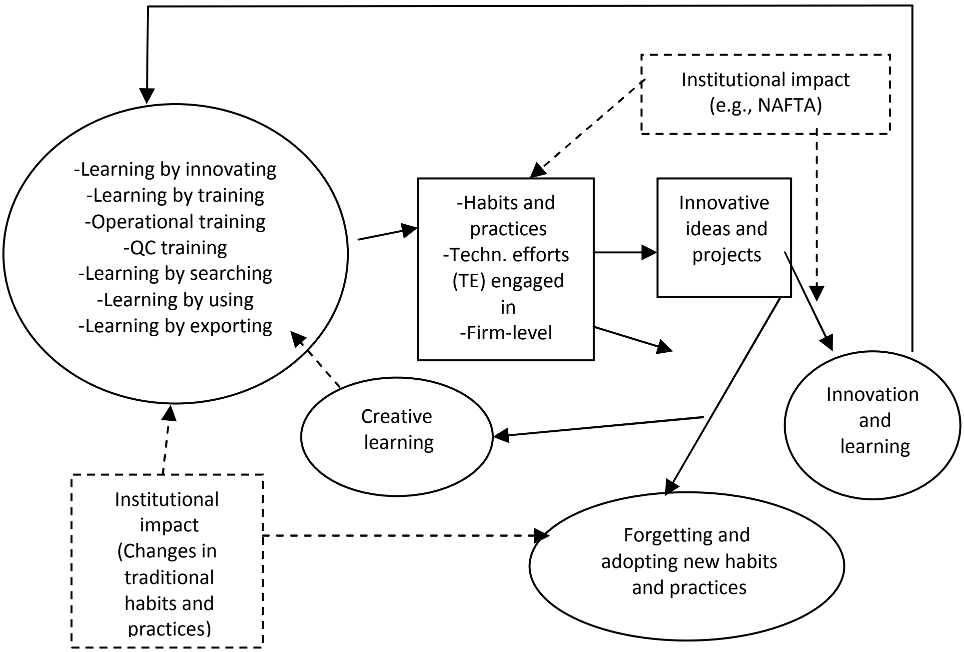
C. Linkages with knowledge centers

The case of Nigerian breweries illustrates how firms contracted university researchers, undertook personnel training at the facilities of technical [foreign] partners and employed engineering graduates in order to build the required manpower to compete under new market regulations (Oyelaran-Oyeyinka 2003a).

Universities are considered to play a relevant role in the innovation system of countries. In developing countries the role played by these knowledge institutions is particularly important, as they are supposed to create certain important scientific knowledge necessary for production activities. They are the main trainers of professionals (i.e., human capital), who in turn will transmit their knowledge to the firm, generating organizational learning. Chapter 4 explores changes in the linking and networking patterns of a set of 192 firms before and under NAFTA.

Figure 2-4 presents a modification of Johnson's 1992 illustration (presented in Figure 2-1 earlier in this chapter) with the elements discussed in our work. The figure illustrates the institutional impact in shaping and interacting with informal institutions (e.g., traditional habits and practices, engagement in technological efforts) and innovation and learning behavior in firms.

Figure 2-4 Learning and Innovation Relations Used in This Analysis



Source: Adapted by the author based on Johnson (1992).

These innovation and learning behaviors affect firms' choices for learning mechanisms. The adoption of different learning mechanisms gradually affects the habits, practices and technological efforts of the firm and influences its internal characteristics; all this has an impact on the innovation and learning patterns of the industry. Changes in formal and informal institutions also have a gradual impact on the adoption of learning mechanisms, which in turn feeds the dynamics of the circle.

2.6 Appendix – Chapter 2

Table 2-1 Empirical Case Studies on the Relationship Between Firm-Level Characteristics, TE and Learning in Developing Countries

Authors	Region/ Country	Data	Variables	Technique	Results
Katz (1987)	Latin America (LA)	Industrial case studies at the firm level	Engineering activities, industrial organization and production planning No clear distinction between TE and TC	Statistical descriptions of case studies	Market size and shortages of human capital limit vertical integration in manufacturing in Less Developed Countries (LDC). TE in LA followed a wide variety of objectives and firms' idiosyncrasy.
Katz, Gutkowski, Rodrigues et al. (1987)	Argentina	Primary data at the firm level from a rayon plant in ARG	TE (using tube-spinning and high solids spinning); Performance indicators (total volume of output, raw materials/kg/output, quality improvements and new products)	Case study and a simple model of firm behavior	TE are likely to be undertaken in the search for less expensive factors and raw materials.
Biggs, Manju and Pradeep (1995)	Ghana, Kenya, Zimbabwe	Primary data at the firm level; 3 countries, 4 industries	Learning mechanisms (training, R&D, supplier-buyer relationships, firms' interaction, industry networks, hiring of local/foreign consultants); TE; TC; TFP	-Descriptive -Stochastic -Frontier Methods for levels of efficiency	Learning mechanisms constitute the most important category of technological capabilities. Technological capabilities are the results of deliberate efforts carried out by firms.
Figuereiro (2001)	Brazil	Interviews at 2 steel manufacturing firms	Investment, product technology and production organization, machinery and equipment (variety, intensity and function)	Comparative case study	Efforts of capital acquisition by the firm should be done in parallel with organizational learning. Efforts on the intensity and functioning of learning processes are crucial to TC.
Oyelaran-Oyeyinka (2003a)	Nigeria	33 firms in the Nigerian brewing sector	Institutional actors, firm size, ownership structure, technical skills of labor force, foreign/domestic technical assistance	Qualitative analysis descriptive statistics	Size, manufacturing skills and ownership factors in the innovation success of firms that survived and prospered under a changing industrial environment.
Jonker, Romijn and Szirmai (2006)	Indonesia (West Java)	29 individual paper machines and their operators across 6 firms	TE (level of education of managers, training, machine check-ups, job rotation, linkages); TC (net production, product differentiation, ISO certification preparation); economic performance (gross value added)	Pearson or Spearman rank correlations for linkages between TE, TC and performance	No significant positive correlation between technological efforts and technological capabilities. Significant, positive relationship between capabilities and performance.

Table 2-2 Thesis Distribution: Chapters, Statements and Empirical Support

LEARNING AND INNOVATION UNDER CHANGING MARKET CONDITIONS: The Auto Parts Industry in Mexico

RESEARCH QUESTIONS: What has been the innovation and learning response of Mexican auto parts firms to the new economic conditions brought about by NAFTA? How have state policies and established habits and practices affected these responses?

CH 3. THE MEXICAN ECONOMY, AUTOMOTIVE POLICIES AND THE EMERGENCE OF THE AUTOMOBILE INDUSTRY
STATEMENT EXPLORED: Innovation support system for automotive firms has been inadequate under circumstances of market change.
EMPIRICAL SUPPORT: Research of events over time.

CH 4. THE MEXICAN AUTO PARTS INDUSTRY AND GLOBAL AUTOMOBILE PRODUCTION TENDENCIES
STATEMENT EXPLORED: Networking among Mexican auto parts firms has been weakened by the convergence of factors brought about by NAFTA.
EMPIRICAL SUPPORT: Empirical evidence from other studies on the Mexican auto parts sector during the same time frame (e.g., JICA 1996; Carrillo 1993, 1995; Jasso and Torres 1998; Bancomext 1999, 2000).

CH 5. THE ADOPTION OF LEARNING MECHANISMS UNDER CHANGING MARKET CONDITIONS
STATEMENTS EXPLORED: a. The nature and direction of innovation and learning mechanisms adopted by automotive suppliers have changed since the introduction of NAFTA in 1994. b. Domestic innovation and learning mechanisms in the auto parts industry are correlated with firm size, ownership structure and supplier tier level.
EMPIRICAL SUPPORT: ENESTyC surveys (1991 vs. 1994, 1998 and 2000). 192 firms (same set of firms over time).

CH 6. EXPORTING MEXICAN AUTO PARTS FIRMS
STATEMENTS EXPLORED: a. An important proportion of imported parts and components are significantly preferred in production over those that are domestically supplied, thereby weakening the domestic supply chain. b. The production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms, and these firms differ widely in their internal knowledge, size and technological efforts.
EMPIRICAL SUPPORT: SIEM Database – year 2002. 257 firms.

CH 7. INTEGRATION IN THE MEXICAN AUTO PARTS SECTOR
STATEMENTS EXPLORED: a. An important proportion of imported parts and components are significantly preferred in production over those that are domestically supplied, thereby weakening the domestic supply chain. b. The production regime brought about by NAFTA has led to segregation of firms into strongly and poorly innovating firms, and these firms differ widely in their internal knowledge, size and technological efforts.
EMPIRICAL SUPPORT: Ministry of Economy, Automobile Industry Department, internal database. Years 1995 to 2002. About 350 OEM firms per year.

Chapter 3

The Mexican Economy, Automotive Policies and the Emergence of the Automobile Industry

Abstract

This chapter presents the historical development of the automobile industry in Mexico from a systems perspective. The chapter establishes the roles that different actors have played over time in the development of this industry as well as the nature of their linkages and how these developed. The chapter puts special emphasis on the historical patterns of the industry because, as we argued in Chapter 2, they condition “routines” and these, in turn, condition linkages and learning. This is indeed very relevant because without understanding the roots of routines and institutional learning established over time, it is difficult to understand learning-based development.

3.1 Introduction

This chapter pays special attention to the policies and practices behind industrial development. It shows that the historical patterns of development matter because they condition routines, habits and practices, and these, in turn, condition linkages and learning.
The chapter puts special emphasis on the import substitution industrialization period and the transition to trade liberalization in the early 1980s. Since the national policies affecting the automobile industry focused on the assemblers and only in 1977 involved the auto parts firms, most of the chapter presents the industry's development with a focus on the assemblers. The chapter presents historical evidence reviewing changes in ownership structure, the lack of local content integration and the evolution of the institutional setting affecting the industry. This provides the impression that the innovation system supporting the auto industry was poorly developed in the pre-NAFTA period and that the situation did not improve under NAFTA.

The chapter is divided into five sections. Section 2 presents the historical evolution of the structural context in Latin America. Section 3 looks at the specific development of the automobile industry in Mexico through the different development strategies adopted. Section 4 highlights the learning and innovation patterns of firms in the industry. Section 5 concludes with the main lessons of the chapter.

3.2 Historical Structural Context

A. Import Substitution Industrialization Period

In the early 1950s, Latin America adopted an Import Substitution Industrialization (ISI) model as its strategy for development. This was based on the arguments of Prebish and Singer that technological progress in the North reduces global demand for Southern countries' primary products (Singer 1950; Prebish 1959). Authors advocating ISI argued that countries in the South should concentrate their efforts on putting in place new industrial activities to make domestic production competitive and gradually move away from their agricultural base (Bruton 1998; Barry Jones 2001). The industrial policies encouraged under ISI were derived from the *infant industry protection* theory, which promoted strong long-term protection by the state for newly created industries through several policy instruments, shielding these industries from international competition (Barry Jones 2001). Tariffs and licenses were "the most important instruments [adopted in the region] not only for commercial policy but also for the general industrialization policy" (Ten Kate and Wallace 1980). During this period, "nominal tariff levels appeared to be determined simply by what was deemed necessary to allow an activity into existence" (Bruton 1998).

In the case of Mexico, the state granted import licenses to firms on the basis of whether the good was produced in the country or not (Ten Kate and Wallace 1980; Fernandez 2000). By the mid 1950s, a system of lists of industrial products that could be imported complemented this licensing system. These lists were published annually, and through them, the Mexican government guided all possible investments into the "preferred" sectors.

By the mid 1960s, most countries in the region experienced increasing market distortions, created by high levels of industrial protection. The ISI model started to show signs of stagnation as the rate of economic growth (measured in terms of GDP) declined and problems of balance of payments (BoP) started to appear. There was increasing evidence that the instruments utilized by the government to "guide" the development of the industry (i.e., import licenses, investment permits, government contracts) created lucrative rents for those firms that obtained them, contributing to increasing market distortions and failures rather than solving them.[33]
It was at this point that contending developmental models started to be debated among developing countries. On the one hand, East Asian countries started to implement corrective policies for market distortions created under the ISI phase and to dismantle price and exchange rate controls, moving into a rapid transition from ISI to an export-led strategy.[34]By the late 1970s, Malaysia, Thailand, Indonesia, the Philippines and China moved more decisively towards export orientation but maintained significant infant industry protection elements of the ISI model (Narula 2002). The sustained high levels of growth and export rates achieved by East Asia attracted international attention from academics and policy-makers who strongly criticized the ISI model with arguments of rent-seeking costs and minimal government, a phenomenon known as the New Political Economy – NPE (Krueger 1974).

The NPE had the objective not only of stabilizing the economy but also of transforming its productive structure through a complete liberalization from government interference (Reinhardt and Peres 2000). It argued for the substitution of the government by the market as an independent actor pursuing the national interest and as a driver of growth and corrector of market failures (Bruton 1998). Taiwan and

[33] Krueger (1974) presented an important analysis on costs of rent-seeking behavior between firms, showing how the costs allocated by firms in trying to capture these rents should be added to costs of monopoly and market distortions.
[34] Most successful Asian countries – e.g., Korea and Taiwan – kept some protection as they opened their markets and sequenced policies in such a way that local firms were not hit with a need to adjust in a time frame that was not feasible.

South Korea were the pioneers in this trend by implementing marked policy changes in their development strategy while maintaining the basic objective of ISI by building up domestic industrial capacity but at the same time liberalizing their exchange rates, encouraging exports through subsidies, allocating credits and lifting trade restrictions.[35] Firms were encouraged to export through incentives and tariff exemptions on raw and intermediate inputs, as well as on capital goods. The incentives also included reductions in direct taxes on firms' profits from exporting (Bruton 1998). The export-led strategy contributed to an increase in Korean exports, leading to growth in capital investment. However, more than just capital investment is needed to foster sustainable development of national industrial activities. Investment must be accompanied by changes in traditional habits and practices with regard to in-house learning, innovation and technological upgrading, as the Korean experience in the information technology (IT) industry illustrates (Mytelka and Ernst 1998).

Unlike Asia, Latin America did not adopt export-oriented policies in the 1970s, and it embraced a stronger version of the ISI model. The region entered a new stage characterized by tighter state control and protectionism. Aiming to reactivate and promote development, the state became the main investor in the economy. In the Mexican case, the state participated in building physical infrastructure (e.g., irrigation, transportation, communication and electric power) and in developing basic industries (e.g., steel, fertilizers, petroleum). Moreover, it also acted as the main entrepreneur, making investments in about 3,000 public firms and in the manufacturing of automobiles, auto parts, freight cars, paper, cement, mining and sugar refining (Hansen 1971; Bennett and Sharpe 1980).

By the late 1970s, ISI was reinforced in the region, accompanied by high inflation, public deficit, macroeconomic instability and deficits in the current account and BoP.

Despite the obvious macroeconomic failures of the model, Latin American countries kept increasing public spending and adjusting the exchange rate.
Following the *coup d'état* in Chile that brought General Pinochet to power, that country abandoned the ISI model during the period 1974-1978 in the wake of trade reform and reduced market participation by the government. The rest of the countries, especially Mexico, underwent lighter structural changes. On the one hand, countries in the region started to introduce export subsidies and policies aiming to remove the anti-export bias created under the first stage of ISI. On the other hand,

[35] See San Gee and Wenjeng Kuo and Mytelka and Ernst (both in Ernst, Ganiatsos and Mytelka 1998) on processes for catching up and getting ahead followed by Korea and Taiwan.

the state maintained strong participation in industrial development and implemented high import tariffs (Willianson 1991).

In order to continue with the ISI strategy, the region went deeper into public external financing, strong exchange rate depreciations and, in cases like Mexico, the expropriation of commercial banks as a desperate measure to preserve the already unsustainable macroeconomic situation (OECD 1994; Fernandez 2000). Gradually, the region was unable to pay its short-run external debt commitments.
With the crash of international oil prices, the capital account and BoP deficits became unsustainable, generating a debt crisis in the early 1980s. It was then more than evident that an urgent change in strategy was unavoidable (Ramírez 1994).[36]

Four decades under ISI left Latin America immersed in a structural crisis that took a long time to overcome. In contrast, East Asia promoted the acquisition of technology and managerial know-how in its domestic sectors and built domestic industrial capacity and technology transfer processes.[37] East Asian countries voluntarily moved to an export-orientation strategy while maintaining the basic objective of building up domestic manufacturing capacity. Latin America, on the contrary, did not adjust its ISI strategies in order to reflect comparative advantages differences among countries, but it sought to duplicate the same breadth of industrial sector regardless of its initial specialization and resource endowments (Narula 2002). The region shifted towards a New Economic Model (NEM) due to the large external debt and BoP crises and the need for greater export earnings, taking inspiration from the East Asian success but not following a development plan that was properly and explicitly structured.

The following sections present a more detailed description of the development of the Mexican auto industry and its main actors in this period.

3.3 Historical Development of the Mexican Auto Industry

During the 1960s, manufacturing activities of multinational corporations (MNCs) in the developing economies consisted largely of assembling completely knocked down (CKD) kits. This type of production required the grouping of machinery by type on the shop floor. Every time the production of a different type of product was required, it was necessary to rearrange the machines. This type of manufacturing technique only allowed producing small batches of the same product.

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[36] Chile started with a radical trade liberalization in 1974, Mexico and Bolivia in 1985, and most other countries during 1989-1993 (Agosin and Ffench-Davis 1993).

[37] In this sense, East Asia followed an autonomous model, which combined important elements of ISI (i.e., infant-industry protection) and export orientation into its specific context (Narula 2002).

By the late 1960s, the demand for automobiles increased and the production organization of the industry changed. During this period, the industry comprised three broad groups of firms: assemblers, component manufacturers and subcontractors. The assemblers traditionally produced the chassis, key automotive components and assembled vehicles. The component manufacturers developed functional components in close collaboration with the assemblers, which allowed them to develop certain technological capacity. The third group was formed by subcontractors that produced parts and simpler components according to specifications given by the assembler, a component manufacturer or another subcontractor (Watanabe 1987).

The need to increase production volume and to standardize several parts and components took automotive production from batch production to flow production methods. This change in production methods required the rearrangement of special purpose machines into sequences that allowed series of operations to be conducted one after the other. In the late 1960s, when the industry reached even larger production volumes, the production floor was again reorganized. It was then that the industry introduced Special Purpose Machines (SPMs) designed to execute specific types of work. SPMs worked faster and were able to perform tasks that could not be done by general purpose machines. The SPMs were substituted gradually (Maxcy and Silberston 1959; Watanabe 1987).
With SPMs, the assemblers also started to introduce transfer machines to the production process. Transfer machines were early forms of automatization in the automobile industry that transferred parts processed in one production station to another one; once a station had carried out its work, the part was transferred to the following station and then to the next one, etc. (Watanabe 1987).

The incorporation of transfer machines allowed for more efficient use of machines, which reduced the demand for labor. These machines reduced stock-piling spaces, decreased production defects and improved production quality and consistency (Maxcy and Silberston 1959). The introduction of SPMs and transfer machines led to a considerable increase in the volume of production as well as more efficient timing and quality. SPMs were specific to a particular set of operations for a particular part or component, implying that with changes in the design of that specific part the whole machine needed to be replaced by another one – SPMs could not produce differentiated models. In this sense, although SPMs allowed for automation, it was a sort of fixed automation.

A. The Institutionalization of the Industry – The 1962 Automotive Decree

Automotive operations began in the early 1920s in Brazil, Mexico and Argentina, evolving from the importation of completely finished vehicles to the initial assembly of vehicles with CKD kits in the 1940s. After World War II, with the entrance of the ISI model, Latin American industrial policies were redirected to stimulate domestic industrial production. This took two main forms. Brazil and Argentina focused their efforts on domestic sourcing requirements, banning imports of completed vehicles and of auto parts when these were locally available. These countries focused on strengthening high local content requirements and industrial policies towards domestic production and capacity. This set of policies resulted in the early development of domestic technological capabilities in metalworking in general and, once the supplier base became more integrated, in the auto industry in particular. In addition, Brazil and Argentina imposed a freeze of about 7 years between automotive model changes, allowing domestic firms to incubate production capabilities, which by the late 1950s allowed the automotive industry to be the major source of diffusion of engineering, organizational and managerial know-how. The development of this industry served as a diffusion channel for new quality control techniques, production planning and work organization throughout other industries in these countries (Morales and Katz 1995).

In contrast to the Brazilian and Argentinean experience, the Mexican approach involved the introduction of fiscal incentives, reduced import duties on auto parts and components and systems of import quotas for complete vehicles and automotive material (Bennett and Sharpe 1985; Moreno 1994). It was not until the early 1960s, strongly influenced by the experiences of the region, that the Mexican government started to look towards the creation of its own automotive industry (Bennett and Sharpe 1985). With this in mind, Mexico's development banking institution, Nacional Financiera (known as NAFIN), undertook intense research and made technical visits to Brazil and Argentina. The result was reflected in a report titled: "Elements for a development policy in automotive vehicle manufacturing in Mexico," which contained specific recommendations for the market and ownership structure of the new industry (NAFIN 1960). The following were the more controversial points of this report:

a) There would be no more than four or five firms manufacturing passenger vehicles and two for mid-sized trucks. This implied a strong reduction in the number of firms already operating in Mexico[38].

b) Each producer would limit its manufacturing to only one model. Model changes would only be permitted every 5 years. The production of luxury vehicles would be forbidden, and production emphasis would be directed to simple compact vehicles. Reducing the frequency of model changes would allow domestic firms to master

[38] There were 10 terminal firms operating in Mexico in the early 1960s. See Table 3-1.

production capabilities that otherwise would not be mastered. This strategy was inspired by Brazil. Argentina, India and South Africa followed similar strategies in the 1960s and 1970s.
c) Firms having no relationship to the automobile manufacturers would produce auto parts and components. Automotive manufacturers would be limited to assembly operations and engine production. This recommendation implied the creation and development of a Mexican auto parts industry not yet in existence.
d) The standardization of auto parts among assemblers would be strongly encouraged. This would allow auto parts firms to reach adequate production volumes that would keep them in the market. It also made possible the development of a spare parts industry. This strategy aimed to increase the level of domestic content integration, allowing for linkages with supporting inter-industry sectors (i.e., the automobile supporting industry).
e) Automotive firms would be mostly nationally owned. However, joint ventures and licenses with MNCs would be allowed. Originally, the report hinted at the possibility of excluding foreign ownership completely, seeking to have only nationally owned firms with technology licenses and designs from MNCs. However, hardly anyone in the government thought this point would be feasible.

In the early 1960s, the operating structure of the auto industry worldwide was oriented towards maintaining the main production activities in MNCs' countries of origin, and shipping completely finished vehicles and CKD kits to their facilities in developing countries. This operating mode allowed MNCs to extend their production runs with a minimum of disruption while expanding their international presence.[39] Therefore, it is not surprising that the recommendations presented by NAFIN were not welcomed by Ford, General Motors (GM) and International Harvester.[40]

As an attempt to institutionalize the development of the industry, the Ministry of Trade and Industries (SIC)[41] elaborated the first automotive decree in the 1960s. On the governmental side, SIC and the Ministry of Finance (SHCP) were the only two actors involved in the development and negotiation of the decree. NAFIN played an important role as a coordinating agent with other ministries, namely the Ministry of National Properties (SPN) and the Ministry of Communications and Transport (SCT). On the producers' side, the only firms invited to negotiate were Ford, GM, Interna-

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[39] There were also other Japanese and European firms licensing and operating as joint ventures in Mexico.

[40] International Harvester Company (now Navistar International Corporation) manufactured not only agricultural machinery construction equipment, but also vehicles, commercial trucks and household and commercial products. Till 1975, International Harvester was also a maker of relatively successful and innovative "light" lines of vehicles, competing directly against Ford, Chrysler and GM. The most common were pick-up trucks, i.e., light trucks (Wendel 2004).

[41] SIC is today's Ministry of Economy.

tional Harvester and Fábricas AutoMex (which manufactured for Chrysler). All other firms, including DINA (the only state-owned firm), were excluded from the process.

The following were the key reasons behind SIC's promotion of this industry (Samuels 1990):[42]

a) The auto industry was considered the key element to develop a manufacturing base. The role played by this industry in the rapid development of Brazil and Argentina strongly encouraged this perspective.
b) The automotive industry was one of the largest sources of imports, contributing in an important way to the current account and BoP deficits. Consequently, it was the first industry in which high requirements of local content integration were imposed.
c) The industry was seen as an important source of employment, which was an important element in Mexican policy-making. Even though employment was kept as a priority in the elaboration of the decree, the National Union of Workers (CTM) was not involved in the negotiation process of the new law.

The 1962 Automotive Decree underwent important changes and modifications from its first draft (based on NAFIN's recommendations) to its final edition. The following paragraphs present the main changes in its elaboration as an example of the way the system of innovation of the industry was shaped in the 1960s.
Three key elements in the NAFIN recommendations were designed to promote the development of capabilities and know-how in the industry. These were: the attempt to limit the number of makes (models) per firm, the standardization of parts by the assemblers and the freezing of model changes to every 5 years.[43] NAFIN's plan also sought to rationalize domestic production by reducing the number of firms and models, with the objective of encouraging economies of scale and reducing costs. This would have contributed to creating opportunities for backward linkages to local suppliers and thus promoting employment – a key goal in the automobile policy in Mexico. These initiatives were in direct opposition to the production strategy followed by the MNCs internationally, which was based on product differentiation through yearly model changes. Consequently, these points were excluded from the final draft of the decree after intense lobbying by the three U.S. assemblers.

The U.S. Department of State also informed the Mexican government that the exclusion of any of the U.S. firms operating in Mexico would be considered unsympathetic. Due to the dependence of the Mexican economy on the U.S., any pressure

[42] It is important that the reader keep in mind these three arguments because they are implicit in most policy-making decisions in the various automotive decrees here mentioned.
[43] These three elements were key in the development of the auto industry in Brazil and Argentina, which allowed domestic firms to incubate technological capabilities and domestic learning in auto production.

by this country had to be considered seriously. As a result, the reduction in the number of firms operating in the industry and ownership constraints were also omitted from the final draft of the decree (Bennett and Sharpe 1979; Bennett and Sharpe 1985; Samuels 1990).

Only one out of five of the controversial suggestions made by NAFIN were present in the 1962 automotive decree. The point about achieving higher levels of domestic integration through higher local content requirements was included in the decree. To achieve this objective, SIC established a list of locally manufactured parts that the assemblers would be obligated to use, and which they would no longer be allowed to import (Samuels 1990). The government declared itself explicitly opposed to the vertical integration of assemblers and announced that non-compliance with the new regulation could result in "the definite closing of assembly plants that may be found offering any resistance." The decree also stated that the level of local content integration achieved would also establish the volume of production allowed to each firm (SEGOB 1962). The BoP deficit was the reason behind the government's implementation of this point. However, the enforcement of local content requirements without explicit policies promoting learning and capability building in the industry simultaneously did not stimulate learning and the development of local inputs in Mexico. Consequently, the few auto parts firms operating in the 1960s were not able to build the technological capabilities needed to produce parts and components with the standards and specificities required by the assemblers. This point of the decree was not successfully accomplished.

A.1. Technological Capacity and Innovation Responses – Origins of the Industry

In August 1962, the first automobile decree reinforced the role of the government as the driver and supreme regulator of development.[44] The new law stated that automotive firms operating in Mexico would have to submit to SIC their investment plans, import schedules and timetables for official approval. In addition, production quotas were issued to ensure the participation of national firms in the market. The decree also allowed firms that exported completed vehicles, auto parts or components the right to import parts and components "essential" to production (i.e., body stamping) up to the value of their total exports. The decree prohibited the importation of completely assembled automobiles, engines and power trains after September 1964. It also fixed local content requirements to a minimum level of 60%, measured by their direct cost of production (SEGOB 1962).[45] However, the level of

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[44] This decree prohibited the importation of vehicles, engines and other assembled mechanical components starting April 1, 1964.

[45] In Brazil, Argentina and South Africa, initial local content requirements were established at about 90-98% of the vehicle weight, while in Mexico the measure was based on the direct cost of production. The

local content requirements was unattainable considering the almost non-existent auto parts industry in the country.

The 1962 Automobile Decree did not reduce the number of firms as much as had been hoped in the rationalization strategy. But it did lead to the unintended consequences of major changes in ownership (Table 3-1) and substantial new investment in production capacity. The latter could have opened the way to considerable learning and innovation in production, as well as to the creation of local supplier firms. However, this did not happen. The evidence suggests that the policies targeted automobile assemblers and gave no consideration to the integration of auto parts suppliers into the production chain. Moreover, the policies never explicitly targeted learning and capacity building in the industry, instead aiming at employment and BoP issues.

After the submission of investment plans, 10 out of 18 firms were “approved” to continue in operation. As expected, Ford, GM and International Harvester were selected. The seven other firms were: DINA, Promexa, Vehiculos Automotores Mexicanos (VAM), Fábricas AutoMex, Representaciones Delta, Planta Reo de México and Impulsora Mexicana Automotriz (MIB 1991). The first column of Table 3-1 presents all firms “approved” by the 1962 Automobile Decree.

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difference in these measures had strong effects on the capabilities developed by the industry in these countries. In the 1980s, when the industry shifted towards lightweight energy saving materials, the Brazilian industry was pushed into the use of heavy materials due to its regulations on local content requirements. Similar experiences were found in Argentina and South Africa (Kagami, Humphrey and Piore 1998; Barnes and Kaplinsky 2000). The fact that Brazil continued to use heavy materials was bad for its industry in the long run. It was more costly to produce and export heavy cars – which consumed more gasoline – not to mention that Brazil was not producing the latest models of the industry. Consequently, Brazil manufactured autos exclusively designed for the Brazilian market and old models no longer produced in developed countries – because the new models were based on lighter materials, they were not produced in Brazilian plants – leaving Brazilian cars at a disadvantage in the export market. Brazil built capacity in supporting industries such as steel. However, these types of capabilities did not fully match the requirements of an industry that was globally changing and demanding other sorts of knowledge and skills. The Mexican way of measuring local content provided greater opportunities for learning and TC building because it was based on the same models – and technological requirements – of the industry globally. However, the institutional setting prevented the Mexican auto parts industry from building the required TC.

Table 3-1 Ownership Evolution of the Mexican Automobile Industry, 1962-1964

1962		1964	
Firm	Ownership Status	Firm	Ownership Status
Foreign-Owned		Foreign-Owned	
Ford	100% foreign-owned	Ford	100% foreign-owned
General Motors	100% foreign-owned	General Motors	100% foreign-owned
Int. Harvester	100% foreign-owned	International Harvester	100% foreign-owned
		Volkswagen	100% foreign-owned
		Nissan	100% foreign-owned
		VAM	60% foreign (AM)/ 40% by the government
Nationally Owned		Nationally Owned	
Promexa	100% domestic/private	Fábricas AutoMex	33% foreign (Chrysler), 67% domestic
VAM	100% domestic/private	DINA	100% domestic (state-owned)
Fábricas AutoMex	100% domestic, licensed by Chrysler	FANASA	100% domestic/private
DINA	100% domestic (state-owned)		
Impulsora Mexicana Automotriz	100% domestic/private		
Planta Reo de México	100% domestic/private		
Reps Delta	100% domestic/private		

Source: Elaborated by the author with data from Bennett and Sharpe (1979, 1980, 1985).

The 1962 decree stipulated that in order to operate in Mexico, firms should manufacture their products in Mexico. Therefore all "approved" firms started to build or buy assembling plants.
Ford also built a second assembly plant in 1964 at Cuautitlán (20 miles north of Mexico City), which included a V-8 engine plant and an engine casting plant.[46] The plant in Cuautitlan started to assemble vehicles in 1969.[47]

GM built a plant manufacturing engines in Toluca. It started producing V-4 and V-8 engines in 1964 (MIB 1991).

International Harvester stopped producing light trucks and vehicles internationally in 1975.[48]

[46] This was a high level of technology for a developing country's auto industry in 1964.
[47] Ford purchased the ex-Studebaker plant and converted it into a specialized tooling factory, seeking to supply its manufacturing plants worldwide.
[48] It changed its name to Navistar and specializes in medium and heavy trucks and mid-range diesel engines.

Promexa bought out the assembling plants of Automóviles Ingleses in Xalostoc (40 miles away from Mexico City) and the plant of Automotriz O'Farrill in Puebla (70 miles away from Mexico City). It assembled Volkswagen Werke (VW) vehicles for 2 years. Then in 1964, VW bought Promexa, and SIC passed to VW the import quotas authorized to Promexa without major objections (MIB 1991).

Vehiculos Automotores Mexicanos (VAM) had its own assembly plant (built in 1953) in which it assembled Jeeps. It also assembled Austins, Datsuns (from Nissan) and Peugeots. In the 1960s, it added models from the American Motors Corporation (AMC) and Keizer Industries (KI) to its assembling lines. By 1964, AMC and KI bought 40% of VAM's shares (Bennett and Sharpe 1985).

Fábricas AutoMex operated under a Chrysler license dating from 1938. By the late 1950s, it had a complete Chrysler line, with models such as Valiant, Plymouth, Dodge, DeSoto and Chrysler. It also produced Simca (owned by Chrysler) and Fiat at its plant in Lago Alberto, in Mexico City. In 1959, Chrysler bought a third of the stock of Fábricas AutoMex (Bennett and Sharpe 1985).
The ownership status of Fábricas AutoMex did not allow it to compete with foreign firms. Even though the prices of vehicles were held at the same level as those of other firms, Fábricas AutoMex had much higher production costs. Chrysler was not willing to sell parts to its partners at the same price that it did to its other subsidiaries, forcing Fábricas AutoMex to sell 45% more in shares to Chrysler.

Representaciones Delta manufactured Auto Union and DKWs. It also got a special quota – due to a presidential favor – to import Mercedes-Benz. Representaciones Delta opened a plant to produce DKW engines in León, Guanajuato. However, a year later the plant was closed due to its lack of technical and managerial know-how. Its import permits were gradually rescinded, and by 1965 all operations stopped.

Planta Reo de México also ceased operations because of managerial problems in 1963. Nissan asked SIC for authorization to substitute Planta Reo de Mexico with a Nissan plant. SIC argued against Nissan's petition, saying that the market was already saturated with too many assemblers. However, the Japanese government used Mexico's dependence on its cotton imports (about 70% of Mexico's exports of this commodity) as a bargaining tool to secure SIC's approval of Nissan's request (Noticias 1964). By late 1964, Nissan received approval from SIC and started operating in Mexico (Bennett and Sharpe 1985; MIB 1991).

Impulsora Mexicana Automotriz bought the closed Borgward plant in Bremen, Germany. Due to financial problems, it changed its name to Fábrica Nacional de Automoviles (FANASA) in 1963. Then difficulties in setting up its production plant in

Monterrey delayed its start of operations until 1967. FANASA manufactured the only complete Mexican automobile,[49] but it was unable to keep operating, and by 1969 it was taken over by DINA.[50] With the closure of FANASA's operations, the most significant effort to promote a complete Mexican automobile industry also disappeared (Bennett and Sharpe 1985).

Two years after the 1962 decree's approval, the terminal industry underwent a dramatic change in ownership. Table 3-1 presents the status of the terminal industry at the moment when the decree was published (1962) and the ownership status of terminal firms 2 years after it was implemented (1964). Higher foreign ownership in the terminal industry exposed the auto parts industry to higher organizational and technological demands.[51]

B. Shift to an Export-Led Strategy – The 1972 Automotive Decree

By 1967, it was evident that most domestic automotive firms were inefficient, had higher costs and made products that did not meet international quality standards.

Terminal firms' development teams, in dealing with the few existing national parts suppliers, insisted to SIC on the importance of adopting the quality control (QC) standards prevailing internationally. It was not until the early 1970s – due to pressure from Ford (which had already started to develop a strategy of global supply) – that SIC agreed to adopt the standards of the Society of Automotive Engineers

[49] Attempting to capture the market left by Mercedes – held previously by Impulsora Mexicana Automotriz – FANASA produced the most expensive model of the Borgward line – with no more than 3,000 vehicles sold per year. The cost of production of each Borgward was around 100,000MXP. Each vehicle was sold to dealers for 44,000MXP and then to the public for 55,000MXP. The remaining 56,000 was financed by the government with a credit to FANASA.

[50] Gregorio Ramírez (owner of FANASA) abandoned the firm to his creditor, SOMEX, in return for a note absolving him of any further debt in 1969.

[51] This phenomenon of denationalization was not unique to the Mexican auto sector. A similar situation took place in the Brazilian automotive industry. From the original six assemblers in 1962, the number of firms in the Brazilian terminal industry rose to 11 by 1965 – Fábrica Nacional de Motores, Ford, GM, International Harvester, Mercedes Benz, Scania, Vabis, Simca, Toyota, Vemag, VW and Willys Overland. However, the rapid increase in vehicle models, the limited purchase power parity (PPP) of the market and high local content requirements resulted in the underutilization of established plant capacity, along with inefficient and expensive production. These conditions, in addition to the austerity program following the military takeover in 1964, contributed to the shutdown of four of the original automobile producers in Brazil. By 1968, all Brazilian-owned firms passed to foreign control (Mericle 1984; Morales 1994).

The South African automotive industry also transitioned in the late 1990s from a domestic-owned and controlled assembly industry – where firms operated through franchises with MNCs – to a foreign-owned industry, in which MNCs took a majority of shares and managerial control of the industry (Barnes and Kaplinsky 2000).

(SAE). QC was probably the only effort that encouraged learning and innovation in the sector at that time. SIC's agreement to adopt international QC standards was not explicitly supported by any public policy focused on learning and capacity building in the auto parts sector.[52]

In a series of studies, Bennett and Sharpe (1979, 1980, 1985) present a historical review of the auto parts sector that documents its struggle for survival in the early 1970s.

Table 3-2 presents the changes in ownership that the terminal industry underwent from 1964 to 1975.

Table 3-2 Ownership Evolution in the Mexican Automobile Industry, 1964-1975

1964		1975	
Firm	Ownership Status	Firm	Ownership Status
Ford	100% foreign-owned	Ford	100% foreign-owned
General Motors	100% foreign-owned	General Motors	100% foreign-owned
International Harvester	100% foreign-owned		
Volkswagen	100% foreign-owned	Volkswagen	100% foreign-owned
Nissan	100% foreign-owned	Nissan	100% foreign-owned
VAM	60% foreign (AMC)/ 40% by the government	VAM	60% foreign (AMC)/ 40% by the government
Fábricas AutoMex	33% foreign (Chrysler) 67% domestic	Fábricas AutoMex	78% foreign (Chrysler) 22% domestic
DINA	100% domestic (state-owned)	DINA	100% domestic (state-owned)
FANASA	100% domestic (private)		

Source: Elaborated by the author with data from Bennett and Sharpe (1979, 1980, 1985).

The new ownership conditions in the terminal industry brought about by the 1972 decree affected auto parts firms with foreign equity more than the Mexican-owned firms. These authors report that by 1975, about 40 auto parts firms were exporting,

[52] It was not common outside Japan in the 1960s and 1970s to focus explicitly on building learning linkages between terminal firms and parts suppliers. In Canada, such linkages started to be encouraged in the late 1980s through R&D partnership programs run by academic granting councils. One of the first of these involved a partnership between professors from one of the local universities in Quebec (Sherbrook) and the then-manufacturer of trains, Bombardier. It involved both actors in developing a training program for parts suppliers, who would make parts for snowmobiles and upgrade to some parts for trains, and who, with their higher skills and quality, could also subcontract for work from other companies in Quebec and Ontario during off-seasons. The motivations for Bombardier to engage in this program were (a) the need for higher overall quality in their efforts to sell globally and (b) the cost of training suppliers, only to have them leave to work for others in off-seasons and not come back. So they wanted to develop a program that included opportunities for wider use of their skills and kept them loyal to Bombardier.

and that three of these, TREMEC-Clark Equipment (41.7% foreign-owned), Equipo Automotriz Americana (15.3% foreign-owned) and Rassini Rheem-Rheem International (13.2% foreign-owned) accounted for about 70% of total auto parts exports. This suggests that the Mexican auto parts industry was not producing with the quality and specifications required for the industry at the international level in the 1970s.

The competitive disadvantages of the domestic terminal firms (i.e., weak networking, lower production volume – linked to lower technological and quality levels) and the employment pattern of the industry, in addition to the rise of imports in the sector (affecting the BoP situation) motivated a shift in policy in the industry that sought to increase exports rather than to reduce imports.

In an attempt to solve the BoP problem, which was the main objective of public policy, the government shifted to a new industrial strategy that was more export-oriented. This strategy provided for a transition period in which the government made an effort to foster exports. In 1979, the Mexican Institute for Foreign Trade (IMCE) was created. The IMCE implemented a system of export subsidies certificates called CEDIs, which played a key role as trade instruments during the first stage of the liberalization process. In 1972, the Fund for Industrial Equipment (FONEI) was created to finance export-oriented activities.

As early as 1968, the Mexican Central Bank (Banxico) was seriously concerned about the rising BoP deficit. Banxico created a trust fund with contributions from other governmental agencies to promote the merger of auto firms in the market. It believed that rationalizing the models and increasing the production volume per firm would increase levels of local integration, contributing to reducing imports and solving the BoP situation.

Three proposals were submitted to the government. The first one, by Fábricas Automex and Chrysler, suggested a merger with VAM, FANASA and DINA into a single Mexican majority-owned company affiliated with Chrysler. The proposal planned to increase domestic production, reduce imports and increase production efficiency by replacing the models being manufactured by these four firms with models from Chrysler.[53] Even though VAM, FANASA and DINA were mentioned in this proposal, they were never consulted about it or even called to participate in the proposal elaboration. Therefore, these three firms presented their own independent proposals to Banxico (Bennett and Sharpe 1985).

[53] The Renault R-4 (by DINA) would be replaced by Chrysler's Simca, and the Borgward (by FANASA), the Rambler and the Jeep (by VAM) would all be eliminated. The only condition in the proposal imposed by Chrysler was to have management control through a minority of shares.

The second proposal to Banxico was submitted by DINA and Renault in 1969. It proposed a merger with the other domestic firms (VAM, FANASA and possibly AutoMex – this last one was not consulted). The government would have majority ownership and AMC, Renault and Chrysler would have minority shares. The new firms would manufacture models from the three foreign firms and would replace the Borgward (by FANASA) with Jeeps and pick-up trucks. The emphasis in this proposal was on the maximization of production volume rather than models (Bennett and Sharpe 1985).

A third proposal was presented by VAM and AMC, but the technical committee organized by Banxico did not consider it.
Banxico established a technical commission to analyze the proposals. The committee was composed of SIC, SHCP, SPN and NAFIN. Once again, neither the CTM nor the auto parts firms were invited for consultations.

The technical commission – especially SHCP – accepted the proposal submitted by Fábricas AutoMex and Chrysler. However, before the resolution was made public, Ford – supported by SIC – submitted another proposal suggesting an export plan in which each terminal firm would be required to compensate for its import quotas with a steadily rising percentage of exports.[54] The expected results were that eventually each firm would export as much as they imported.

After a series of consultations, the president (advised by Banxico) selected the export plan presented by Ford. The rationale behind this decision was that the export plan offered shorter-run BoP effects than the merger plans suggested by the other two proposals.

The export agreement stated that each terminal firm had to balance its imports of parts and components with an increasing percentage of exports. Of the percentage of exports, manufactured products from the terminal firms themselves would account for 60% of their required export quota and the other 40% would come from exports by their suppliers. This type of exports is known as “indirect exports” and they are exports generated by auto parts suppliers and not by the terminal industry itself. The export agreement was formalized in 1972 in a second automotive decree. The 1972 decree aimed to make significant improvements in the industry and more specifically to contribute to improving the BoP. The export obligations (30% of imports) were only met in 1973 and in no other year.

[54] In 1970, firms were required to export at least 5% of their imports to maintain their basic import quota. This percentage was to rise to 15% in 1971 and to 25% by 1972.

Between 1964 and 1975, the number of Mexican-owned terminal firms continued to decline and the preference among foreign-owned terminal firms was to acquire parts from their subsidiaries. This preference of foreign-owned terminal firms to acquire parts from their subsidiaries rather than from independent Mexican suppliers was an important factor in shaping the pattern of behavior developed in the assembler-supplier relations of the industry. [55] Table 3-2 shows the changes in the industry over the decade 1964-1975.

C. The Further Denationalization of the Industry – The 1977 Automotive Decree

The export requirements contained in the 1972 decree were only fulfilled in a single year – 1973. Under these conditions, the country's BoP did not improve and the levels of local integration of the industry were not achieved.

In 1973, SIC called the terminal firms to discuss a new automotive decree. For the first time, the two auto parts manufacturers associations were invited to participate in the discussions: the National Association of Manufacturers of Automotive Products (ANFP)[56] and the Mexican Association of Manufacturers of Automotive Parts (AMPPA). The National Chamber of Manufacturing Industries (CANACINTRA) was also invited for the first time to participate in the decision-making process.

CANACINTRA argued with SIC that if the terminal industry would acquire only parts that were domestically produced – and stop importing them – then higher levels of local integration could be achieved. This would allow the auto parts industry to gradually modernize towards the required international standards (CANACINTRA 1976). Convinced by CANACINTRA, the government increased the level of local content requirements to 80%.[57] The reaction of terminal firms to this initiative was two-fold. On the one hand, Ford, GM, Chrysler and Nissan defended the previous scheme presented by the 1972 decree. On the other hand, DINA, VAM and VW favored the new proposal.

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[55] Mytelka (1978) shows that the state-owned firms in the Andean group behaved no differently from the private/foreign firms when it came to the issue of choosing to develop their own products or buy in the technology. The change in behavior came years later.

[56] On June 23rd, 1981, ANFPA changed its name to the National Auto Parts Industry Association (INA).

[57] CANACINTRA administered a questionnaire to 225 firms from both ANFPA and AMPPA. The survey asked them to detail which additional components they could supply to the terminal firms. Based on their responses, CANACINTRA estimated that by 1977 the auto parts industry could achieve 69.2% local content by taking advantage of the existing capacity. CANACINTRA also forecasted that by 1978 about 74.6% local content integration could be achieved by making only small investments in used technology and facilities.

In June 1977, a third automotive decree called Decree for the Promotion of the Automobile Industry was promulgated without much discussion (SECOFI 1977). It attempted to ensure employment, increase production efficiency through economies of scale and reduce the increasing trade deficit of the industry.

The new decree assigned to the government the power to decide the number of models produced by the terminal industry and the amount of foreign currency available to firms to import. It presented two alternatives to terminal firms. The first was to increase exports, and the second was to increase local content integration.

The main elements proposed by the decree were: 1) terminal firms would have to increase their exports steadily over the next 5 years until trade deficits were eliminated. Firms would have to compensate with exports – including indirect exports (i.e., exports from their parts suppliers) – for: i) their imports, ii) their foreign payments (i.e., technical assistance, insurance, replacement parts for dealers) and iii) the percentage of imported content included in the parts used. 2) Mexican-owned firms (*DINA* and *VAM*) would receive special protection due to their higher exporting difficulties. 3) Local content integration should increase to 80%. 4) Price controls should be eliminated from the industry.

Existing production plants were based on previous manufacturing specifications and did not allow the terminal industry to fulfill the new export requirements. In addition, the parts suppliers did not increase their exports – probably due to the lack of capabilities – even though they had received higher levels of fiscal subsidies since 1962. Therefore, as in the previous decrees, the 1977 decree did not achieve its trade goals.

Immediately after the promulgation of the decree, the Mexican government was confronted by the U.S. government, which expressed its concerns regarding the implications of the new regulation on trade, investment and labor. The U.S. Commerce Department and the U.S. Labor Union were concerned about a possible relocation of U.S. automotive plants to Mexico. The U.S. Treasury Department was troubled about a massive increase of exports from Mexico to U.S. firms, taking advantage of diverse export and fiscal incentives given to U.S. firms. The U.S. Department of State worried about the impact of the Mexican regulation on the jobs of U.S. employees. The U.S. Bureau of Economic Affairs and the U.S. Office of International Finance and Development were concerned about investment opportunities for U.S. firms rather than about trade issues.[58] Due to the complexity of the bilateral

[58] The lighter export burden for domestically owned firms (DINA and VAM) and the exclusion of foreign-owned ones from diesel-truck manufacture in the decree were taken as examples of discrimination against U.S. investors.

relationship between the U.S. and Mexico, a consultative mechanism was created to deal with the new automotive policy.

In November 1977, GM broke the "coalition" agreement with other terminal firms by announcing its investment program oriented to generate enough export volume to comply with the decree.
After this announcement, the other terminal firms started to announce their own investment plans, disintegrating the coalition.

In 1978, GM also announced plans to build four production plants: one for assembling operations, one to manufacture engines and two more to produce parts for engines (AMIA 1979).

Ford and VW planned to expand their production capacity for domestic and export production (AMIA 1979).

Chrysler opened a plant in Coahuila to produce V-4 engines.

AMC announced plans to export more manual transmissions to the U.S.

Nissan expressed its intention to increase exports of engine parts to Japan.

Ford negotiated several joint ventures with domestic industrial groups, such as with *Grupo Alfa* producing aluminum cylinder head castings, with *Vidrio Plano de Mexico* making automotive glass and with *Valores Industriales, S.A.* producing plastic parts.[59]

In 1982, Chrysler Corporation acquired AMC. Fábricas AutoMex sold the rest of its shares to Chrysler, and the VAM shares of AMC passed to Chrysler. When the terminal firms began to withdraw their initial opposition, the consultative mechanism fell apart. The U.S. enacted its new policy on illegal immigration and, mindful that a scarcity of jobs in Mexico would drive more illegal immigrants across the border in search of work, by 1978 the U.S. government stopped its pressure on the Mexican government.

D. The New Economic Model

In the early 1980s, Latin America shifted away from the ISI policy that the region had followed for the past 40 years. Strong macroeconomic imbalances forced the region to move towards a market liberalization strategy. In a special issue of *World*

[59] In each of these associations, Ford had minority equity but maintained a voice in management.

Development (2000), this strategy was coined the New Economic Model (NEM). The adoption of trade liberalization measures promoted by the NEM was not conceived in a long-term, structured plan but borne of a deep economic crisis in Latin America.

The NEM was therefore a child of necessity, implemented as part of the stabilization and structural adjustment programs of the IMF and the World Bank (WB) when no other route was left. It was based on "a strategy aimed at penetrating large and growing international markets on the basis of specialization and comparative advantage." In that strategy, "resource allocation [was] determined by the interplay of free and unregulated prices … [and] the private sector [was] the key agent of dynamism in the economy" [p. 1703] (Ramos 2000).

The NEM was strongly shaped by the 10 most significant demands imposed on Latin American economies by "the Washington Consensus" in the early 1990s: fiscal discipline, a change in public expenditure priorities (e.g., health care, education and infrastructure), tax reform, interest rate liberalization, a competitive exchange rate, trade liberalization, liberalization of inflows of foreign direct investment, privatization, deregulation and secure property rights.
In complying with these requirements, the NEM shifted industrial policies towards a horizontal orientation emphasizing training, credit for SMEs and scientific and technological infrastructure building. It also shifted technology policy in the direction of demand-driven instruments (Ramos 2000).[60]

The policy prescription under the NEM emphasized the free play of market forces as the only way to overcome the macroeconomic problems that plagued Latin America under the ISI model. The NEM promised to bring to the region a more efficient allocation of resources, which would then set the region on a sustainable growth path with a steady increase in per capita income. After more than a decade of its implementation, the real gains of the NEM in the region were still subject to political and theoretical debate. On the one hand, trade and financial liberalization brought the inflation rate down, increased the volume of non-traditional exports and contributed to the appreciation of the exchange rate. On the other hand, economic growth and productivity were not as large as expected. (See Table 3-3.)

[60] The automotive sector in Latin America was the exception to the rule. Under the ISI the sector was under heavy protection by the state, and under the initial phases of the NEM its protected status did not change considerably.

Table 3-3 Economic Evolution in Latin America: 1945-1998

	1945-80	1980-90	1990-1998
Inflation rate (%)	20	> 400	> 1200 → 10
Export growth (volume/year)	2.1	4.4	8.8
Growth of GDP (yearly) (%)	5.6	1.2	3.5
Productivity growth (GDP/worker)	3.1	-1.8	1.0
% poor	> 50 → 35	35 → 41	41 → 38

Source: Cited in Ramos (2000, 1705).

Under the NEM, Latin America undertook the massive privatization of public monopolies (e.g., telecommunications, energy and financial institutions) built during the ISI period, reducing the size of the state, based on the belief that eliminating subsidies and opening the market would lead to more competition and that this would stimulate firms to become more efficient in order to survive. The manufacturing sectors of the region were substantially restructured in an effort to incorporate them into export activities, especially industries such as apparel, electronics and automobiles (Ramos 2000).

Larger firms that had developed export markets were the only kinds of firms that were able to become more efficient under the new competitive conditions created by the rapid opening of domestic markets. Smaller local firms that had not engaged in learning and innovation processes did not have the time nor resources to undertake the kinds of changes needed to compete and thus were generally driven from the market.

Ramos (2000) mentions that the industrial structure of Latin America under the NEM was characterized by the entry of Multinational Corporations (MNCs) into those industries where old public monopolies or conglomerates had been traditionally dominant. These industries gradually became today's export leaders, while traditional and non-exporting industries consist mainly of domestic SMEs with poor learning and economic performance (Reinhardt and Peres 2000).

In the Mexican case, the privatization process was intensified during 1988-1994 (OECD 1994).[61] By the end of 1992, only 217 enterprises out of 1,155 that existed in 1982 remained state-owned, while the rest were privatized or shut down (Fernandez 2000).

[61] This consisted of selling public enterprises, such as: TELMEX (telecommunications); the commercial banks (nationalized in 1982); ASEMEX (the largest Mexican insurance company); CANANEA (copper mining) and airlines (Aeronaves de México and Mexicana de Aviación).

E. The Development of the Auto Industry Under the NEM

In 1978, Mexico discovered large oil reserves and launched a new wave of heavy public expenditures, financing them with foreign loans on oil guarantees (OECD 1994; Fernandez 2000). This injection of money into the economy resulted in a strong increase in the inflation rate and a higher current account deficit. When in 1981 the oil prices collapsed, the BoP deficit became unsustainable, forcing the implementation of a stabilization program by the IMF that combined public sector austerity with trade liberalization measures.

In an attempt to institutionalize the shift to an export regime, a new automotive decree was promulgated in 1983. This decree had important effects on the development of the industry because it explicitly created two industrial regimes. The first involved vehicles and parts whose final destination would be the domestic market. The second one covered all production and projects oriented to foreign markets. Both branches of the industry were regulated by different sets of rules. The first type of production was regulated by strong local content requirements and the second one by more relaxed local content and foreign ownership restrictions.[62] Although the industry was already oriented towards the domestic market, the 1983 decree institutionalized more flexible conditions for those firms exporting to foreign markets.

The historical review suggests that the government could not shift its attention away from employment and the BoP deficit – a reflection of the macroeconomic situation of the country at that time. However, it also made no efforts to put into place explicit policies to stimulate or support learning and innovation in the industry. Under the 1983 decree, once again, the auto parts sector was not explicitly targeted with programs that would help it to build the necessary capabilities to integrate into the exporting production chain, which required higher quality and technological mastery. Without this type of explicit investment, it is not surprising that the auto parts sector did not integrate fully to the export-oriented production market.

In 1989, the last automotive decree was issued, setting the auto industry on a liberalization course. The 1989 decree proposed to integrate the domestic auto industry with the global auto industry through exports and through the gradual elimination of protection from external competition.

[62] The same division took place in Thailand in the textile industry and led to difficulties for the Thai industry in developing domestic backward and forward linkages, which ultimately weakened its exporting industry. For more, see the chapter on Thailand in Ernst, Ganiatsos and Mytelka (1998).

The 1989 decree kept the distinction between production for domestic and foreign markets as stated in the 1983 decree. This decree allowed passenger vehicles and light trucks to be imported by terminal firms and reduced local content requirements for domestic market production to 36%. The decree also withdrew all ownership requirements from the industry.

In 1989, only foreign-owned terminal firms operated in Mexico, namely Ford, GM, Chrysler, Nissan, VW and Renault.[63]

The last step in the process of Mexico's trade liberalization was the proposal in 1991 to establish a North American Free Trade Agreement (NAFTA) with Canada and the United States. The NAFTA went into force in 1994, and the following year, Mexico's automobile industry legislation was modified to conform to NAFTA regulations (see Appendix – Chapter 3 in the appendix to this chapter).[64] NAFTA brought about a number of important structural changes in the Mexican automobile industry. The most important structural change was the abolishment of the production divide between domestic and foreign-oriented production, institutionalized under the 1983 decree. The second, more important change was to progressively end the local content protection that enabled local inefficient firms to continue to sell in the domestic market (where all terminal firms were already foreign-owned).

NAFTA's entrance into force unified automotive manufacturing into a single production sector, with the same regulations for both export and domestic market production. Consequently, since NAFTA the Mexican industry has been required to produce at the quality and technology levels required internationally – requirements that the terminal industry has gradually imposed on its suppliers.

Since 1994, Mexico has joined different trade organizations and signed diverse FTAs with several regions in the world, further exposing Mexico to international requirements and manufacturing standards. Table 3-4 presents the FTAs signed by Mexico since 1994. Although each of these agreements represents a higher level of exposure for Mexico to global conditions and requirements, NAFTA is the FTA with the strongest impact on the Mexican Economy (INEGI 2003).[65]

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[63] After DINA was acquired in 1989 by the Mexican Consortium G, its production focus shifted to buses and heavy trucks.

[64] The 1995 decree reduced to zero the national added value required in vehicles and parts produced in Mexico over a period of 10 years – for the auto parts industry and for the national suppliers from 30% to 20%, and for the assemblers from 36% to 0% by 2004. The content required from Canada, the U.S. and Mexico (called regional content or NAFTA content) was increased from 50% in 1995 to 62.5% in 2004.

[65] According to the National Institute of Statistics (INEGI), during the period of analysis of this thesis (i.e., 1993-2003) about 90% of Mexican exports in technology products were going to the U.S. Imports of these types of goods grew from 58% in 1994 to 70% in 2000.

This process of liberalization in the Mexican market brought new actors and relationships into the system of innovation. With the total denationalization of the terminal industry in the late 1980s, domestic actors were no longer in charge of the decision-making processes, as foreign firms began to play an increasingly relevant role.

Table 3-4 Free Trade Agreements Signed by Mexico

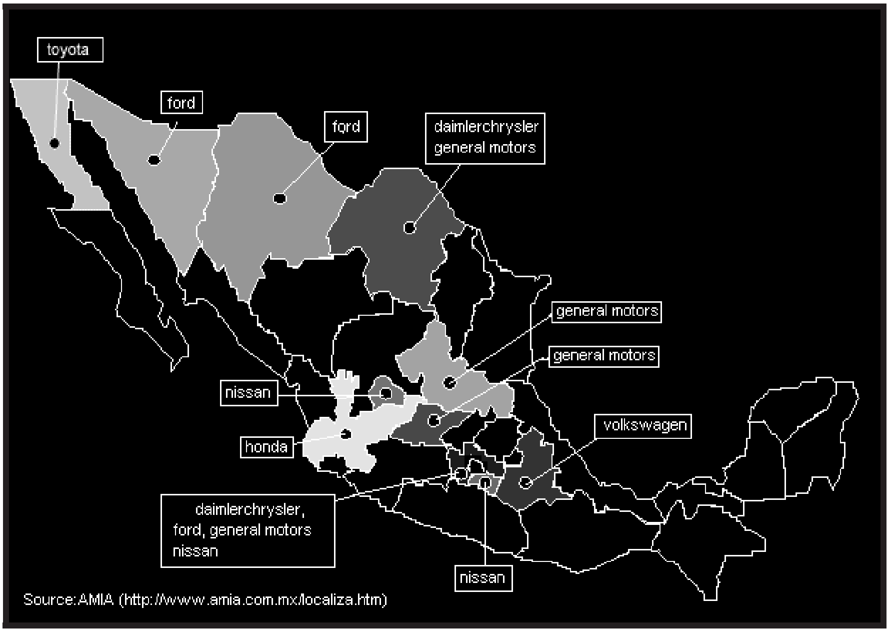
Free Trade Agreement (FTA)	Commercial Partners	Year
FTA with North America (NAFTA)	United States of America and Canada	1994
FTA with G3	Colombia and Venezuela (valid till Nov. 2006)	1995
FTA with Costa Rica	Costa Rica	1995
FTA with Bolivia	Bolivia	1995
FTA with Nicaragua	Nicaragua	1998
FTA with Chile	Chile	1999
FTA with the EU	European Union	2000
FTA with Israel	Israel	2000
FTA with Central America	El Salvador, Guatemala and Honduras	2001
FTA with AELC	Iceland, Norway, Liechtenstein and Switzerland	2001
FTA with Uruguay	Uruguay	2004
Economic Association Agreement with Japan	Japan	2005

Source: Ministry of Economy (http://www.economia.gob.mx).

By 2006, there were 13 terminal firms affiliated with the Mexican Automobile Industry Association (AMIA). However, only seven of these firms conduct manufacturing activities – namely Ford, GM, DaimlerChrysler, VW, Nissan, Toyota Motor and Honda. The rest are commercial representations that import assembled vehicles for sale in the Mexican market (i.e., BMW, Fiat, Peugeot, Renault, Subaru and Suzuki Motor).

See Figure 3-1 for the geographical location of automotive assembling plants in 2006.

Figure 3-1 Assembling Plants in Mexico (2006)



3.4 Summary

In the 1980s, Latin America went into a strong macroeconomic crisis that led to structural changes in the market. In order to survive the new competitive economic environment, firms were forced to undertake substantial changes and investments in a short period of time (Macario 2000a). During this period, there were three main changes that took place at the firm level. First, firms' performance varied according to their nature and size. Second, firms linked to international markets took the lead under the new market conditions. Third, the development of endogenous technological capabilities and the establishment of linkages with knowledge actors were weakened (or not developed at all) under the new economic scenario (Alcorta 2000; Dijkstra 2000; Macario 2000a; Reinhardt and Peres 2000). The findings of this research – presented in the following chapters – corroborated these three results.

In the case of Mexico, the implementation of NAFTA institutionalized a change in market conditions towards a liberalized economy. Mexico never implemented policies to build capabilities in the machine tools industry before opening its industry to global competition. It was assumed that the industry would develop itself with the integration of local content in the production process.

Chapter 3 shows that learning was never explicitly considered by the Mexican government as a process that requires time and efforts to be internalized by firms, and therefore no technology policy was ever implemented. Consequently, supporting automotive industries were never strongly developed, and imports of raw materials and technology assumed increasing importance in the evolution of the industry (see Chapters 6 and 7).
This reminds us of the importance that traditional habits and practices play in the development of the industry. As Mytelka and Barclay (2004) demonstrate, past habits and practices – developed under ISI – are what shape firms' learning and innovation capacity. As firms are able to modify these informal institutions, they will be able build the innovation capacity needed to face new market challenges and move forward towards higher performance and competitiveness levels.[66]

Polices and practices that shaped the development of the auto industry – and which this chapter describes in detail – are elements of particular relevance in this research. These institutional aspects are important elements of the SI – particularly in developing countries – because they shape the way policies that build learning and innovation capabilities are constructed (or destroyed).

Auto policies helped to create habits and practices that did not encourage local firms to expend the effort to develop their capabilities for learning and innovation or even to engage in the mastery of techniques and technologies (e.g., quality control) that would make them more efficient producers. Unrealistic expectations in the absence of complementary policies supporting a process of learning and innovation in the auto industry, as well as the lack of enforcement and coherence (characterized by constant policy changes), determined the interaction between actors in the system and shaped the learning and technological capability habits and practices of the industry.
The historical background presented in this chapter helps us to understand the evolving roles of different actors over time in the development of the industry. This chapter pays special attention to the role played by traditional habits and practices (and changes in them) as an important idiosyncratic element of the SI of the Mexican automotive industry. The chapter establishes the routines and institutional learning that characterized the system. This issue is revisited in our final chapter (Chapter 8), where the micro-level findings of Chapters 5, 6 and 7 are analyzed under the umbrella of the SI approach, offering a richer view of the interaction and behavior of the whole system and allowing us to explain the sector's performance by going beyond a firm-level perspective.

[66] The empirical work presented in the following chapters illustrates how firms holding onto their old organizational, learning and technological habits and practices perform less efficiently than those that have been able to modify them according to the new market needs.

3.5 Appendix – Chapter 3

Table 3-5 Transition Scheme Established by NAFTA for the Automobile Industry

	Decree (1989)	NAFTA										
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Required added-value												
Auto parts suppliers*	30%		20%									0%
Automobile assemblers	36%		34%				33%	32%	31%	30%	29%	
Required trade balance for auto assemblers	100%	80%	77.2%	74.4%	71.6%	68.9%	66.1%	63.3%	60.5%	57.7%	55%	0%
Taxes on 10 year-old imported automobiles	20%	10%	9%	8%	7%	6%	5%	4%	3%	2%	1%	0%
NAFTA content requirements	–	–	50%	51.4%	52.8%	54.2%	55.5%	56.9%	58.3%	59.7%	61.1%	62.5%
Maquiladoras allowed domestic sales	20%	55%	60%	65%	70%	75%	80%	85%	100%			

Note: *Includes auto parts firms classified officially as Auto Parts Industry or as National Suppliers.
Source: Mexican Trade Commission (Bancomext 2000, 2004)

Chapter 4

The Mexican Auto Parts Industry and Global Automobile Production Tendencies

Abstract

This chapter analyzes the changing characteristics of the global auto industry. It presents technological characteristics at the firm level in the auto parts industry during the NAFTA transition period (1993-1995). The chapter then looks more closely at firm level characteristics, local content integration and networking features of the sample analyzed in the following chapters. It provides the intersection between the changing production characteristics of the global automotive industry and the restructuring of the Mexican auto industry under NAFTA.

4.1 Introduction

In 1991 the governments of Mexico, the United States and Canada started negotiations to establish a North American Free Trade Agreement (NAFTA). NAFTA has been in force since 1994 and has marked an important difference between the process of trade liberalization in Mexico and that of the rest of Latin America. NAFTA was expected to provide a competitive advantage for Mexico in terms of trade due to the country's lower wages and to the geographical proximity between Mexico and the U.S. – the main commercial partner of the region.

Due to its economic importance in the Mexican economy, the automobile industry had always received special treatment through tailor-made policies and local content programs (i.e., automobile decrees) aimed at creating incentives for exports. Under NAFTA, the automobile industry also received special consideration. A fixed time frame of 10 years was established, during which a gradual process of deregulation would take place. This, it was assumed, would allow time to build the necessary capabilities to bring automotive production up to international standards (see **Table 3-5** in the appendix to Chapter 3). This thesis argues that the institutional setting and the interaction between earlier habits and practices in the Mexican auto industry, as well as technological and organizational changes in the global automobile industry in the context of an increasingly open market, prevented this from happening in the auto parts sector in Mexico.

This chapter looks in more detail at the global reorganization of the auto industry that began in the early 1980s and then moves on to analyze the initial response of the Mexican auto parts sector. The structure of the Mexican auto parts industry at the beginning of the NAFTA period is presented, based on empirical findings from two auto parts studies realized in the immediate NAFTA years by Jasso and Torres (1998) and JICA (1996). The chapter also introduces the pre- and post-NAFTA data used in the empirical analyses of Chapters 5 to 7 and provides empirical analysis on the linkages and networking of the auto parts firms with knowledge centers before and under NAFTA.

4.2 Automobile Firms' Classification

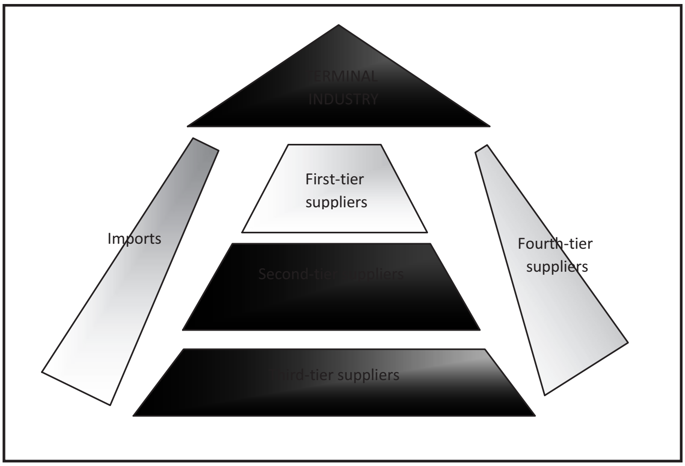
The automobile industry organizes its suppliers in tiers according to the levels of complexity of the products they produce. Figure 4-1 shows the present structure of the automobile industry as a pyramid. The terminal industry is the apex of the pyramid, followed by different tiers of auto parts producers. This industry manufactures automobiles and sells them to both domestic and foreign markets. Following the pyramidal structure, three different tiers of automotive producers are found under the assemblers.

First-tier suppliers are those at the top. There is a continuous information flow among assemblers and first-tier suppliers on the quality, price, technology and level of achievement of the parts produced by the supplier. They master the technology, but the involvement of the assembler is necessary since it is the last actor who coordinates and ensures technological coherence among the diverse modules and their integration in final automotive production (Pavitt and Soete 1980; Dosi, Teece and Winter 1992).[67]

Next in line in the structure are the so-called *second and third-tier suppliers*. These segments are formed basically by domestic SMEs. Imported parts and components supply inputs to all the tiers in the pyramid, including the terminal industry. Second and third-tier suppliers are normally directly related to first-tier suppliers, but their relationship with the assemblers is almost non-existent – except in the case of some components that are integrated in the final phase of automobile assembling (Alaez, Bilbao, Camino et al. 1996; Lara Rivero, Trujano and Garcia Garnica 2004).

Complementing the pyramid we also find the *fourth-tier suppliers*, commonly known as the *supporting industry*. These are firms whose core production specialization is located outside the range of the automobile industry.

Figure 4-1 Graphic Representation of the Automobile Industry



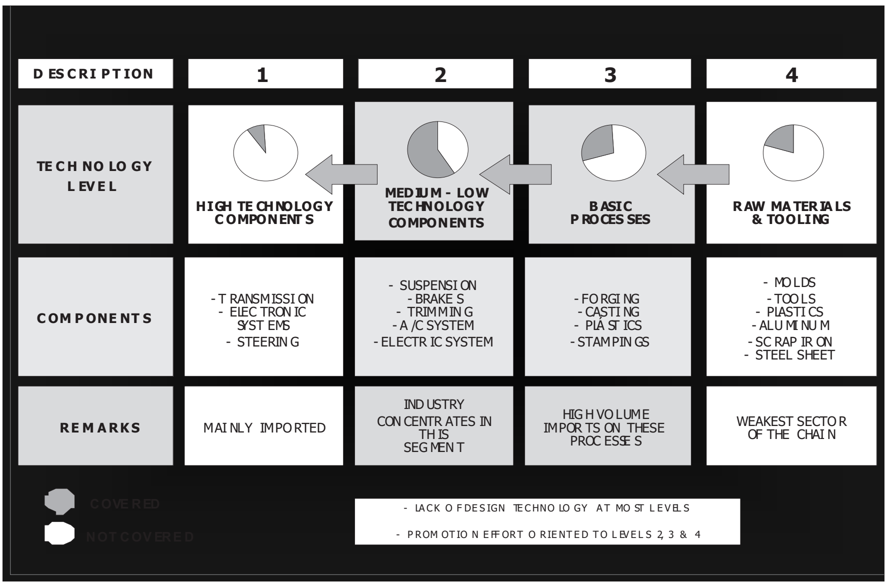
[67] An illustrative example is the role of Johnson Controls Inc., which assembles plastic dashboards and mounts the instruments and delivers plug-in systems for DaimlerChrysler in the U.S.

The analysis in this thesis only covers tier suppliers manufacturing the six core auto parts classified into the core automobile categories of the CMAP (as specified in Chapter 2):

a) Manufacture and assembly of bodies (384121)
b) Manufacture of engines and their parts (384122)
c) Manufacture of power train systems, parts and components (384123)
d) Manufacture of suspension systems, parts and components (384124)
e) Manufacture of brake systems, parts and components (384125)
f) Manufacture of other [main] parts and components (384126)

Figure 4-1 illustrates the technological levels achieved in the Mexican automotive industry. Based on the division of parts and components mentioned above, Figure 4-2 reports the findings of Bancomext (2000), in which Raul Alfaro classifies these manufacturing activities by technological complexity levels.

Figure 4-2 Technology Levels Achieved in the Mexican Automotive Industry



Source: Bancomext (2000).

Raul Alfaro also mentions that there is a lack of design technologies at most levels in the industry (Bancomext 2000). Figure 4-2 shows that Mexican auto parts firms are mainly concentrated in medium-low technology activities (e.g., suspension and brake systems). Only a few auto parts firms produce high technology components; therefore, there are large imports of these products. There is also a high volume of imports of products requiring basic technological processes, such as forging, casting and stamping.

A. OEM and After-Market Suppliers[68]

There are two main groups of auto parts products: i) Original Equipment Manufacturer (OEM) or genuine parts manufacturers and ii) non-original parts manufacturers (i.e., spare parts or after-market parts).
OEM firms are those that are marketed under the brand name of the car manufacturer for whom the supplier operates and sells through its distribution channels. OEM parts and components symbolize the reliability of the car manufacturer, and these parts or components are the ones employed when the manufacturer's guarantee is required or when a vehicle is repaired in a manufacturer-associated workshop.
Genuine parts (e.g., pistons, steering mechanisms) are only available for a maximum of 7 to 9 years. They are expensive, involve more sophisticated technology in their production and have higher commercial margins.

After-market or non-original parts are generally those parts that require relatively frequent replacement (e.g., batteries, light bulbs, gasoline filters, spark plugs, tires). In general, spare parts are cheaper, have lower quality than original parts and are distributed by different market channels than the OEM parts.

The general analysis conducted in this thesis does not classify firms into OEM and non-original parts suppliers – however, the analysis in Chapter 7 covers only OEM firms and their characteristics. The research does not attempt to explore the changing supplier relationships in the automobile industry; however, it recognizes that it does have an important impact on the development and integration of the auto parts industry.

4.3 Main Global Production Trends of the Automobile Industry

The automobile industry is characterized by its constant restructuring – activity that with the globalization since the early 1990s has been particularly dynamic (Lamming 1993; Calabrese 2000).

An important change regarding production in the early 1990s is that the automobile manufacturers no longer own or produce all parts necessary to assemble a complete vehicle. The industry has become less vertically integrated by outsourcing not only parts and components but also processes (Economist 2002).
This outsourcing phenomenon has increased competitive pressures in the industry and triggered an accelerated process of concentration of assemblers. In the late

[68] This section is based on interviews with Raul Alfaro (Bancomext, The Netherlands), Ricardo Carrasco (Bancomext, Mexico).

1990s, massive mergers among the main assemblers took place. The takeover of Chrysler by Daimler-Benz resulting in DaimlerChrysler in 1998, followed by its alliance with Mitsubishi, is just one of such examples. Volvo was taken over by Ford. Renault established an alliance with Nissan in 1999, and Fiat and GM had a mutual exchange of capital stakes (Economist 2005). The effects of these changes have reached each supplying tier in the production chain and consequently have had strong consequences for the organization of processes, management and networks of the whole industry (Economist 2005).

The appearance of microprocessors brought remarkable changes in the production of automobiles. The introduction of Numerically Controlled Machine (NCM) Tools and Robots[69] in production moved the industry to a greater level of production flexibility (i.e., working with different shape designs, diverse batch sizes and several materials) and enabled the handling of delicate shape designs that conventional machine tools could not produce (Watanabe 1987). The incorporation of NCMs considerably reduced delivery times and inventories and assured stricter unitary cost controls.

There is no doubt that the new computerized and Information and Communication Technologies (ICT) play a key role in the production of automobiles. Emerging from previous mechanical paradigms, the incremental introduction of ICT in production, organizational and managerial processes brought a complete re-definition of the production system, relationships and networking among firms in this industry (Lung 2001; Mytelka 2003). The incorporation of microprocessors in NCM tools allowed for sophisticated process control and program editing on the shop floor. This system structure, known as Computerized Numerical Control (CNC), was important in reducing system dependence on large central computational facilities. This coupling of electronic functions with traditional mechanical engineering routines is what the literature calls *mechatronics*. It resulted in the use of relatively complex machinery with routines that tend to demand higher and specialized skills.
The implications for firms are two-fold. First, additional learning efforts are required to master the new electronic functions embedded in mechatronics. Second, a reorganization of the workplace function is often required, because digital-based technologies do not stand alone but rather work within networks.

The widely adopted lean production methodology was introduced in the 1980s by Toyota Motor Corporation. It conjoins advanced manufacturing techniques with a set of organizational strategies that go beyond a mere production strategy and

[69] Robots are reprogrammable multifunctional manipulators designed to move material, parts, tools or specialized devices through variable reprogrammed motions for the performance of a variety of tasks (Robot Institute of America).

involve the development of an organizational culture with continuous learning and interaction as the pillars for success. The systemic organization characterizing lean production allowed the industry to move into a new path of more complex and interactive manufacturing and organizational techniques, such as production in modules. Modular production requires a higher level of technological interdependence between the terminal industry and their main suppliers, which in turn requires more dynamic and constant communication between them and also among suppliers.[70]

A. Lean Production – The Toyota Model

The Toyota Production System (TPS) is a system relentlessly focused on the elimination of waste, on the exposure of quality problems through line stoppages and on forcing management to fix problems at their roots (Monden 1983; Sako 2004). TPS resulted from learning through trial-and-error practices aimed at solving the practical problems and needs of Toyota Motor Manufacturing, Inc.

TPS is strongly supported by three fundamental tools: just-in-time inventories, standardization and quality control. These tools or elements cannot be implemented in isolation and without the adoption of advanced information and production technologies. Clearly, in order to succeed with this model of production, a more skilled workforce that facilitates firms' efforts and investments to upgrade the capabilities is required.[71]

A.1. Automation and Lean Production in the Mexican Auto Industry

This section presents the main findings of two studies of the automobile industry in Mexico: the report by JICA (1996) and the work of Jasso and Torres (1998). These two studies provide descriptive data on the technological and organizational structure of the industry in the NAFTA transition period.

These two studies (i.e., JICA 1996 and Jasso and Torres 1998) are used as background information to the analyses presented in Chapters 5, 6 and 7. Most importantly, the empirical information presented in these two studies helps us to understand the extent of technological capabilities achieved in the auto parts industry in the early years of NAFTA.

[70] Good examples of knowledge and technology transfer originating in a supplier are the development and diffusion of engine management technologies by Bosch of Germany (Amey 1995), Delphi-Mexico's processes and business coordination and development activities (Lara Rivero and Carrillo 2003b, 2003a) and the case of automobile seats and interiors by Lear Corporation in Mexico (Lara Rivero, Trujano and Garcia Garnica 2004).

[71] See Sako (2004) for more on organizational capability enhancement and transfer in Japanese automobile suppliers by Honda, Nissan and Toyota.

As noted in Chapter 2, we understand *technological capabilities* as a variety of knowledge and skills positioned as core elements in a firm's ability to acquire, use, adapt, change and create technology (Ernst, Mytelka and Ganiatsos 1998). Understanding the extent of capabilities achieved by the auto parts industry in the years previous to our analysis provides us with an understanding of the level of engagement of firms in undertaking explicit efforts for learning and innovation.

The Jasso and Torres (1998) study focused on the extent of learning and the technological accumulation process in auto parts and petrochemical firms. The authors interviewed 20 auto parts firms (first-tier suppliers). Their analysis shows that firms oriented towards international markets were those who interacted more with suppliers and customers and produced products that were more technologically complex (i.e., engine components, driving gear, fuel supply, electromechanical components). These firms were mainly foreign-owned or joint ventures acquiring their technology through foreign direct investment (FDI). In contrast, domestically owned firms acquire their technology largely through licenses.[72]

Mytelka (1978) shows how licensing inhibited technological efforts and learning within the firm in the Andean case. Her study does not look at firms' market orientation, as in the case of Jasso and Torres (1998), but compares locally owned firms that developed their own technology to other types of firms that licensed technology, whether these were locally owned, both state and private, joint ventures or wholly foreign-owned firms. Her findings suggest a correlation between licensing, the choice of imports of machinery and equipment and R&D activities. This correlation reduced opportunities for learning and led to a *technological dependence syndrome* in which the technology for new or related products would once again be licensed in the future

C. The Mexican Auto Parts Situation (1993-1996)

In their analysis of the auto parts industry, Jasso and Torres (1998) find that on average, no emphasis was put on product development due to the dependence of the Mexican automobile industry on the strategies and designs of the assemblers. However, in some cases, foreign firms and firms with joint ventures adapted products to local market conditions – i.e., luminosity, corrosion, road resistance (Unger, Jasso, Paredes et al. 1994; Jasso and Torres 1998). Jasso and Torres (1998) report that on average, most first-tier suppliers have introduced the three fundamental tools of lean production – i.e., just-in-time inventories, standardization and quality

[72] Joint ventures are also licensing technology, but they might have greater access to new/improved technologies from their JV partners than an arm's length (locally owned) licensor firm might have and thus be better able to compete in export markets than a locally owned licensor.

control – allowing them to increase automation, probably motivated by the new market and business conditions created by the emergence of NAFTA in 1994.

Table 4-1 presents the main technological characteristics of the selected auto parts firms in the Jasso and Torres (1998) study.

Table 4-1 Auto Parts Sector Technological Levels (1993-1995; N = 20 firms)

Ownership	Automation Level	Organizational Strategies	Main Technological Adaptations	Market Orientation
Domestic	Normal	QC, JIT, SPC, TA	Minor product changes	Domestic
Joint Ventures	High	QC, JIT, SPC, TC, CAD (regular)	Process automation, technological adaptation and minor process changes	Domestic International
Foreign*	High	QC, JIT, SPC, TC, CAD, CAM	Process improvement	International

*Includes maquiladoras. QC = Quality Control; JIT = Just-in-time; SPC = Statistical Process Control; TA = Testing and Analysis; TC = Technological Center; CAD = Computer Assisted Design; CAM = Computer Assisted Manufacturing.
Source: Jasso and Torres (1998).

Table 4-1 shows that between 1993-1995, exporting firms started to adopt computerized organizational strategies and innovation activities (i.e., the introduction of CAD/CAM systems) seeking process improvement, while firms oriented towards the domestic market concentrated their efforts on the adoption of some TPS organizational strategies (i.e., quality control, JIT, SPC and testing and analysis) as well as on minor product changes. The results show that automation is higher in firms oriented to the export market.[73]

Table 4-1 also shows that the type of automation and organizational strategies adopted by firms during this period differ by ownership structure. The table also gives us a basis to think that at the beginning of NAFTA, *domestic innovation and learning in the auto parts industry were correlated with ownership structure*; and that *the auto parts industry was divided into strongly and poorly innovating firms* (i.e., based on the main technological adaptations mastered by each group of firms, as well as by their market orientation), *and these firms differed widely in their skills* (i.e., automation level and organizational strategies adopted). These two statements will be further explored in Chapter 5, where we analyze changes over time and provide a deeper analysis of the effect of the adoption of these technological and organizational efforts on changes in learning and innovation in firms.

[73] The study of Jasso and Torres (1998) does not indicate which came first, the fact that firms automated their processes or that they were exporting and upgrading to meet competitors' standards.

The Jasso and Torres (1998) findings can be complemented by those of JICA (1996), allowing us to get a more complete view of the technological situation in the auto parts industry between 1993 and 1996.

JICA (1996) conducted interviews with different auto parts firms showing the technological level that had been achieved in the auto parts industry in Mexico as of 1995-1996.[74] The JICA (1996) study includes domestic and foreign-owned firms as well as *maquiladoras*. Maquiladoras is the Spanish name given to foreign-owned assembling plants located in Mexico that import duty-free all the inputs, machinery and parts needed for their assembling processes (to assemble and/or transform in some way) and then in turn export them all – mainly to the United States (Wilson 1992; Made in Mexico February 2nd, 2010).[75]

Table 4-2 presents different production technologies among firms. While some firms have technology at international levels and are mainly oriented to the OEM market or the export market, others have well maintained but old machinery, inappropriate plant layouts and excessive stock of materials (JICA 1996: 5.1-8 to 5.1-11). Some others have modern machine tools, including NCM tools, machining tools and CAD/CAM systems, while others are mostly limited to repairing and maintaining older equipment (JICA 1996: 5.1-2.8).

Table 4-2 also shows that foreign-owned firms (including maquiladoras) and joint ventures produce at the average technological level of OEM firms in industrialized countries. Domestic firms were reported to produce at a level of technology similar to that in firms from the ASEAN area (i.e., Thailand, Philippines, Malaysia and Indonesia).

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[74] The JICA study only interviewed OEM.

[75] The maquiladora program ended in January 2001. Since 2001, those firms operating under the maquiladora regime are subject to taxation and are allowed to sell in the domestic market. Other synonymous terms to maquiladora are: offshore operation, production sharing, twin plants and in-bond. For more on the maquiladora regime, see Wilson (1992) and http://www.madeinmexicoinc.com

Table 4-2 Technology Level of the Automobile OEM (1995-1996)

Ownership	Production Level: Facilities	Production Level: Technology	Quality Control and Assurance Level: Equipment /Facilities	Quality Control and Assurance Level: Systems and Technology	No. firms
Domestic	a. OEM b. International brand (ASEAN) c. Local market	a. OEM b. International brand (ASEAN) c. Local market	a. OEM b. International brand (ASEAN) c. Local market	a. OEM b. International brand (ASEAN) c. Local market	21
Joint Ventures	a. OEM b. International brand c. International market	a. OEM b. International brand c. International market	a. OEM b. International brand c. Local market	a. OEM b. International brand c. Local market	16
Foreign*	a. OEM b. International brand c. International market	a. OEM b. International brand c. International market	a. OEM b. International brand c. International market	a. OEM b. International brand c. International market	10

Source: JICA (1996). * Includes maquiladoras.

Regarding the adoption of Quality Control (QC) systems, Table 4-2 shows that most of the auto parts firms interviewed had insufficient systems of total quality control or were limited to Statistical Quality Control (SQC). In the case of export-oriented firms or corporate groups, QC standards were well adopted (JICA 1996).

From the results of both studies – JICA (1996) and Jasso and Torres (1998) – reported in Table 4-1 and Table 4-2, we can conclude that in the early years of NAFTA, firms in the auto parts industry differed in automation and production technologies, organizational strategies, quality control and market orientation. These differences seem correlated with firms' ownership structure.
Once again the empirical evidence showing the type of production and technological capabilities achieved by the industry indicates that domestic auto parts firms oriented their production towards the domestic market and firms with foreign participation to the export market. Differences between exporting and non-exporting firms are further explored empirically in Chapters 6 and 7.

4.4 Review of data on the Mexican auto parts industry in the pre- and post-NAFTA period

The empirical evidence presented in this study is based on three different national databases and internal reports of the Mexican Trade Commission (Bancomext) regarding the automobile industry. These three databases are used in our three empirical chapters. The following sections discuss each of them, including their time frames, comparability, complementarities, strengths, weaknesses and limitations. Tables with the descriptive statistics of the main variables analyzed are presented as an introductory view of the deeper analysis presented in each of the corresponding analytical chapters. The final subsection presents the compatibility among them and how they relate to the conclusions of this thesis.

A. Database on Technology and Training

The main firm-level data used in this thesis is based on *The National Survey on Employment, Salaries, Technology and Training* (ENESTyC). In Chapter 5, it provides the data for an analysis of how the adoption of learning mechanisms evolved under the changing market conditions brought about by NAFTA and whether *domestic innovation and learning mechanisms in the auto parts industry are correlated with firm size, ownership structure and supplier tier level*.

The Division of Special Surveys at the Mexican National Institute of Statistics (INEGI) conducts the ENESTyC survey. As in the case of many developing countries, the ENESTyC surveys are unequally spaced, containing information for the years 1991, 1994, 1998 and 2000. Although there are some differences in the structure of the questionnaires in the different years, they maintain the same objectives and methodology, allowing comparative analysis across years. To work with the unequally spaced characteristic of the sample, we considered firms in 1991 as our reference sample for the period before NAFTA, and pooled data (allowing for different intercepts over time for the years 1994, 1998 and 2000) to represent the industry's behavior under NAFTA.

After extensive screening, we selected those firms belonging to different tiers of the auto parts industry. Firms from the terminal industry (i.e., assemblers) are excluded from our sample since they are not within the scope of the analysis of this research. Firms with less than 20 employees, commercial retailers and workshops with no manufacturing production are also excluded. Due to the sample methodology of this survey, a few firms are randomly missing for 1994 and 1998; therefore, the analysis is based on an unbalanced panel of firms. Our study analyzes 192 firms that operated through the whole period from 1991 to 2000, from which 164 firms were surveyed in 1994 and 181 in 1998.

A.1. Firm-level Characteristics

a. Size of the firm

Empirical studies from the capability building literature suggest that a firm's size is positively related to its technological capabilities (Gregersen 1992; Rasiah 2003;

Jonker, Romijn and Szirmai 2006). In our analysis in Chapter 5, we include this variable as a firm characteristic affecting firms' probability of adopting certain learning mechanisms.

Table 4-3 examines changes in the number and size of Mexican auto parts firms in the pre-NAFTA period (1991), in 1994 (the year NAFTA went into effect) and in the post-NAFTA years (1998 and 2000). We define firms' size as follows: Small firms are those with less than 100 employees; medium-sized firms those with 100 to less than 500 employees; and large firms are those with 500 or more employees (SEGOB 1999). Table 4-3 shows the size distribution of firms in the period before and under NAFTA.

Table 4-3 ENESTyC Sample Distribution by Size (number of employees)

Variable	# Firms	% Firms	Mean	Std. Dev.	Min	Max
Before NAFTA (192 firms)						
Small firms 1991	10	5,21	67,7	17,5819	45	95
Medium firms 1991	124	64,58	275,23	109,5721	100	494
Large firms 1991	58	30,21	1069,31	854,0114	500	6394
Under NAFTA						
1994=164 firms, 1998=181 firms, 2000=192 firms, NAFTA_pooled=537 firms						
Small firms 1994	13	7,93	72,2308	21,3157	24	93
Small firms 1998	3	1,66	80,6667	27,46513	49	98
Small firms 2000	9	4,69	79	20,4939	39	99
Medium firms 1994	106	64,63	231,5189	99,7689	103	499
Medium firms 1998	115	63,54	269,0348	114,8156	101	498
Medium firms 2000	120	62,50	277,3917	118,9096	100	487
Large firms 1994	45	27,44	986,3333	666,3632	506	4114
Large firms 1998	63	34,80	1002,841	546,7126	502	3386
Large firms 2000	63	32,81	1074,317	829,1398	516	6011

Note: Small: firms with less than 100 employees; medium: 100-499 employees; large: more than 500 employees (SEGOB-Diario Oficial de la Federacion, 1999)

Table 4-3 shows a slight decrease in the average number of employees in medium (i.e., 260 employees) and large firms (i.e., 1025 employees) under NAFTA compared with these averages in 1991, prior to NAFTA. The technological complexity of the industry may explain the low amount of small firms in the sector, which decreased between 1991 and 2000. Table 4-3 presents the number of firms in the medium category, which decreased from 124 before NAFTA to 120 in 2000. The number of large firms grew under NAFTA to 63, compared with 58 in 1991. Although changes in firms' size were not significant between the period before NAFTA and the period under NAFTA, from the information on means presented in Table 4-3 we can say that small firms grew into medium-sized firms[76] and medium-sized firms grew into large firms.[77]

b. Ownership structure

Table 4-4 presents the distribution of firms by foreign participation. We divided firms into four categories according to their ownership structure: a) Those with only local ownership; b) Firms with 50% or less foreign participation; c) Firms with 50% or more foreign ownership; and d) Firms with 100% foreign ownership.

Table 4-4 shows no radical changes in the ownership structure of firms under NAFTA. The table shows that about 65% of firms were 100% locally owned before and under NAFTA. This is an important point in this thesis, since we would expect that locally owned firms with the particular habits and practices they developed as a result of the various automotive decrees would have a more difficult time in adjusting to the new requirements for learning and innovation that were introduced by NAFTA.

An interesting feature of Table 4-4 is the fluctuation in the number of firms with foreign equity over time. Before NAFTA, there were more firms with less than 50% foreign equity (i.e., 18% of firms in 1991) and only a few firms with 50% or more foreign ownership. Under NAFTA, the number of firms with 50% or more foreign equity increased from 4% in 1991 to 16% by 2000. Another interesting characteristic from Table 4-4 is that 100% foreign-owned firms increased from 26 firms in 1991 to 35 in 1998, but after that, there was an important reduction to only 18 firms in 2000.[78]

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[76] As we can see, in the remaining small firms the number of employees grew slightly from 68 in 1991 to 76 in 2000 (under NAFTA).

[77] The analysis is done for the same set of firms over time – there is no entry/exit of firms. Due to the unbalanced characteristic of the panel data, we base our comparisons on differences between 1991 and 2000 – the years where the panel was balanced and contained the same number of firms. The differences in the number of firms may be explained by the flexibility of Mexican labor laws, which allow firms to hire and fire employees at their convenience.

[78] Although we do not know with certainty the reason for this phenomenon, it may be a reaction to 1) the finalization of the maquiladoras program in 2001; 2) uncertainty in the market that made foreign firms more attracted to sharing ownership than to having full ownership of firms.

Table 4-4 ENESTyC Sample Distribution by Ownership

Variable	No. firms	% Firms	Mean	Std. Dev	Min-Max
Classification by ownership structure					
Before NAFTA (1991 = 192 firms)					
1991 national ownership = 100%	124	64,59%	0	0	0-0
1991 national ownership 100%<x<50%	34	17,70%	0,3429	0,1485	0.01-0.49
1991 foreign participation 100%<x>= 50%	8	4,16%	0,8025	0,1796	0.55-0.99
1991 foreign participation = 100%	26	13,55%	1	0	1-1
Under NAFTA					
1994 = 164 firms					
1994 national ownership = 100%	95	57,93%	0	0	0-0
1994 national ownership 100%<x<50%	31	18,90%	0,3581	0,147	0.01-0.49
1994 foreign participation 100%<x>= 50%	10	6,10%	0,806	0,1813	0.55-0.99
1994 foreign participation = 100%	28	17,07%	1	0	1-1
1998 = 181 firms					
1998 national ownership = 100%	118	65,20%	0	0	0-0
1998 national ownership 100%<x<50%	14	7,73%	0,4279	0,0879	0.24-0.49
1998 foreign participation 100%<x>= 50%	14	7,73%	0,8192	0,2258	0.5-0.99
1998 foreign participation = 100%	35	19,34%	1	0	1-1
2000 = 192 firms					
2000 national ownership = 100%	125	65,10%	0	0	0-0
2000 national ownership 100%<x<50%	19	9,89%	0,4053	0,1043	0.2-0.49
2000 foreign participation 100%<x>= 50%	30	15,63%	0,9033	0,172	0.5-0.99
2000 foreign participation = 100%	18	9,38%	1	0	1-1
Source: Elaborated by the author with data from the Enestyc surveys					

c. Tier supplier level

Table 4-5 indicates size and ownership structure of first-tier suppliers. The upper part of the table indicates the number of first-tier suppliers by size, and the bottom part shows the ownership structure of these first-tier suppliers over time.

Table 4-5 presents the size distribution of these first-tier suppliers. The table follows the size distribution of Table 4-3, dividing firms into small, medium and large categories. From the table we can see that the greatest number of first-tier suppliers are medium-sized firms, followed closely by large firms. This may be explained by the extent of requirements not only in quality and delivery times for first-tier products, but also by the technological requirements (and the investment required) that terminal firms impose on these types of suppliers.

Following the same classification for ownership structure as Table 4-4, we find that first-tier suppliers in the auto parts industry in Mexico are mostly nationally owned. In 1991 about 53% of first-tier suppliers were nationally owned, and this increased to 71% of first-tier suppliers in 2000. Although the number of first-tier suppliers is small compared with the sample (i.e., 34 out of 192), we found it interesting that more than 50% of them are foreign-owned. That reflects that some sorts of capabilities already existed in 1991 that allowed these firms to remain in the market under NAFTA.

Table 4-5 Distribution of First-Tier Suppliers by Size and Ownership Structure

Variables	Total No. Firms	No. firms (% firms)	No. firms (% firms)	No. firms (% firms)	No. firms (% firms)
		SIZE OF FIRMS			
		Small	Medium	Large	
Before NAFTA (1991 = 192 firms)					
Tier 1 firms in 1991	34	0	20 (58.82%)	14 (41.18%)	
Under NAFTA (1994=164 firms, 1998=181 firms, 2000=192 firms, NAFTA_pooled=537 firms)					
Tier 1 firms in 1994	30	0	17 (56.67%)	13 (43.33%)	
Tier 1 firms in 1998	30	0	14 (46.67%)	16 (53.33%)	
Tier 1 firms in 2000	34	1 (2.94%)	17 (50%)	16 (47.06%)	
Tier 1 firms under NAFTA (pooled)	94	1 (1.06%)	48 (51.07%)	45 (47.87%)	
Note: Small: firms with less than 100 employees; medium: firms with 100-499 employees; large: firms with more than 500 employees					
		OWNERSHIP STRUCTURE			
Ownership		100% national ownership	<50% foreign ownership	>=50% foreign ownership	100% foreign ownership
Before NAFTA (1991 = 192 firms)					
Tier 1 firms in 1991	34	18 (52.95%)	12 (35.29%)	1 (2.94%)	3 (8.82%)
Under NAFTA (1994=164 firms, 1998=181 firms, 2000=192 firms, NAFTA_pooled=537 firms)					
Tier 1 firms in 1994	30	15 (50%)	8 (26.67%)	4 (13.33%)	3 (10%)
Tier 1 firms in 1998	30	18 (60%)	3 (10%)	2 (6.67%)	7 (23.33%)
Tier 1 firms in 2000	34	24 (70.59%)	4 (11.77%)	3 (8.82%)	3 (8.82%)

Elaborated by the author with data from the ENESTyC surveys (1991, 1994, 1998 and 2000).

A.2. Linkages with Knowledge Centers

Table 4-6 presents changes in the number of firms reporting that they conducted innovation activities in collaboration with different knowledge organizations. [79] The

[79] As mentioned previously in Chapter 2, we consider that a firm conducts innovation activities if it realizes any of the following three activities: a) design of new products, including increasing the variety of products; b) process and product quality improvement, including the adoption of new (or improved) productive processes that contribute to increased productivity and quality control; and c) design, improvement and manufacture of machinery. See footnote 26 for more on the construction of this variable.

table presents these relationships by dividing auto parts firms into two categories: ownership structure and size.

The results of Table 4-6 are based on the ENESTyC database – using the same set of 192 firms for 1991 and 2000. The table reports a reduction in the number of firms conducting innovating activities from 132 in 1991 to 96 in 2000. Regarding the location of these innovation activities, only 123 firms (out of these 132) provided information in 1991.

Table 4-6 reports a reduction in the number of firms conducting innovation activities in-house. In 1991 (before NAFTA) 92 out of 123 firms reported conducting their innovation activities in-house; in the year 2000 (under NAFTA) only 70 out of 96 firms conducted their innovation activities in-house. There is also a reduction in the number of firms conducting innovation activities externally to the firm, from 31 firms in 1991 to 26 in 2000.

The reduction of innovative activities in-house is more notorious in firms with 50% or more domestic ownership than in firms with more than 50% foreign equity. In this first group of firms, 77 were conducting in-house innovation in 1991 and only 56 of them kept doing this type of activity in 2000. Out of firms with more than 50% foreign ownership, only one firm stopped conducting in-house innovation by 2000, reducing the number of 15 firms from in 1991 to 14 in 2000.

Table 4-6 Location of Auto Parts Firms' Innovation Activities, 1991 and 2000

	OWNERSHIP STRUCTURE		SIZE OF FIRMS		
	>50% foreign ownership	>50% domestic ownership	Small	Medium	Large
	No. firms (% firms)	No. firms (% firms)	No. firms (% firms)	No. firms (% firms)	No. firms (% firms)
Prior to NAFTA					
1991 (132 out of 192 firms conducting innovation activities)*					
A. In-house	15 (78.95%)	77 (74.04%)	8 (88.89%)	58 (72.50%)	26 (76.47%)
B. External:					
a. National subsidiary	2 (10.53%)	7 (6.73%)		6 (7.50%)	3 (8.82%)
b. Foreign subsidiary/ headquarter					
c. University	1 (5.26%)	5 (4.81%)		5 (6.25%)	1 (2.94%)
d. Foreign training centers/firms		10 (9.62%)	1 (11.11%)	7 (8.75%)	2 (5.88%)
e. National consultants*	1 (5.26%)	3 (2.88%)		3 (3.75%)	1 (2.94%)
f. Foreign consultants		2 (1.92%)		1 (1.25%)	1 (2.94%)
Total number of firms	*19 (100%)*	*104 (100%)*	*9 (100%)*	*80 (100%)*	*34 (100%)*
* Out of 132 firms reporting they conducted innovation activities, only 123 firms responded to this question. The results for 1991 are based on these 123 responses.					
Under NAFTA					
2000 (96 out of 192 firms conducting innovation activities)					
A. In-house	14 (58.33%)	56 (77.78%)	3 (75%)	40 (71.43%)	27 (75%)
B. External:					
a. National subsidiary	1 (4.17%)	6 (8.33%)		4 (7.14%)	3 (8.33%)
b. Foreign subsidiary or headquarter	8 (33.33%)	6 (8.33%)		10 (17.86%)	4 (11.11%)
c. University		1 (1.39%)			1 (2.78%)
d. Foreign training centers/firms	1 (4.17%)	1 (1.39%)		2 (3.57%)	
e. National consultants**		1 (1.39%)			1 (2.78%)
f. Foreign consultants		1 (1.39%)	1 (25%)		
Total number of firms	*24 (100%)*	*72 (100%)*	*4 (100%)*	*56 (100%)*	*36 (100%)*

Note: This table only reflect those firms in the sample that reported they conducted innovation activities.
** Includes Industrial associations and public training centers
Source: Elaborated by the author with data from the Enestyc surveys (1991, 2000)

Table 4-6 shows that under NAFTA, the data on innovation activities conducted externally to the firm indicate a marked trend in firms with more than 50% foreign ownership to move innovation activities to their headquarters or foreign subsidiaries.[80] This could reflect the fact that auto parts manufacturing in Mexico is mostly based on specifications and product design requirements established by the terminal firms. Assuming that foreign firms operating in Mexico have an existing, long-standing relationship with the terminal industry, it is not surprising that they would

[80] Studies conducted by Casas, de Gortari and Luna (2000) and by Dominguez and Brown (2004) find similar results on the migration of R&D and innovation activities to foreign countries in the manufacturing industry in Mexico.

move their innovation activities closer to the assembler's headquarters or to their strategic design and development centers in foreign countries, rather than in Mexico, particularly considering that under NAFTA there are no longer any regulations on ownership and investment in firms.

Table 4-6 shows that among external innovation, that conducted in university-industry collaboration was already low in 1991, and it has diminished under NAFTA.[81] A few private universities and technology centers (e.g., Instituto Tecnológico y de Estudios Superiores de Monterrey – ITESM) have joint programs with terminal firms, mainly for high-level training of students enrolled in majors related to the industry. This may account for the continued participation of these centers as R&D and innovation studies providers.

The second part of Table 4-6 shows the relationship between the size of firms and the location of innovation activities. The results show an important reduction in medium-sized firms conducting innovation activities under NAFTA, from 80 firms in 1991 to only 56 in 2000.

More than 70% of these firms conducted innovation activities in-house, decreasing from 58 firms in 1991 to only 40 in 2000. The number of large firms conducting these activities internally remained almost the same before and under NAFTA.
Medium-sized firms conducting innovation activities externally to the firm also decreased from 22 in 1991 to 16 in 2000. The number of small and large firms conducting this activity externally remained almost unchanged in both periods.

The pattern of existing interactions and collaboration between firms and knowledge organizations before and after NAFTA reveals the poor level of involvement of the industry with other actors in the system (particularly with knowledge actors). This is an area that has not been explored much in the Mexican context – due to the lack of data – and it provides this research with a basis to state that *networking among Mexican auto parts firms has been weakened by the convergence of factors brought about by NAFTA*.

B. Database on Auto Parts Firms – SIEM

The SIEM database is an electronic database collected yearly by both the *Manufacturing Industry National Chamber* (CANACINTRA) and the Ministry of Economy. It is electronically administered by the *Mexican Entrepreneurial Information System*

[81] These results are similar to those by other authors for the general case of Mexican manufacturing industries, which conclude that the interaction within firms and with knowledge centers (i.e., universities) is largely weak and insufficient (Casas, de Gortari and Luna 2000; Dominguez and Brown 2004).

(SIEM).[82] This database is used in the empirical analysis presented in Chapter 6, presenting information for the year 2002.[83]

After screening out from the database those auto parts firms involved in commercial activities and those registered as "sole proprietorship"[84], as well as firms with less than 20 employees (to keep conditions similar to the analysis of the ENESTyC survey), we obtained a sample of 257 auto parts establishments.

Table 4-7 provides descriptive statistics on exporting and non-exporting firms by the size of the firm for the year 2002.

Table 4-7 SIEM Sample Distribution by Size – Number of Employees (2002)

Variable	# Firms	% Firms	Mean	Std. Dev.	Min	Max
			Under NAFTA (2002 = 257 firms)			
Small firms	62	24,12	48,7096	22,7224	23	96
Medium firms	111	43,20	248,4144	120,7297	100	499
Large firms	84	32,68	1288,964	962,4989	500	5572
			Exporting firms (105 firms)			
Small firms	13	12,38	58	26,0032	23	89
Medium firms	50	47,62	238,08	111,1276	100	499
Large firms	42	40,00	1598,69	1188	531	5572
			Non-exporting firms (152 firms)			
Small firms	49	32,24	46,2449	21,38977	23	96
Medium firms	61	40,13	256,8852	128,3542	100	482
Large firms	42	27,63	979,2381	517,2236	500	3563

Note: Small: firms with less than 100 employees; medium: firms with 100-499 employees; large: firms with more than 500 employees (SEGOB-Diario Oficial de la Federacion, 1999)
Source: Elaborated by the author with data from the SIEM database

The results show that exporting firms are mostly medium and large firms. Although there are a few small exporting firms (i.e., 13 firms), most firms in this size category are non-exporters.

Chapter 6 builds upon these data to analyze the internal structure, productivity and innovative capabilities of exporting auto parts firms in comparison with non-exporting firms.

[82] The SIEM is a dependency of the Ministry of Economy. The data are collected by CANACINTRA, and the database (and the public portal) is administered by SIEM.

[83] The objective of the SIEM's system is merely informative; therefore, no historical records of data are kept and the author was only able to obtain information for the year 2002.

[84] The set of firms oriented to commercial activities and those with *sole proprietorship* status constituted about 55.9% of the total population of automotive firms registered in 2002.

Based on the classification of firms by manufacturing activities that we cover in this research[85], we elaborated Table 4-8 showing the distribution of exporting and non-exporting firms by economic activity (using the CMAP classification used throughout this research and mentioned previously in Chapter 2).

Furthermore, we roughly classified these manufacturing activities by technology level, based on the work of Raul Alfaro in Bancomext (2000) on the technology level achieved in the Mexican automotive industry (see Figure 4-2 for more details).[86]

Table 4-8 SIEM Distribution of Firms by Economic Activity – CMAP (2002)

CMAP Code	Technology level	Total No. Firms	No. Firms	% Firms	No. Firms	% Firms
			Exporting firms		Non-exporting firms	
384121	High	24	9	37,50	15	62,50
384122	High	56	20	35,71	36	64,29
384123	Medium/Low	15	5	33,33	10	66,67
384124	Medium/Low	13	6	46,15	7	53,85
384125	Medium/Low	15	4	26,67	11	73,33
384126	Basic	134	61	45,52	73	54,48
No. firms		257	105		152	

Source: Elaborated by the author with data from the SIEM database and following the classification by Raul Alfaro in Bancomext (2000) according to technology levels achieved in the Mexican auto industy

The results in Table 4-8 indicate that 152 out of 257 firms were not exporting in 2002. Although the number of exporting firms is quite high – 105 firms out of 257 – in all manufacturing categories the number of non-exporting firms is larger than that of exporting firms.

From the distribution of firms, we can see that about 50% of firms in the auto parts sector in Mexico are concentrated in basic processes such as the manufacture of

[85] As mentioned in Chapter 2, this research only covers those firms operating under any of the following six manufacturing classifications:
- Manufacture and assembly of bodies (384121)
- Manufacture of engines and their parts (384122)
- Manufacture of power train systems, parts and components (384123)
- Manufacture of suspension systems, parts and components (384124)
- Manufacture of brake systems, parts and components (384125)
- Manufacture of other [main] parts and components (384126)

[86] The author made this classification under the supervision of Raul Alfaro in 2007. However, due to the broad classifications of the CMAP code, we consider it a very rough classification and it should only be considered as a broad indicator.

other [main] parts and components (384126). The second group in which Mexican auto parts firms are concentrated is the manufacture of engines and their parts (384122). Although we classified this group as components of high technology, we recognize that within this group there are auto parts firms only producing parts related to engines, which may not require a high level of technology (see footnote 86).

There is also a concentration of firms in components of medium-low technology producing power-trains parts, suspension and braking systems. We find a few exporters in this category of firms.

This is the only database in which this research presents a division of firms by their economic activity – see the analysis in Chapter 6. However, a restriction agreed upon when accessing the databases used in this research prevents the author from disclosing both the name of the firm and its economic activity.[87]

C. Local Content Integration Database – SEC

The third database used in this thesis was compiled internally by the Auto Parts Department of the Ministry of Economy (SEC). It consists of 1,304 firms, with data from 1995 till 2002.

The SEC database was created with the objective of monitoring the share of local content integration of the automotive industry; therefore, this database does not contain a large number of variables. Its relevance is based on the number of years covered systematically.

Table 4-9 illustrates the distribution over time of firms by size and ownership structure.

[87] Due to confidentiality issues, the author was not permitted to disclose the names of the firms present in these three databases. We were also not allowed to mention the detailed automotive parts or components produced by these firms.

Table 4-9 OEM Firms – Sample Distribution by Size and Ownership Structure

Variable	Exporting firms				Non-exporting firms			
	No. firms	Mean	St. Dev	Min-Max	No. firms	Mean	St. Dev	Min-Max
Small_1995	46	55,93	23,73	23-95	72	60,2	24,06	23-99
Medium_1995	62	228,14	108,9	100-498	69	226,98	99,76	100-486
Large_1995	26	2266,88	2679,94	550-13839	29	1287,79	1126,67	506-4704
Small_1998	41	58,65	21,89	24-96	38	52,57	19,48	25-95
Medium_1998	79	250,97	121,18	100-490	75	217,13	91,25	100-468
Large_1998	43	1690,97	1889,11	531-11295	34	1872,76	2325,77	503-10500
Small_2000	34	64,58	20,85	26-99	41	59,68	22,07	28-96
Medium_2000	100	246,33	111,66	100-498	69	228,52	109,62	100-482
Large_2000	71	1926,5	2733,88	513-17022	31	2721,41	4245,91	505-15000
Small_2002	28	53,85	19,88	23-88	26	56,19	23	23-98
Medium_2002	102	268,79	114,78	100-494	69	239,69	114,32	104-491
Large_2002	83	2305,33	4003,76	500-30844	36	1682,38	2413,91	501-12258

Note: Small: firms with less than 100 employees; medium: firms with 100-499 employees; large: firms with more than 500 employees (SEGOB-Diario Oficial de la Federacion, 1999)
Source: Elaborated by the author with data from the Ministry of Economy

Table 4-9 shows that OEM exporting firms are mostly medium and large firms. An increasing number of exporting firms is observed over time, while firms oriented to the domestic market did not change significantly in number. The results also show an important reduction in the number of small firms (i.e., firms with less than 100 employees) over time. This could be due to increasing market requirements that small firms are unable to achieve. The table also shows that large OEM exporting firms have a considerably larger number of employees than large OEM firms that do not export.

4.5 Comparability Across Databases and Variables Used in this Research

As mentioned in the previous section, the three databases used in the empirical analyses of this thesis come from different sources. Therefore, they are not compatible and cannot be used as one combined database. Thus, we conducted separate analyses, which we believe provides this research with a better, more comprehensive representation of the auto parts industry.

Table 4-10 presents the variables and time lag analyzed in each empirical chapter. This allows us to connect the different results of the separate analyses.

Table 4-10 Variables Used in Different Empirical Analyses of this Research

	Chapter 5 (ENESTyC Database)	Chapter 6 (SIEM Database)	Chapter 7 (SEC Database)
Dependent Variables	X		
Learning through training	X	similar variables used in the analysis	
a. Operational training	X		
b. Training in quality control	X		
Learning by innovating	X		
Learning by searching	X		
Learning by using	X		
Exports		X	X
Explanatory Variables:			
Size of the firm (number of employees)	X	X	X
Foreign equity participation	X	X	X
Experience of the firm	X		
First-tier supplier	X		
Adoption of mechatronics	X		
Workforce with university studies	X		
Managers with graduate studies	X		
Adoption of lean production	X		
Adoption of statistical process control	X		
Industrial classification (CMAP)		X	X
Quality control certifications		X	
Training		X	
Use of imported main inputs		X	
Share of imports in output (gross sales)			X
Period analyzed:			
1. Prior to NAFTA			
1991	X (N = 192)		
2. Under NAFTA			
1994	X (N = 164)		
1995			X (N = 304)
1998	X (N = 181)		X (N = 310)
2000	X (N = 192)		X (N = 345)
2002		X (N = 257)	X (N = 344)

Source: Elaborated by the author with information from the ENESTyC database (1991, 1994, 1998, 2000), the SIEM (2002) database and the SEC database.

Chapter 5 reports the technological efforts and characteristics of firms adopting different varieties of learning mechanisms. The analysis conducted in this chapter covers the period prior to and under NAFTA.

Chapter 6 shows the characteristics and technological efforts of exporting versus non-exporting firms during the year 2002 (under NAFTA). The chapter considers the adoption of quality control certifications and learning by training as TE. These two variables were considered as dependent variables in the analysis conducted in Chapter 5.

Chapter 7 also analyzes the characteristics of exporting firms for the years 1995, 1998, 2000 and 2002. The difference between this analysis and the one conducted in Chapter 6 is that Chapter 7 only covers OEM. This may make a difference since we are assuming that OEM firms have higher technological capabilities, as they need to fulfill international production and quality requirements.

The connection between databases is not straightforward; therefore, the author considered that the use of these three databases in independent analyses with similar variables allows us to see different perspectives of the learning and innovation trends in the auto parts industry in Mexico. When all this is presented together in Chapter 8 under the umbrella of IS, we get a richer analysis of the auto parts sector in Mexico than if we were only exploring one database without the umbrella of the institutional context.

Chapter 5

The Adoption of Learning Mechanisms Under Changing Market Conditions

Abstract

This chapter analyzes the changes in the adoption of different learning mechanisms before and under the implementation of NAFTA. The analysis uses a multivariate probit model to tests the relationship between critical firm-level variables and technological efforts and the likelihood of adoption of five different learning mechanisms over time. The results show that the learning mechanisms adopted by firms change significantly over time. There has been a significant decrease in the adoption of learning by innovating since the institutionalization of new economic and competitive market conditions (represented by NAFTA). This suggests that the level of dynamic learning by which firms build and strengthen their technological capabilities in the Mexican auto parts sector is decreasing. The results of this analysis have applications beyond the Mexican context and are relevant to other developing countries experiencing a changing economic and market environment.

5.1 Introduction

This chapter explores how the adoption of learning mechanisms evolves under circumstances of market changes, such as the ones brought about by NAFTA. The empirical exercise analyzes two statements. First, whether *the nature and direction of innovation and learning mechanisms adopted by automotive suppliers have changed since the introduction of NAFTA in 1994*. Second, whether *domestic innovation and learning mechanisms in the auto parts industry are correlated with firm size, ownership structure and supplier tier level*.

The chapter examines broad trends in the adoption of learning mechanisms by firms in the auto parts industry and provides a clearer picture of firms' learning behavior under a changing market environment. The empirical analysis is based on data from a set of 192 auto parts firms, obtained from the Enestyc surveys (i.e., National Survey on Employment, Salaries, Technology and Training) for 1991, 1994, 1998 and 2000.

The chapter is organized as follows: Section 2 describes the methodology used in the empirical analysis. Section 3 presents the data and variables analyzed. Section 4 presents the descriptive statistics of the learning mechanisms and provides the explanatory variables that were analyzed, along with preliminary insights on changes in trends followed by firms in the period previous to NAFTA and under it. Section 5 presents the empirical results of the model and examines the degree of association between critical firm-level variables, technological efforts and the choice of learning mechanisms or processes by firms in the sector. Section 6 describes the main findings and implications of the analysis.

5.2 Methodology

The econometric analysis estimates the firm's probability of adopting learning mechanisms through which TC are built. As illustrated in Figure 2-4 in Chapter 2 of this thesis, the model assumes that learning mechanisms do not operate in isolation, and that the adoption of one type of mechanism will influence the probability of adoption of the others.[88] Based on this assumption, we developed a multivariate probit model that explains the effect and relevance of critical firm-level characteristics and TE on the firm's probability of adopting the learning mechanisms analyzed.

[88] Owing to the binary nature of these variables, the model only observes whether a firm chose these learning mechanisms or not; it does not investigate the ratio or intensity of the mechanisms' adoption.

The model accounts for correlation between the learning mechanism variables, as it avoids any efficiency loss that would occur if the correlation were not taken into account.

Formally, the model is written as:

$$y^{*}_{ij} = \beta_j x'_{ij} + \varepsilon_{ij}, \; i=1,\ldots N, \; j = 1, 2\ldots, J \qquad \text{(eq. 5.1)}$$

where y^{*}_{ij} can be interpreted as firm i's incentive to adopt learning mechanisms and is unobservable, x_{ij} is an observable vector of explanatory variables, β_j the associated vector of parameters to be estimated and ε_{ij} the unobservable variables affecting firm i's incentive to adopt learning mechanisms. The observed counterpart y_{ij} is observed to be 1 if firm i's incentive to adopt learning mechanisms is sufficiently high ($y^*_{ij}>0$), and 0 otherwise.

The model is estimated for the year 1991 (prior to NAFTA), in which case $N = N_{1991}$ with $N_{1991} = 192$, and for the years 1994, 1998 and 2000 (a period under NAFTA) in which case $N = N_{1994} + N_{1998} + N_{2000} = 537$, where $N_{1994} = 164$, $N_{1998} = 181$ and $N_{2000} = 192$. The years analyzed allow for comparison of trends in the adoption of learning mechanisms before and under NAFTA.

J is the total number of learning mechanisms considered in this study (i.e., 5).

A. Maximum Likelihood Estimation

In order to estimate the model by maximum likelihood, the individual vector of error terms $\varepsilon_i=(\varepsilon_{i1},\ldots\varepsilon_{ij})$ is assumed to have a multivariate standard normal distribution with zero mean and a JxJ positive definite covariance matrix whose main term is $\mathrm{cov}(\varepsilon_{ij}, \varepsilon_{ik} | x_{ij}\, x_{ik}) = \rho_{jk}\sigma_j\sigma_k$ ($k \neq j$) where σ_j and σ_k denote the standard deviations of the distribution for learning mechanisms j and k, and ρ_{jk} is their correlation. Hence, the individual likelihood function is written as

$$L_i = \int_{l_{iJ}}^{u_{iJ}} \cdots \int_{l_{iJ}}^{u_{iJ}} f(\varepsilon_{i1} \ldots \varepsilon_{iJ}) \partial \varepsilon_{i1} \partial \varepsilon_{iJ} \qquad \text{(eq. 5.2)}$$

where f (.) is the J-variate standard normal probability density function of ε_i.

The multiple integral in equation (2) cannot be evaluated analytically, hence the need to use numerical procedures. As numerical approximations perform poorly in

computing high-order integrals, we use the Geweke-Hajivassiliou-Keane (GHK) smooth recursive simulator to approximate these integrals (Greene 1997).[89]
The approximation is obtained by averaging a set of R replications obtained by transforming draws produced by a random number generator (Hajivassiliou, McFadden and Ruud 1996). The resulting simulated likelihood estimator is consistent, as R goes to infinity (Greene 1997).

B. Marginal Effects

The model measures probabilities, so the absolute scale of the coefficients obtained from the probit estimation provides a misleading proportion of the response of the dependent variables to changes in the regressors.
After the final results of the model are obtained, it is necessary to estimate the marginal effects of the explanatory variable x_{ij} in order to observe the proportional change in the dependent variable, y_{ij}. This procedure is done using the standard normal density function ϕ as the scale factor that translates the raw parameter estimates obtained for the multivariate probit model into marginal effects.

The marginal effects in the probit model with respect to a certain regressor, say r, are equal to $\delta E[y_{ij}|x_{ij}] / \delta x_{ij}r = \phi(\beta'_j x_{ij})\,\beta_j$, where $\phi(\beta'_j x_{ij})$ is the univariate standard normal density function. As $\beta'_j x_{ij}$ becomes increasingly positive, $\Phi(\beta'_j x_{ij})$ approaches 1, and $\phi(\beta'_j x_{ij})$ and the marginal effect therefore approaches 0. Similarly, as $\beta'_j x_{ij}$ becomes increasingly negative, $\Phi(\beta'_j x_{ij})$ approaches 0, and $\phi(\beta'_j x_{ij})$ and the marginal effects again approach 0 (Andersen and Newell 2003).

The discrete effect of a dummy explanatory variable, d, is obtained by taking the difference of the predicted probabilities, y_{ij}, with that dummy variable being equal to 1 and 0; i.e.,

$$P[y_{ij}=1|d = 1] - P[y_{ij}=1|d = 0] \qquad \text{(eq. 5.3)}$$

5.3 Data

The analysis is based on firm-level data obtained from four waves of the innovation survey (i.e. ENESTyC) pertaining to the years 1991, 1994, 1998 and 2000. We use the 1991 cross-sectional data to estimate the determinants of different learning

[89] Hajivassiliou, McFadden and Ruud (1996) reviewed 11 simulators and found that for multivariate normal distributions the GHK was the most reliable method.

mechanisms before the implementation of NAFTA. For the period under NAFTA, we pool the 1994, 1998 and 2000 data, including time dummies[90].

Due to the survey sampling methodology, a few firms are randomly missing for 1994 and 1998. Therefore, the data used under NAFTA is an unbalanced panel. Furthermore, the ENESTyC data is unequally spaced: There is a 4-year gap between 1994 and 1998 and a 2-year gap between 1998 and 2000. Hence, the data under NAFTA is also unequally spaced.

A. Dependent Variables

1. Learning Mechanisms[91]

a. Learning by training

Training in firms is divided across subject areas ranging from employee motivation seminars to quality control issues. This study is confined to training related to quality control and training related to the use and reparation of machinery and equipment.[92]

As the training is related specifically to the technologies used by the firm, we limit our definition of training to these two categories. It gives a better approximation of the efforts made by the firm in relation to production improvements. Thus, we have:

a) *Operational Training activities*, a binary variable indicating whether or not a firm conducts training by repairing and maintaining machinery and equipment.

b) Quality Control Training activities, a binary variable indicating whether or not a firm conducts training in quality control.

b. Learning by innovating [93]

This variable captures the presence of innovation activities in the firm, and it is constructed by assigning the value 1 if at least one of these activities is carried out in the firm, and 0 otherwise.

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[90] By using this specification, we allow for different slope coefficients and different correlations among the learning mechanisms before and under NAFTA.

[91] More in Chapter 2, Section 2.5.

[92] This kind of training covers the use of materials and tools, as well as basic and advanced courses in mechanics, electrics, hydraulics, electronics and related subjects.

[93] As mentioned in Chapter 2, this variable includes three activities: a) design of new products, including increasing the variety of products; b) process and product quality improvement, including the adoption of new (or improved) productive processes that contribute to increased productivity and quality control; and c) design, improvement and manufacture of machinery. See footnote 26 for more details on this variable.

c. Learning by searching

This variable is given a value of 1 if the firm acquires technology by purchasing technological packages or if it receives a technology transfer from its headquarters, and 0 otherwise.

d. Learning by using[94]

This variable is binary with value 1 if the firm acquires machinery or equipment, and 0 otherwise. We consider learning by using to refer to the use of *new* machinery or equipment.

B. Explanatory Variables

The explanatory variables include firm characteristics and technological efforts.

1. Firm Characteristics

a. Firm size

This study uses the number of employees (in the log) as a measure of size. This variable is expected to have a positive relationship with a firm's probability of learning.

b. Ownership structure

This variable is the proportion of foreign equity (on a scale of 0 to 1) and is expected to have a positive effect on firms' probability of learning.

c. Experience of the firm

This variable is measured by the number of years (in the log) the firm performs the same manufacturing activity. The variable is expected to have a negative correlation with the probability of conducting learning activities.

d. Tier supplier level

This variable is binary with value 1 if the firm belongs to the first-tier supplier level, and 0 otherwise. The variable is expected to have a positive relationship with the probability of adopting learning mechanisms.

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[94] Although the acquisition of machinery and equipment is not a learning mechanism *per se*, we assumed that it entails learning processes by enabling workers to operate machinery and equipment more efficiently and consequently contributing to firms' learning. We consider equipment procurement to be an important aspect of sector modernization after the implementation of NAFTA: It represents one of the several technological (and financial) efforts that firms need to make in order to be competitive. Learning by using is a necessary though not sufficient condition for capability upgrading in firms.

2. Technological Efforts

a. Adoption of mechatronics in the production process

This variable is measured by the proportion of computerized machine tools (CMT) and robots in the total machinery and equipment used in the production process. The adoption of mechatronics is expected to be positively associated with firms' likelihood of adopting any of the learning mechanisms analyzed.

b. Adoption of lean production techniques

This variable takes on value 1 if the firm adopts just-in-time (JIT) or Total Quality Control (TQC), and 0 otherwise. We expect a positive relationship between this variable and the probability of the firm to adopt learning mechanisms.

c. Adoption of Statistical Process Control (SPC)

This variable takes the value 1 if the firm uses statistically controlled processes and computerized process controls (i.e., CAD), and 0 otherwise. The variable is expected to have a positive relationship with the firm's probability of adopting learning mechanisms.

d. Learning by hiring

Level of education of the workforce

This variable is expected to have a positive association with firms' likelihood of engaging in learning mechanisms. It is measured by:

a) The number of managers with post-graduate education divided by the total number of managers in the firm.
b) The number of workers with university education (excluding managers) divided by the total number of employees in the firm.

5.4 Descriptive Statistics

Table 5-1 presents descriptive statistics of dependent and explanatory variables that compare the changes in the implementation of learning mechanisms before and under the implementation of NAFTA in the same set of firms. T-tests are performed to assess whether the differences between the means of the two groups (before and under NAFTA) are significantly different from each other.

The results reported in Table 5-1 indicate that learning by innovating was the only mechanism that decreased significantly under NAFTA. This phenomenon tallies with the findings of Archibugi and Pietrobelli (2003) on the globalization of technology and its implications in developing countries, in which the authors show that in Latin America the level of in-house R&D activities for both domestic and foreign firms is very low. The results presented in Table 4-6 corroborate a tendency for reducing innovative activities in Mexico, as well as poor networking between firms and domestic knowledge actors (e.g., universities, trade associations, private consultants).

Table 5-1 shows an increase in the number of firms adopting learning by searching, learning by using and learning through training in quality control. This may reflect the need for upgrading manufacturing and organizational standards due to stronger foreign competition and the changing market conditions institutionalized by NAFTA.[95]

No significant changes were observed in learning through operational training between both periods.

No meaningful changes are observed across periods in firm-level characteristics like size, ownership or being a first-tier supplier or not. The experience of firms increased significantly under NAFTA.

Table 5-1 shows a significant effort to increase the level of education of managers and the workforce. We conjecture that due to stiffer competition under the NAFTA framework, firms have shifted their recruiting requirements to attract more people with university and graduate education.[96]

Labarca (1999) finds that in Latin America, firms have no incentive to invest in the formation of basic skills and knowledge in their labor force, preferring instead to benefit from their employees' prior learning, probably to rapidly build up and strengthen their capabilities and concentrate their training efforts in subjects more specific to the needs of the firm.

The results also found an increase in the adoption of mechatronics in production, the endorsement of flexible production techniques and the adoption of statistically controlled processes (SCP). This may illustrate increasing technological efforts by firms in the auto parts industry towards modernization and automatization of production plants and the adoption of organizational strategies in line with lean and modular production.[97]

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[95] NAFTA institutionalized a change in the orientation of automobile production in Mexico towards the export market, especially to North America.

[96] The author is aware that the rising education level of the manufacturing workforce is not exclusively due to NAFTA, but is also an effect of the national educational policies in Mexico, which have raised the education level of the workforce generally. The causality of the NAFTA effect in this variable is rather tenuous and beyond the scope of this analysis.

[97] See Chapter 4 for more on these two types of manufacturing production.

Table 5-1 Descriptive Statistics Before and Under NAFTA

	Period before NAFTA (1991) Number of firms =192				Period under NAFTA Number of firms = 537				Group means T-test		T-test findings
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	t-statistic	p-value	
Dependent Variables											
Learning through training											
a. Operational training	0.5833		0	1	0.5810		0	1	0.0560	0.9553	No changes
b. Training in quality control	0.2239		0	1	0.4059		0	1	-4.5729	0.0000	Increased under NAFTA
Learning by innovating	0.6875		0	1	0.4674		0	1	5.3359	0.0000	Decreased under NAFTA
Learning by searching	0.3125		0	1	0.3798		0	1	-1.6684	0.0478	Increased under NAFTA
Learning by using	0.5677		0	1	0.6461		0	1	-1.9305	0.0270	Increased under NAFTA
Explanatory Variables											
Size of the firm (number of employees in log)	5.8531	0.8273	3.8066	8.7631	5.8329	0.8398	3.178 0	8.7013	0.2868	0.7743	No changes
Foreign equity participation (%)	0.2295	0.3688	0	1	0.2838	0.4109	0	1	-1.6117	0.1075	No changes
Experience of firm (in log)	3.0546	0.5738	1.3862	4.1743	3.2282	0.5748	0	4.3176	-3.5932	0.0002	Increased under NAFTA
First-tier supplier (dummy)	0.1770		0	1	0.1750		0	1	0.0636	0.9493	No changes
Adoption of mechatronics in production (%)	0.0482	0.1229	0	0.9000	0.1279	0.2141	0	0.9300	-4.8781	0.0000	Increased under NAFTA
Participation of workforce with university studies (ratio)	0.0933	0.0825	0	0.4898	0.1273	0.1535	0	2.0454	-2.9174	0.0018	Increased under NAFTA
Participation of managers with graduate studies (ratio)	0.2142	0.3376	0	1	0.1637	0.2675	0	1	2.0871	0.0186	Decrease under NAFTA
Adoption of lean production (JIT or TCQ) (dummy)	0.1562		0	1	0.5195		0	1	-8.6476	0.0000	Increased under NAFTA
Adoption of Statistical Process Control (dummy)	0.1822		0	1	0.4171		0	1	5.9685	0.0000	Increased under NAFTA

5.5 Empirical Results

We conduct a likelihood ratio (LR) test to assess if the nature and direction of innovation and learning mechanisms adopted by automotive suppliers have changed since the introduction of NAFTA in 1994.

Table 5-2 presents the results of the LR test and recommends the use of a model assuming different parameters prior to and under NAFTA rather than the use of a general model assuming no differences across time (LR chi_2 (60) = 93.80; p-value = 0.0034).

Table 5-2 LR Test Results

Model	No. observations	ll (model)	No. parameters
General Model			
Before NAFTA	192	-551.559	65
Under NAFTA	537	-1723.831	75
Restricted Model	729	-2322.286	80

The results of Table 5-2 confirm those already suggested by the means tests presented in Table 5-1, which suggest that the effects of the explanatory variables on the different learning mechanisms differ between the two periods (i.e., before and under NAFTA). Based on the LR-test results we ran a multivariate probit model with five dependent variables for the period prior to NAFTA (192 observations) and another one for the period under NAFTA (537 observations).

A. Pre-NAFTA Period (1991)

A Wald test is conducted to measure the extent to which the equation estimates fail to satisfy the correlations hypothesized.

A Wald test with chi2 (4) = 4.92 and p-value = 0.2955 indicate that learning through training in quality control is not significantly correlated with any other learning mechanism in the period prior to NAFTA. Table 3-2 presents the marginal effects for this variable.

Table 5-3 Marginal Effects of Learning through Training in Quality Control (1991)

	Learning through training (QC)	
Number of firms = 192	dy/dx	Std. Dev
Explanatory Variables	Y = Pr (Training in QC) = 0.2066	
Size of firm	0.0809***	0.0392
Foreign equity participation	-0.1117	0.0929
Experience of firm	0.0087	0.0527
First-tier supplier♣	-0.0931	0.0692
Adoption of mechatronics in production	-0.1206	0.3030
Participation of workforce with university studies	1.3392**	0.3910
Participation of managers with graduate studies	-0.0173	0.0897
Adoption of lean production♣	-0.00007	0.1134
Adoption of Statistical Process Control♣	0.0298	0.0794

Notes: * significant at 1%, ** significant at 5%, *** significant at 10%.

♣ dy/dx for dummy variables is a discrete change from 0 to 1.

The first four columns of Table 5-4 present the results of a multivariate probit model for 1991 with four independent variables ($chi_2(6) = 10.6857$ Prob > $chi_2 = 0.0986$). Table 5-3 indicates that firms learning by innovating have a significant probability of also learning through operational training.

Table 5-4 shows that prior to NAFTA, firms employing a workforce and managers with a higher level of education were more likely to learn through operational training.

Learning by training in QC was more likely to occur in firms with a higher educated workforce.

The results indicate that firms adopting lean production organizational techniques have a significantly higher probability of learning by searching and learning by innovating.

The adoption of SPC has a significant positive effect on firms' probability of adopting learning by innovating as a mechanism to build and strengthen their TC. This result was to be expected since, in the late 1980s, the industry was starting to globally adopt this type of organizational management. It follows, therefore, that firms in Mexico that had adopted these organizational structures by 1991 were more competitive and were closer to the industry's requirements worldwide.

Table 5-4 illustrates that auto parts firms with more years of experience were significantly less likely to engage in learning by innovating and learning by using activities. These results are not surprising since older firms (more years of experience) have a “memory” formed during the import substitution industrialization period, which makes it difficult for them to adapt their strategies to new technological paradigms requiring more complex learning mechanisms.

5.6 Period Under NAFTA

Table 5-4 presents the results of a multivariate probit model with five dependent variables for the period under NAFTA. Correlation between learning mechanisms is corroborated significantly with a Wald test (chi-square (10) = 47.6351; p-value = 0.0000).

Table 5-4 indicates that relationships among learning mechanisms differ considerably from those found prior to NAFTA. The results show that learning by searching has a negative but significant relationship with learning through training in QC (at a 90% confidence level) and a positive and significant relationship with learning by using (at a 99% confidence level). This may suggest that firms acquiring technology through technological packages or technology transfers from their headquarters have already achieved a certain level of manufacturing maturity and complexity and acquired the “know-how” and types of knowledge that training in QC in Mexico offers to the firm, making additional training unnecessary.

Learning through training in QC and operational training held a negative and significant association (at a 99% confidence level). This may be due to a significant substitution effect between the nature of the training that firms provide and the type of capabilities they achieve through other learning mechanisms.

Table 5-4 shows that firms learning by innovating are those with a larger number of employees and a more educated workforce and managers.

This supports the arguments in the technological capability and organizational theory literature proposing that higher levels of education in the workforce allow for more complex processes of knowledge acquisition. And this in turn supports the “skill-bias” proposition that as firms move into activities involving sophisticated technical contexts, they tend to employ more technically competent people (Piva and Vivarelli 2004; Piva, Santarelli and Vivarelli 2005).

Table 5-4 also illustrates that firms with a higher proportion of managers with graduate studies are more likely to engage in learning by training in QC.

First-tier suppliers have a positive and significantly higher likelihood to acquire new machinery and equipment than suppliers from other tiers.

The adoption of lean production techniques is significantly and positively associated with firms engaging in learning by searching. It may be that as firms increasingly incorporate more complex technologies into their manufacturing operations, they acquire higher technological and absorptive capabilities that allow them to engage in more complex ways of learning (mechanisms).

The use of advanced organizational techniques tends to demand higher and more specialized skills.

Table 5-4 Multivariate Probit Results (Prior to and Under NAFTA)

	Prior to NAFTA (Number of firms = 192)				Under NAFTA (Number of firms = 537)				
	Wald chi2 (36) = 54.62; p-value = 0.0240				Wald chi2 (55) = 99.05; p-value = 0.0003				
	Learning by innovating (1)	Learning by using (2)	Learning by searching (3)	Learning by operational training (4)	Learning by innovating (1)	Learning by using (2)	Learning by searching (3)	Learning by operational training (4)	Learning through training in QC (5)
Explanatory Variables:	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)	Coeff (Std. Err.)
Size of firm	-0.0544 (0.127)	0.064 (0.119)	0.141 (0.125)	0.141 (0.125)	0.236** (0.072)	0.050 (0.072)	0.050 (0.072)	0.074 (0.071)	-0.027 (0.070)
Foreign equity participation	-0.250 (0.297)	0.376 (0.286)	0.075 (0.295)	0.075 (0.295)	-0.018 (0.142)	0.088 (0.141)	0.088 (0.141)	0.182 (0.142)	0.062 (0.140)
Experience of firm	-0.382*** (0.179)	-0.406*** (0.170)	-0.010 (0.172)	-0.017 (0.171)	-0.059 (0.098)	0.077 (0.987)	0.144 (0.988)	-0.124 (0.098)	0.037 (0.098)
First-tier supplier♣	0.428 (0.295)	-0.229 (0.258)	0.022 (0.272)	0.415 (0.281)	0.151 (0.154)	-0.287*** (0.152)	-0.077 (0.155)	0.100 (0.154)	-0.098 (0.153)
Adoption of mechatronics	0.487 (0.917)	-0.130 (0.758)	-0.706 (0.836)	-1.007 (0.797)	0.410 (0.267)	-0.022 (0.266)	-0.239 (0.278)	0.223 (0.275)	0.031 (0.271)
Workforce with university studies	0.705 (1.365)	-0.460 (1.236)	0.754 (1.276)	3.516*** (1.410)	0.853*** (0.381)	-0.029 (0.375)	0.332 (0.377)	-0.527 (0.399)	0.003 (0.377)
Managers with graduate studies	-0.177 (0.301)	1.059 (0.856)	-1.237 (0.897)	0.631*** (0.299)	0.394*** (0.217)	0/112 (0.215)	0.046 (0.209)	-0105 (0.208)	0.343*** (0.207)
Adoption of lean production♣	1.390*** (0.546)	0.134 (0.346)	0.728***(0.248)	0.176 (0.357)	0.047 (0.205)	0.261 (0.205)	0.379*** (0.212)	-0.159 (0.204)	-0.150 (0.205)
Adoption of Statistical Process Control♣	0.831** (0.294)	-0.023 (0.242)	0.233 (0.248)	3.167 (0.253)	-0.003 (0.136)	0.363 (0.138)	-0.025 (0.135)	0.049 (0.135)	0.117 (0.135)
1998					0.669*(0.161)	0.169 (0.159)	0.449** (0.158)	0.117 (0.157)	-0.155 (0.156)
2000					0.439***(0.199)	-0.131 (0.196)	-0.096 (0.205)	-0.118 (0.195)	-0.042 (0.195)
Correlation coefficients:	rho 21:	0.0912	rho 42:	-0.0352	rho 21:	0.1028	rho 42:	0.6543	
	rho 31:	0.0730	rho 43:	-0.0021	rho 31:	0.0188	rho 52:	0.0455	
	rho 41:	0.3698**			rho 41:	0.0698	rho 43:	0.2885	
	rho 32:	0.1333			rho 51:	0.0406	rho 53:	-0.1477***	
					rho 32:	0.2660*	rho 54:	-0.3256	

Note: * significant at 1%, ** significant at 5%, *** significant at 10%.

5.7 Discussion of Findings

The analysis in this chapter was designed to test two statements. First, that the nature and direction of innovation and learning mechanisms adopted by automotive suppliers have changed since the introduction of NAFTA in 1994. Second, that domestic innovation and learning mechanisms in the auto parts industry are strongly associated with firm size, ownership structure and supplier tier level.

Three different tests of the empirical evidence seem to support the first statement, namely group-means, likelihood ratio test and correlation coefficients.

Group means tests indicate a significant increase in the number of firms learning through training in QC compared to the number adopting this activity in 1991. Adoption levels of learning by searching (through the acquisition of technological packages and technology transfers) and learning by using new machinery were also high among auto parts firms in the period under NAFTA. With respect to more complex and dynamic mechanisms, such as learning by innovating, the means tests illustrate an intriguing reduction in firms' likelihood of conducting these activities under NAFTA.

The means tests also indicate that the level of adoption of operational training among firms did not vary significantly between the two periods, while training in quality control increased significantly under NAFTA. This suggests that training is focused on the operational knowledge needed to execute daily production activities and is not really part of the chain between formal education and the use and management of new technology – a function of training. This may also imply that firms concentrating only on this sort of training are moving towards a lower level of dynamic learning and a concentration on operational activities.

The means tests show that the acquisition of new machinery and equipment rose from being the third most widely adopted learning mechanism in the sector in 1991 to become the most important way chosen by firms to build their TC in the period under NAFTA. These results are in line with Jonker, Romijn and Szirmai (2006), who in their study on Indonesia found that the pulp and paper sector in West Java grew mainly through investments in embodied technologies.

The tests also suggest that the types of machinery and equipment acquired by the sector are heavily concentrated in the low to medium specialization levels, as indicated by the poor level of TE undertaken in the acquisition of mechatronics – computerized machine tools and robots – for production. These results are in line with those of the Mexican Trade Commission (Bancomext 1999, 2000, 2004), whose findings state that in domestic manufacturing, auto parts production is concentrated in medium and low technology components (see Figure 4-2 in Chapter 4).

The results of the LR-tests show that the effects of explanatory variables (i.e., firm level characteristics and technological efforts) on learning mechanisms are significantly different before and under NAFTA. This supports the results already suggested by group-means tests and the use of a general model over a restricted one.

While we found that all five mechanisms were significantly related for the period under NAFTA, Wald tests indicate that learning through training in QC in the period before NAFTA was not significantly correlated to any other learning mechanisms.

Correlation coefficients of the multivariate analysis indicate changes in the correlation among learning mechanisms across the two periods analyzed. In the period before NAFTA, we found that firms that adopted learning by operational training were significantly more likely to engage in learning by innovation activities. In the period under NAFTA, however learning by innovating was not significantly correlated to any other learning mechanism.

Also, in the period under NAFTA, learning by searching has a negative but significant relationship with learning through training in QC, and a positive and significant relationship with learning by using new machinery and equipment, suggesting some sort of reinforcing a lack of learning between these mechanisms and indicating that firms acquiring new embodied technologies have significantly greater likelihood of acquiring the know-how through packages or transfers. There is an increasing tendency to import high-level knowledge from foreign countries, while training seems simply to be focused on maintaining rather than upgrading capabilities. It is likely that financial factors play a role. This finding is in line with other studies (Blili and Raymond 1993; Oyelaran-Oyeyinka and Lal 2006).

The econometric analysis did not find robust evidence to support our second statement. We find significant and positive associations between the size of a firm and the firm's likelihood to learn by training in quality control in the period prior to NAFTA, as well as between firm size and the likelihood of learning by innovating under NAFTA. This association was also found by Oyelaran-Oyeyinka (2003a) in his study on Nigerian firms and by Rasiah (2003, 2004) for East Asian manufacturing firms.

The age of the firm was found to be negatively and significantly associated with firms' likelihood to learn by innovating and by using in 1991. Under NAFTA, this variable did not have any significant effect on firms' election of learning mechanisms. There was no significant association between being a first-tier supplier and the adoption of learning mechanisms, with the exception of a negative relationship between this variable and the probability of acquiring new equipment in the period under NAFTA.

Contrary to our expectations and to the findings in other empirical studies of manufacturing firms in developing countries (Oyelaran-Oyeyinka 2002, 2003a), the nature of the ownership of firms did not play a significant role in either period. However, regardless of the econometric results presented here (which only reflect that the number of foreign firms did not change significantly over time), the presence of foreign auto parts firms is an important factor to consider because of their relevance in shaping practices in the Mexican market.

Lastly, the econometric analysis revealed that under NAFTA, the technological efforts engaged in by firms to build and strengthen their TC had a positive and significant effect on the adoption of learning mechanisms. We found that firms with a higher participation of university graduates and graduate managers in their workforce are more likely to learn by innovating. Managers with graduate level education had also a significant effect on learning through training in quality control activities.

We believe that the results presented in this chapter could be generalized to other developing countries facing changes in their macro environments due to stronger exposure to globalization (e.g., via Free Trade Agreements). The study also makes a contribution to the quantitative work on trends and characteristics of changes over time in firms' technological efforts and the specific ways (mechanisms) firms build, strengthen and update their technological capabilities.

It is important to note that the econometric model employed in this analysis does not tackle the quantitative effects of these learning mechanisms in firms' technological capability upgrading; its only objective is to provide insights into changes over time in the relationships among them, and to explain the role of firm-level factors and TE in the firms' election of the specific ways through which they learn. The analysis only considers changes in the trends of this set of firms that were founded in the period prior to NAFTA and does not take into consideration the exit or entry of new firms into the sector. Clearly there is a wide scope for further research.

Chapter 6

Exporting Mexican Auto Parts Firms

Abstract

The chapter analyzes a cross-sectional sample of 257 auto parts firms, illustrating that the production regime of the auto parts firms in Mexico under the NEM is segregated into strongly and poorly innovating firms. The chapter shows that internal knowledge, skills and experience bases differ widely among exporting and non-exporting firms. The analysis sheds some light on the internal structure of exporting auto parts firms and their innovative capabilities, contributing to the understanding of learning and innovation in the automobile industry in Mexico under NAFTA.

6.1 Introduction

According to the U.S. Office of Technology Assessment (OTA), in 1991 only a few Mexican auto parts firms had managed to achieve the cost and quality levels required for the export market.

NAFTA modified the orientation of automotive production to export markets. Exporting thus became a "necessity" under the new market conditions, and consequently, achieving international quality and production standards became a key requirement to be in the automotive supply chain. NAFTA propelled the Mexican industry into the export market (Bancomext 1999, 2000; Ramírez Tamayo 2003; Bancomext 2004). In 1993 there were five terminal firms (i.e., Ford, GM, Chrysler, Nissan and VW), and by 2003 there were seven terminal firms producing in Mexico and six with only commercial representation (see Figure 3-1), allowing domestic consumers to choose among 27 different makers of the same models available to consumers in the U.S., Japan or Europe (Ramírez Tamayo 2003).

Since NAFTA, the productivity of the auto parts and components industry has increased. Research has shown that the levels of automation in auto parts exporting firms are much higher than in firms oriented towards the domestic market (JICA 1996; Jasso and Torres 1998; Dominguez and Brown 2004). In addition, empirical evidence on Mexican manufacturing plants shows that firms with higher foreign ownership control and oriented towards foreign markets present higher productivity levels than those that are domestically owned (Perez Gonzales 2003).

This chapter sheds some light on the internal structure of auto parts firms and their innovative capabilities, comparing exporting versus non-exporting firms and thereby contributing to a better understanding of learning and innovation in the auto industry in Mexico. The chapter is organized into six sections. Following the introduction, Section 2 explains the methodology underpinning the empirical estimation and presents the model specification. Section 3 highlights the determinants of exports at the firm level and presents the data used. Section 4 shows descriptive statistics, while Section 5 presents the analysis of variance and discusses the empirical results. Section 6 summarizes the findings of the analysis.

6.2 Data

The data analyzed are obtained from the Mexican Entrepreneurial Information System (SIEM).[98] The sample consisted of 257 selected auto parts firms for the year

[98] The SIEM is located within the Ministry of Economy, and the data is collected by the National Chamber of the Manufacturing Industry (CANACINTRA).

2002. The selection was done after screening out the assemblers (terminal industry), commercial enterprises, firms registered as "sole proprietorship" and those with less than 20 employees (to keep consistency with the analyses performed in Chapter 5 and Chapter 7).[99]

The analysis made no distinction between firms producing for the after-market and those producing as an Original Equipment Manufacturer (OEM).[100] Due to the binary nature of the data, we estimate firms' probability of exporting with a probit model. The analysis allows us to establish certain patterns of behavior in firms manufacturing auto parts under NAFTA (2002).

6.3 Methodology

A. Probit Model

The econometric analysis assumes that export capabilities depend on a firm's own basic structural characteristics (e.g., size, experience). Formally, the model is written as:

$$y^{*}i = \beta \boldsymbol{x'}_i + \varepsilon\, i, \quad \varepsilon \sim N(0,1), \quad i=1,\ldots N \qquad \text{(eq. 0.1)}$$

where $y^{*}i$ is firm i's incentive to export and is unobservable, $\boldsymbol{x}_i$ is an observable vector of explanatory variables, βj the associated vector of parameters to be estimated and εij the unobservable variables affecting firm i's incentive to export its main product. The dependent variable yi is observed to be 1 if the firm exports, and 0 otherwise.

The model is performed for 257 automotive firms (establishments) in the year 2002 (under NAFTA conditions).

B. Marginal Effects

Because the model measures probabilities, the absolute scale of the coefficients obtained from the probit analysis provides a misleading picture of the response of the dependent variables to changes in one of the explanatory regressors. Therefore, it is necessary to estimate the marginal effects of the explanatory variable x_i in order to observe the proportional change in the dependent variable, y_i. This procedure is

[99] The set of firms oriented to commercial activities and those with "sole proprietorship" status constituted about 55.9% of the total population of automotive firms registered in 2002.
[100] See Chapter 3 for more details on the database.

done using the standard normal density function ϕ as the scale factor that translates the raw parameter estimates into marginal effects.

The marginal effects in the probit model are equal to:

$$\delta E[yi|xi] / \delta x = \phi(\beta x'i)\beta \qquad \text{(eq. 0.2)}$$

where $\phi(\beta x'_i)$ is the standard normal density function. As $\beta x'_i$ becomes increasingly positive, $\Phi(\beta x'_i)$ approaches 1, $\phi(\beta x'_i)$ approaches 0 and the marginal effects therefore approach 0. Similarly, as $\beta' x_i$ becomes increasingly negative, $\Phi(\beta x'_i)$ approaches 0 and $\phi(\beta x'_i)$ and the marginal effects again approach 0.

The discrete effect of the dummy variables included in the explanatory variables is obtained by taking the difference in the predicted probability with and without that dummy variable being equal to 1. Given the normalizations described above, this results in the following simple relationship for the discrete probability effect of a dummy variable:

$$E[yi|d = 1] – E[yi|d = 0] = \phi(\beta x'i + d) – \phi(\beta x'i) \qquad \text{(eq. 0.3)}$$

where *d* is the estimated parameter for the dummy variable.

As $\beta x'_i$ becomes increasingly positive, both terms of this expression ($\Phi(\beta x'_i + d) – \Phi(\beta x'_i)$) approach 1 and the net effect of the dummy variable approaches 0. As $\beta x'_i$ becomes increasingly negative, both terms approach 0 and, again, the net effect of the dummy variable approaches 0 (Andersen and Newell 2003).

6.4 Dependent Variable

Learning by exporting

This is a binary variable with value 1 if “the main product or service of the firm is sold to a foreign market,” and 0 otherwise.

6.5 Explanatory Variables

The explanatory variables used in the model are structural, firm-level characteristics and technological efforts engaged in by the firm.

A. Firm-level Characteristics

a. Firm Size

The study uses the natural logarithm of the number of employees as a measure of size, and it expects a positive significant relationship with the firm's probability of exporting.

b. Experience

To measure the firm's experience, we use the natural logarithm of the number of years since the firm began its actual manufacturing activity. This variable is expected to have a positive correlation with the probability of exporting.

c. Industrial Classification (by CMAP)

This variable has value 1 if the firm's main activity is the:

- Manufacture and assembly of bodies (384121)
- Manufacture of engines and their parts (384122)
- Manufacture of power train systems, parts and components (384123)
- Manufacture of suspension systems, parts and components (384124)
- Manufacture of brake systems, parts and components (384125)
- Manufacture of other [main] parts and components (384126)

B. Technological Efforts

a. Adoption of Quality Control Certifications

This variable has value 1 if the firm has adopted in its organizational management Quality Control Certifications (QCC), and 0 otherwise. QCC adoption is expected to have a positive relationship with probability of the firm of exporting.

b. Learning by Training

Assuming that exporting firms have higher learning capabilities, this variable is expected to have a positive relationship with firms' probability of exporting. It is measured by a dummy variable indicating whether the firm carries out training or not.

c. Adoption of Information and Communication Technologies

We consider Internet access as a proxy for ICT. This variable is measured with value 1 if the firm has access to email or has a web page, and 0 otherwise. It is expected to have a positive association with firms' likelihood to export.

d. Use of Imported Inputs in Production

We consider that exporting firms will acquire imported materials in order to achieve the quality and specifications required internationally. This is a binary dummy coded 1 if the firm acquires its main inputs from foreign markets, and 0 otherwise.

6.6 Descriptive Statistics

Table 6-1 shows descriptive statistics of the dependent and explanatory variables for both exporting and non-exporting firms. T-tests are performed to assess whether the differences between the means of the two groups are significantly different from each other.

Results reported in Table 6-1 show that 40% of firms in the sample export their main product. Significant firm-level characteristics and technological efforts between exporters and non-exporting firms are observed.

Under the assumption that firms oriented to foreign markets are more innovative than those focused on the domestic market, t-test results reported in Table 6-1 present a segregation of firms into exporting and non-exporting groups.

The results also suggest that exporting firms differ significantly in their internal knowledge, skills and experience base. Exporters have significantly more quality control certifications, use of ICT, training programs and use of imported inputs in production. It appears that older firms have a stronger orientation towards the domestic market. This may be part of their "memory" formed during the ISI period and the result of a long protective tradition under which production was domestically oriented and had lower quality standards than those required internationally.

This finding brings into consideration an important element of the SI approach: the role of history in shaping the nature of systems' agents as "products of their environments" (Oyelaran-Oyeyinka and Barclay 2002).

Regarding technological efforts engaged in by all firms in the sector, the results indicate a significant adoption of modern managerial tools (e.g., quality control certifications and communications technology). This may reflect the need to adopt international standards in order to maintain operations locally or internationally.

The same may explain the high percentage of training given in both types of firms. Macario (2000), in her study on Latin American manufacturing firms under the NEM, appoints a set of common innovative strategies especially important to exporting firms, such as the adoption of quality control, just-in-time techniques, information technologies, production and managerial standards and training of personnel.

From these results, we can presume that auto parts firms are trying to cope with those international managerial and production standards that require certain levels of learning to facilitate their adoption and implementation.

With relation to the origin of raw materials used in production, Table 6-1 shows that eight of every 10 exporting firms are importing their main inputs. This is significantly different for non-exporting firms, of which only one out of every 10 imports its inputs.

This finding supports the hypothesis that the supporting industry in Mexico is not well developed (Bancomext 2000). Therefore, firms import their main inputs in order to produce in line with the international production and quality standards. In part, this finding may well indicate the lack of domestic integration of industry in the country. A well-developed system of production will necessarily have more cohesive supplier-producer relationships nationally.

Table 6-1 Descriptive Statistics for Auto Parts Firms (2002)

	Exporting Firms Number of firms = 105				Non-Exporting Firms Number of firms = 152				Group means T-test		T-test findings
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	t-statistic	p-value	
<u>Dependent Variable</u>											
Learning by exporting (N = 257)	0.408	0.492	0	1							
<u>Explanatory Variables</u>											
Size of firm (in log)	5.915	1.239	3.135	8.625	5.257	1.276	3.13	8.17	4.1098	0.0000	X-firms are larger in size
Experience of firm (in log)	2.518	0.687	0.693	3.806	2.644	0.702	0.69	3.97	-1.429	0.0770	X-firms are younger
Industrial classification (dummy):											
a) Body and power-train	0.085		0	1	0.098		0	1	-0.350	0.7266	No changes
b) Engine and engine parts	0.190		0	1	0.236		0	1	-0.883	0.3781	No changes
c) Power-train system	0.047		0	1	0.065		0	1	-0.608	0.5432	No changes
d) Suspension system	0.057		0	1	0.046		0	1	0.397	0.3457	No changes
e) Brake system	0.038		0	1	0.723		0	1	-1.150	0.2510	No changes
f) Other auto parts and components	0.580		0	1	0.480		0	1	1.590	0.0565	Higher number of exporters
Quality control certifications (dummy)	0.790		0	1	0.605		0	1	3.180	0.0008	Higher adoption in exporters
Adoption of ICT (dummy)	0.590		0	1	0.486		0	1	1.638	0.0513	Higher adoption in exporters
Training (dummy)	0.933		0	1	0.822		0	1	2.604	0.0049	More training in exporters
Use of imported main inputs (dummy)	0.790		0	1	0.131		0	1	14.06	0.0000	Higher use by exporters

6.7 Econometric Analysis and Results

Table 6-2 presents the marginal effects of the probability of exporting in auto parts firms in 2002.

The size of the firm and the use of imported inputs in production are the only two positive and significant characteristics associated with firms' likelihood to export. The finding illustrates an important change in the production organization of domestic firms brought about by the NEM. Macario (2000) reports that in Latin American manufacturing firms, the proportion of imported inputs used in firms' production process increased substantially with trade liberalization, as firms had to achieve the standards and requirements established internationally. Large firms are expected to be more capable of coping with these requirements.[101]

The results also indicate that firms producing engines (and engine parts), power-train and brake systems are significantly less likely to export than those producing bodies and power-trains.

Table 6-2 Marginal Effects

Independent Variable: Exports		
	y = Pr (exports = 1) = 0.3718	
Number of firms = 257	Coefficient♣	Std. Err.
Explanatory Variables		
Size of firm (number of employees in log)	0.060***	0.033
Experience of the firm (in log)	-0.005	0.055
Industrial classification (CMAP):♣		
a) Engine and engine parts	-0.347*	0.098
b) Power-train system	-0.252***	0.117
c) Suspension system	-0.170	0.169
d) Brake system	-0.260***	0.115
e) Other auto parts and components	-0.210	0.130
Quality control certifications♣	-0.091	0.103
Adoption of ICT♣	0.012	0.075
Training♣	0.138	0.118
Use of imported main inputs♣	0.679*	0.054

Note: ♣ For dummy variables, it shows a discrete change from 0 to 1. * Significant at 1%, ** significant at 5%, *** significant at 10%.

The technological efforts analyzed were not significant in explaining firms' likelihood to export. This may be due to the quality of the variables, which do not provide the

[101] In Chapter 5, we find that under NAFTA, the size of the firm was positively and significantly associated only with firms learning by innovating.

type of ICT used and training provided in firms. ICT is useful when it is used as a tool to actively interact with foreign markets (e.g., research new customer trends, regulations, market analysis).
The results suggest that the benefits of this tool are not efficiently maximized by firms in the sector (probably the question should be complemented with firms' ability to communicate in foreign languages, but this information is not readily available).

Results in Chapter 5 already provide us with an insight into the type of training (relatively poor) in firms in the sector. Therefore, it is not surprising that training was not found to be significantly contributing to learning by exporting.

6.8 Discussion of Findings

Several authors have considered trade liberalization as a mechanism through which firms improve performance and stimulate economic growth (Pack 1988; Ten Kate 1992). The NEM in Latin America opened the region to foreign competition, bringing about a new economic environment in which exports were the main instrument in achieving development. These market changes forced existing firms to make significant managerial and production changes in order to survive (Macario 1999, 2000a).
In Mexico, the automobile industry is an important example of an industry undergoing this sort of adaptation to new economic conditions. As presented by Bancomext (2003), the auto industry has assumed increasing relevance as an engine of growth of the Mexican economy, mainly due to its significant employment generation and export contribution, about 34% of total exports in 2002 (INEGI 2003).

The analysis conducted in this chapter started from the premise that exporting firms have achieved deeper learning capacities and developed stronger innovative capabilities than non-exporting firms (Feder 1982; Macario 1999, 2000a). We used t-tests to explore firms' basic internal characteristics in order to differentiate exporting from non-exporting firms. The results from the t-tests indicated that larger firms and firms created under NATA are more likely to export, reflecting the nature of the environment under which they were created. The econometric analysis supports the findings regarding the size of the firm, and although it finds a negative relationship between older firms and their export probability, this relationship is not statistically significant.

The t-test results also suggest that the adoption of modern managerial and production techniques (e.g., QC certifications, ICT adoption) and training is significantly higher in exporting firms than in domestically oriented ones. The adoption of these production techniques implies a full understanding of the firm's processes by its employees. It also implies deeper knowledge of the process specifications followed internationally. It means the firm has developed the capacity to control its processes and the capacity to respond and solve any possible problem regarding production control. Therefore, before being able to implement these techniques, firms have to undertake important learning processes that would allow them to maintain the adopted techniques and to keep upgrading to meet international production requirements.

The marginal effects from our probit analysis only support the t-tests' suggestion that large firms and those using imported inputs in production are likely to export. The econometric results indicate that more productive auto parts firms find it increasingly more efficient and profitable to import parts and subcomponents than to produce them, thereby creating manufacturing operations with little local content integration. All this suggests that imported parts and components have displaced domestic supply, leading to a weakening of the domestic supply chain.[102] The results also support the findings reported by Bancomext (2000) in which the poor development of the supporting industry –especially raw materials and high-tech components – is recognized. This may reflect a lack of domestic inputs that can compete international standards in price and/or quality.

Based on the results of our analyses and considering exporting firms as those with more developed innovative capabilities, we do not have enough evidence to reject the following statement: *The production regime of the auto parts firms in Mexico under the NEM is segregated into strongly and poorly innovating firms.* We could also add that the internal knowledge, skills and experience bases of these two groups of firms differ significantly.

The evidence provided is not conclusive enough to assert that a firm that is exporting has higher technological capability levels than one that is not exporting. However, the results suggest a significant relationship between the propensity for learning by exporting and the more complex auto parts produced by exporting firms (i.e., engine and engine parts, power-train and suspension systems].

The automobile industry is considered an important source of economic growth, mainly due to its ability to export. The results of the empirical analysis show that exporting firms are significantly importing their main inputs. This raises important questions about the levels of dependency and integration of the industry on foreign inputs. The evidence suggests that auto parts firms find it more efficient and profitable to import parts and components than to produce them. This phenomenon

[102] These results will be complemented by those of the analysis presented in Chapter 7.

raises even more questions about the levels of local learning, the acquisition of innovative capabilities by local firms and knowledge spillover effects to other sectors of the economy. These issues are analyzed in more detail in the following chapter.

Chapter 7

Integration in the Mexican Auto Parts Industry

Abstract

This analysis calls attention to the significant dependency of auto parts firms on imported inputs. Based on a database with a total of 1304 OEM firms for 4 years under NAFTA (1995, 1998, 2000 and 2002), the analysis explores trends and the relevance of size, ownership and imports in production as factors favoring exports. The results of the analysis suggest that imported parts and components have displaced domestic supply, leading to a weakening of the domestic supply chain, and that the production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms that differ widely in their internal knowledge, size and technological efforts.

7.1 Introduction

In the case of the automotive industry, transferring manufacturing operations outside the country of origin of the assemblers was the most important step in the internationalization of the industry's production process. Gradually the industry started to reduce its vertical integration, selling much of its in-house manufacturing operations and concentrating on designing, engineering and marketing as core activities. To be sure, the assemblers' headquarters remain the *governors* of the automotive value chain; they take responsibility for assisting and satisfying the demands of their customers in this *buyer-driven* chain (Humphrey and Memedovic 2003). Due to the high entry barriers and expensive learning required in automobile production, we find a group of first-tier suppliers, closely linked with the assemblers, manufacturing the key parts and components of the automobiles. These first-tier suppliers commonly follow the assemblers in installing production plants internationally. Domestic firms located in the host country supply parts and components to first-tier suppliers and assemblers' subsidiaries.

In Mexico, automobile production until 1994 was classified according to market orientation. Production for the domestic market had higher levels of local content requirements and lower quality requirements than what applied to export-oriented production firms. The 1989 Automobile Decree [gradually] eliminated the protection barriers to external competition, while maintaining the industry's distinction between firms according to their target market. The decree also significantly reduced import tariffs on vehicles and on parts and components, allowing exporting firms to import parts and components on favorable trade terms. With the arrival of NAFTA in 1994, the industry was united into a single export-oriented market, and exporting firms could import vehicles, parts and components without duty in Mexico. Consequently, under NAFTA, Mexico became an attractive location for vehicle assembly and labor-intensive auto parts production (Lynch 1998). As a result of the massive influx of foreign assemblers [and their first-tier suppliers] into the country, the domestic industry had to cope with international production and quality standards.

Local content requirements were imposed and gradually reduced under NAFTA (see Appendix - Chapter 3) as a way to encourage firms to procure a minimum proportion of intermediate inputs domestically. This implied that firms had to engage in explicit technological efforts in order to achieve the capabilities required to supply the assemblers and other suppliers.

This chapter analyzes the mode and intensity of domestic integration within Mexican auto parts suppliers and the level of import dependence of the industry.

The chapter tests whether an important proportion of imported parts and components are significantly preferred in production over those that are domestically supplied, thereby weakening the domestic supply chain. Without being a value chain analysis, the chapter analyzes the level of integration of the industry with foreign actors. It considers imports of main inputs in output as a proxy for integration. Higher levels of imports may reflect a higher level of dependence on foreign producers and foreign actors' decisions. This may also have an effect on the level of learning and innovation of the industry as some capabilities are substituted by imports.
Considering exporting firms to be more innovative than non-exporting ones, the chapter also tests if the production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms, and if these firms differ widely in their internal knowledge, size and technological efforts.

The following section describes the data used in the analysis. Section 3 describes the methodology followed. Sections 4 and 5 discuss the dependent and explanatory variables. Section 6 discusses descriptive statistics of the data used. Section 7 presents the econometric results. A discussion of findings is presented in Section 8.

7.2 Data

The analysis is based on firm-level data obtained from an internal database collected by the Automobile Industry Department of the Ministry of Economy.
Data were collected to diagnose the level of local content integration of the industry under NAFTA. The database contains information for the years 1995, 1998, 2000 and 2002. After screening out firms with less than 20 employees, we worked with a data pool of 1,304 observations, allowing for different intercepts over time for the years analyzed.[103]

The sample does not include firms from the terminal industry and only includes firms exporting OEM parts and components.

7.3 Methodology

A. Probit Model

The econometric analysis assumes that export capabilities depend on the firm's own basic structural characteristics (e.g., size, experience).

[103] The slopes are assumed to be equal over time.

Formally, the model is written as in equation 6.1, where y^*i is firm *i*'s incentive to export and is unobservable, $\boldsymbol{x}_i$ is an observable vector of explanatory variables, β_j the associated vector of parameters to be estimated and εij the unobservable variables affecting firm *i*'s incentive to export its main product. The dependent variable y_i is observed to be 1 if the firm exports, and 0 otherwise.
The model is performed for 1304 automotive firms (establishments) for the years 1995, 1998, 2000 and 2002 (under NAFTA).

B. Marginal Effects
Because the model measures probabilities, the absolute scale of the coefficients obtained from the probit analysis provides a misleading picture of the response of the dependent variables to changes in one of the explanatory regressors. Therefore, it is necessary to estimate the marginal effects of the explanatory variable x_i in order to observe the proportional change in the dependent variable y_i.
This procedure is done using the standard normal density function ϕ as the scale factor that translates the raw parameter estimates into marginal effects.

The marginal effects in the probit model are equal to equation 6.1, where $\phi(\beta x'_i)$ is the standard normal density function. As $\beta x'_i$ becomes increasingly positive, $\Phi(\beta x'_i)$ approaches 1, $\phi(\beta x'_i)$ approaches 0 and the marginal effects therefore approach 0. Similarly, as $\beta' x_i$ becomes increasingly negative, $\Phi(\beta x'_i)$ approaches 0 and $\phi(\beta x'_i)$ and the marginal effects again approach 0.

The discrete effect of the dummy variables included in the explanatory variables is obtained by taking the difference in the predicted probability with and without that dummy variable being equal to 1. Given the normalizations described above, this results in the following simple relationship for the discrete probability effect of a dummy variable (equation 6.3), where *d* is the estimated parameter for the dummy variable.

As $\beta x'_i$ becomes increasingly positive, both terms of this expression ($\Phi(\beta x'_i + d) - \Phi(\beta x'_i)$) approach 1 and the net effect of the dummy variable approaches 0. As $\beta x'_i$ becomes increasingly negative, both terms approach 0 and, again, the net effect of the dummy variable approaches 0 (Andersen and Newell 2003).

7.4 Dependent Variable

Learning by exporting

This is a binary variable with value 1 if the main OEM product or service of the firm is sold to a foreign market or sold to another firm that will export its final product, and 0 otherwise.

7.5 Explanatory Variables

A. Firm Characteristics

1. Firm Size

The study uses the number of employees as a measure of size, and it expects a positive significant relationship with firms' probability of exporting. As in other analyses, natural logarithm is used for the number of employees.

2. Ownership Structure

To measure the firm's ownership, we give value 1 if the firm has more than 51% foreign equity participation, and 0 otherwise.

B. Technological Efforts

Share of Imported Inputs in Output

We consider that exporting firms acquire imported materials in order to achieve the quality and specifications required internationally. The variable is formed by two components:

a) Share of imported inputs in gross sales. This variable is the proportion of imported inputs in gross sales.
b) Share of imported inputs in exports. This variable is the proportion of imported inputs in exports.

7.6 Descriptive Statistics

T-tests are performed to assess whether the differences between the means of exporters in different years are significantly different from those in 1995.

The results are reported in Table 7-1, which shows that with the exception of a peak in 1998, there are no significant changes in the number of exporting firms with respect to 1995.

The average number of OEM exporting firms under NAFTA is about 34%, although after 1998 we can observe a decline in the number of exporters. With respect to the origin of materials used in export production, Table 7-1 shows that, in order to produce in line with international production and quality standards, about 50% of exports are based on imported inputs. This finding is in line with the findings presented in Chapter 6, and it supports the thesis that the supporting industry in Mexico is not well developed (Bancomext 2002).

Table 7-1 Descriptive Statistics for OEM Exporting Firms (under NAFTA)

	No. firms	Mean	Std. Dev.	Min	Max	Group means T-test t-statistic	p-value	T-test findings (Compared to 1995)
Dependent Variable								
Learning by exporting in 1995	304	0.273		0	1			
Learning by exporting in 1998	310	0.529		0	1	-6.6894	0.0000	More exporters
Learning by exporting in 2000	346	0.315		0	1	-1.1706	0.2422	No changes
Learning by exporting in 2002	344	0.241		0	1	0.9231	0.3563	No changes
Explanatory Variables (in exporting firms)								
Share of imports in exports 1995	83	50.23	22.36	0	85.7			
Share of imports in exports 1998	164	41.55	24.90	0	91	2.6747	0.0040	Decreased
Share of imports in exports 2000	109	49.71	25.42	0	100	0.1487	0.8820	No changes
Share of imports in exports 2002	83	45.82	23.67	0	92.1	1.2323	0.2196	No changes

We assume that firms oriented to foreign markets are more innovative and have higher levels of performance than those focused on the domestic market (Feder 1982).

T-test results reported in Table 7-2 show descriptive statistics of the explanatory variables for both exporting and non-exporting firms. It presents a segregation of firms into exporting and non-exporting groups. The results also show that exporting firms are larger than non-exporting firms. However, both groups of firms reported a similar growth in size during the period analyzed.

The results suggest that imported inputs are relevant not only to exporting firms but also to non-exporting firms – which are oriented only towards the domestic market. Increasing imports of foreign inputs in non-exporting firms and a similarly sized reduction of such imports in exporting firms suggests an interesting convergence trend in the average share of imports in output for both groups.[104] This is not further analyzed in this research, but it opens up a subject that could be explored later.

[104] A possible reason for the convergence could be that the parts imported by firms catering to the domestic market might be spare parts (i.e., parts and components used in car repair and not in the assembly and manufacturing of new cars). A second point that may explain this possible convergence is the globalization of the industry as well as the use of auto platforms with greater standardization of parts across many car models, all of which means that those serving the local and export markets will have to have the same inputs and outputs (this is discussed in section 3.3).

Table 7-2 Descriptive Statistics for OEM Auto Parts Firms (Under NAFTA)

	Exporting Firms				**Non-Exporting Firms**				**Group means T-test**		**T-test findings**
Explanatory Variables	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	t-statistic	p-value	
1995	**Number of firms = 83**				**Number of firms = 221**						
Size of firm	6.157	1.304	3.367	9.535	4.746	0.925	3.135	8.332	10.346	0.0000	X-firms are larger in size
Ownership of firm	0.650		0	1	0.61		0	1	4.659	0.0000	More X-firms are foreign
Share of imports in output (gross sales)	49.142	19.823	0	80	31.363	22.300	0	77.98	6.377	0.0000	Higher use by exporters
1998	**Number of firms = 164**				**Number of firms = 146**						
Size of firm	5.960	1.232	3.295	9.332	4.835	0.981	3.178	7.383	8.818	0.0000	X-firms are larger in size
Ownership of firm	0.567		0	1	0.479		0	1	1.543	0.0619	More X-firms are foreign
Share of imports in output (gross sales)	40.480	21.336	0	78.69	34.867	23.158	0	79	2.220	0.0135	Higher use by exporters
2000	**Number of firms = 109**				**Number of firms = 237**						
Size of firm	6.586	1.333	3.367	9.742	5.162	0.951	3.258	7.766	11.326	0.0000	X-firms are larger in size
Ownership of firm	0.697		0	1	0.544		0	1	2.710	0.0035	More X-firms are foreign
Share of imports in output (gross sales)	46.288	21.882	0	84.22	35.619	21.546	0	79.95	4.2577	0.0000	Higher use by exporters
2002	**Number of firms = 83**				**Number of firms = 261**						
Size of firm	6.853	1.354	3.637	10.33	5.461	1.042	3.135	8.277	9.815	0.0000	X-firms are larger in size
Ownership of firm	0.7108		0	1	0.590		0	1	1.979	0.0230	More X-firms are foreign
Share of imports in output (gross sales)	45.851	19.387	0	78.80	36.783	21.343	0	80	3.444	0.0003	Higher use by exporters

7.7 Empirical Results

Table 7-3 presents the marginal effects of the probability of exporting auto OEM parts and components under NAFTA.

The size of the firm and the share of imported inputs in output are positive and significant characteristics associated with firms' likelihood to export OEM products.[105]

The results support the findings reported in Chapter 6, indicating that imported inputs play an increasingly significant role in exports. This may be explained by the need to achieve the standards and requirements established internationally and may well point to the poor quality or lack of inputs from the domestic supporting industry (Macario 2000a; Macario, Bonelli, Ten Kate et al. 2000; Bancomext 2004).

Table 7-3 Marginal Effects

Independent Variable:	Exports	
	y = Pr(exports=1) = 0.2967	
Number of firms = 1304	Coefficient♣	Std. Err.
Explanatory Variables		
Size of firm (in log)	0.2013*	0.0134
Ownership of firm♣	0.0420	0.0316
Share of imports in output (scale 0 to 1)	0.0036*	0.0007
1998♣	0.2466*	0.0445
2000♣	-0.0525	0.0396
2002♣	-0.1757*	0.0360

Note: ♣ For dummy variables, it shows a discrete change from 0 to 1.
* Significant at 1%, ** significant at 5%, *** significant at 10%.

The results also indicate that as the structural implementations associated with NAFTA intensified, firms' likelihood to export OEM products decreased significantly. This may result from two important reasons. First, the weak technological capabilities developed in the sector. As suggested in previous chapters, the industry has not achieved the level of technological mastery required by the OEM firms to compete internationally. Second, the high dependency on imports promotes sector vulnerability to exchange rate fluctuations. The combination of both factors raises questions about the inadequate innovation support system of the sector. Chapter 8 elaborates more on this issue.

[105] In Chapter 6, we also found that size of the firm was positively and significantly associated only with firms learning by exporting.

7.8 Discussion of Findings

The chapter analyzes firms manufacturing original equipment (OEM), which are assumed to have higher capabilities than those oriented towards the after-market. These are firms that have made significant managerial and productive changes in order to be certified as OEM. They have significantly closer relationships with foreign OEM firms and are assumed to be the best of the automobile supplier pool in Mexico.

The empirical findings of the chapter indicate a significant dependency on foreign inputs by both exporting and non-exporting OEMs. The description of the data also shows that although there is a slight reduction in the share of imported inputs in output for these firms (exporting firms), the percentage of imported inputs used in export production is higher than that used for domestic production. This may suggest that the most internationalized auto parts firms are actually increasing their levels of domestic integration while non-exporting firms are not. This suggests that exporting OEMs still find it significantly more efficient and profitable to import parts and components than to produce them or to acquire them in the national market.

The data also suggest a convergence in terms of import intensity by both exporters and non-exporters. However, it is important to remember that gross sales value – our proxy for output -- includes costs of production (i.e., including inputs), factors payments (e.g., wages and salaries, rent, depreciation of capital) and administrative and marketing expenses. Considering that at least the last three of these items have to be locally supplied, the local content inclusion of manufactured goods in actual production is probably still low.

Increasing imports of inputs in production slows down local learning in the industry and its related sectors (Amsden 1989). Therefore, based on the reduction of imports shares in output by exporting firms, we consider that there is no robust evidence to support the statement that imported parts and components have displaced domestic supply, leading to a weakening in the domestic supply chain. However, based on the empirical evidence of the positive and significant influence of imported inputs in exports found in our analysis, and supported by the recognition of the poor development of the industry – especially regarding raw materials and high-tech components found by JICA (1996) and Bancomext (2004) -- we find that the domestic supply chain has not been strengthened under NAFTA, and that an imported proportion of imported parts and components is significantly preferred in production over those that are domestically supplied, thereby weakening the domestic supply chain.

Based on the different results for exporting and non-exporting firms, the chapter suggests that the production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms. Considering exporting firms as a proxy for innovating firms we deduct that the internal knowledge and technological efforts differ from those non exporting firms.

From the perspective of political factors regulating the value chain of the industry nationally, we conjecture that learning and capabilities acquisition by exporting auto parts firms is strongly and significantly correlated with the disruption of the national supply chain. This raises important questions on the level of dependency and integration of the industry with foreign actors (and inputs). It raises even more questions on the levels of local learning, the acquisition of innovative capabilities by local firms and knowledge spillover effects to other sectors of the economy. These issues are approached in more detail – under the umbrella of the SI – in the next chapter.

Chapter 8

Conclusions and Discussions of Findings

With the coming into force of NAFTA, it was expected that Mexican-owned auto parts firms would be able to build the capabilities needed to compete as auto parts suppliers under the new market structure brought about by this trade agreement.
The research analyzes changes in a set of auto parts firms that started under a different regime than NAFTA (i.e., ISI). In the transition between ISI and trade liberalization (early 1980s), auto assemblers (which were all foreign-owned by the early 1980s) were subjected to state pressures to establish backward linkages in order to fulfill state-imposed local content requirements. However, this was done in a protected domestic market that did not stimulate learning and innovation in the auto parts supply sector. Therefore, there was little learning and innovation in the supply sector before NAFTA, as pointed out in Chapters 3 and 4.

Early data from JICA (1996) and Jasso and Torres (1998) suggested that Mexican-owned firms (i.e., those with more than 50% Mexican equity participation) had not yet adjusted in the early NAFTA years (i.e., early-mid 1990s). Jasso and Torres (1998) found that due to the auto industry's dependency on the strategies and designs of the assemblers (all foreign), the auto parts industry had very little – if any – product development. This took place because prior to NAFTA, regulations changed, allowing foreign automotive assemblers to progressively take over their Mexican-owned domestic competitors, and as foreign firms had already adjusted to the new mode of competition globally by this time, they were likely to be looking to suppliers who could provide them with the quality of inputs that the domestic suppliers could not deliver.

JICA (1996) and Jasso and Torres (1998) found that in the early years of NAFTA, the levels of automation, production technologies, organizational strategies and quality control differed according to the ownership structure of the auto parts firms. These authors found that Mexican-owned auto parts firms were mainly producing for the domestic market, with much lower quality levels than foreign auto parts firms.

This chapter complements the thesis discussion with an analysis of why the Mexican-owned auto parts firms could not catch up under NAFTA. The arguments presented here are based on the innovation systems and capability building literature, and thus we developed tools to analyze changes in learning mechanisms and in innovation. The thesis analyzes changes in the adoption of learning mechanisms by a set of 192 auto parts firms in the pre- and post-NAFTA period. It uses data from the innovation surveys for the years 1994, 1998 and 2000 and compares it with the data for the same set of firms for 1991. Five learning mechanisms were selected and analyzed in a multivariable probit model. These mechanisms are: learning by training (divided into training in quality control issues and training in operational activities), learning by innovating, learning by searching and learning by using.[106] The analysis also includes technological efforts and firm-level characteristics as main explanatory variables.

This thesis thus systematically examines the auto parts sector and, using trade data and data on the ownership composition of the industry (i.e., foreign or locally owned), finds that there were some important, but negative changes with regard to locally owned auto parts suppliers' participation in the export market (see analyses in Chapters 6 and 7). The results found an increasing rise in imported parts and components in export production, suggesting a displacement in the domestic supply and a weakening of the supply chain.

Basing innovation studies on empirical analyses without a deep understanding of the context of the industry could result in superficial insights that are not sufficiently rooted in reality to allow drawing policy conclusions meant to enhance learning-based development. It is only by the combination of both econometric and historical perspectives that we can really appreciate in depth the nature of the problem analyzed. Combining both approaches gives us a more robust understanding of the innovation and learning patterns followed by the Mexican auto parts industry. The main contribution of this thesis does not derive from quantitative results obtained from econometric analyses alone. We combined the historical and the institutional context with our empirical analyses and complemented the econometric results with perspectives provided by the systems of innovation approach.

The following six sections present the main findings and implications of the research supporting the thesis. Section 7 presents the methodological impressions of this research. Section 8 presents policy reflections deriving from the main conclusions and findings reached in the thesis.

8.1 Firm-Level Characteristics and Learning and Innovation Activities.

Firm-level characteristics are relevant when industries face structural changes in their operating environment. The important role firms' characteristics play in sector development is widely recognized in much of the literature. However, from our results, although relevant, they are not always significant variables in determining how the sector builds its innovation and learning capabilities. Institutional factors are the most influential element impacting learning and innovation – as in the case

[106] The composition of these variables can be seen in Section 5.3 of Chapter 5. In addition, see footnote 94 for more details on the construction of learning by using.

of the automotive decrees and NAFTA. These factors also have an indirect impact on firm-level characteristics.

A firm's size, without a doubt, has an important influence on the type of learning decisions a firm makes. It is an important element in generating dynamism in the sector. Large firms are believed to have the capability to face changes in the market and in the macroeconomic conditions of their countries. In the particular case of this research, econometric analyses show that the number of employees is a significant factor related to firms' adoption of traditional learning mechanisms. This variable was significant to firms' probability of learning by innovating and learning by exporting. Means analysis presented in Table 7-2 illustrates that those firms exporting OEM parts are larger than those focused on the domestic market.

In the literature, ownership plays a role in the capability of firms to read and react to market signals and to invest in learning. The nature of ownership also plays an important role in the relationships between the agents of the system, as it leads to different structural alternatives and behaviors between firms. Trade liberalization not only opens the market to external competition and technologies; it also exposes the economy to greater influence by foreign interests, trends and performance.

In the Mexican case, the denationalization of the terminal industry in the early 1970s brought the active influence and participation of foreign actors into the system of innovation (SI) of the industry, along with their own networks and business logic. With the assemblers being totally foreign firms, the national system of innovation was strongly influenced by the international groups, financers, suppliers and governments related to those international firms, linking the development of the national auto industry to international trajectories and, consequently, reducing the government's power to drive and plan the national development of the industry.
Clearly, the assemblers determine to a large extent the developmental route to be followed, while the auto parts industry follows. With all the assemblers being foreign-owned, the composition of local parts suppliers also changed, as foreign first and second-tier suppliers moved to Mexico following the assemblers with whom they already had an established relationship internationally.

The empirical analyses of this case study did not find the role of ownership to be a significant factor either in auto parts firms' decisions to engage in the learning mechanisms analyzed or in their probability of exporting. However, foreign ownership has indirect effects that should not be minimized due to the econometric results. The presence of foreign auto parts manufacturers, although fewer in number than Mexican-owned firms, is more important because they shape practices in the Mexican market. Therefore, the relevance of ownership is considerable for the industry's development, and although we did not find it significant in our econometric exercises, we cannot deny that there are more complex interactive shaping mechanisms at work, such as those suggested in the innovation systems literature. This indicates a need to constantly consider both what we can learn from econometrics and what the broader system changes can tell us about learning and innovation.

No significant relationship between first-tier suppliers and the choice of learning mechanisms was found. This result does not justify the hypothesis that first-tier suppliers are technologically superior to firms from lower tiers (an assumption made at the beginning of this research) and therefore more likely to engage in more complex learning mechanisms. That is probably because high levels of specialization were also found among second and third-tier suppliers.

Thus, based on the empirical results from this thesis, we did not find robust evidence to support the statement that domestic innovation and learning mechanisms of the auto parts industry are correlated with firm size, ownership structure and supplier tier level. However, from the institutional and historical analysis presented in Chapters 3 and 4, we conclude that although not significant, these three characteristics of firms played an important role in shaping the habits and practices of auto parts firms (particularly of Mexican-owned ones), which influenced the development of the sector.

8.2 Learning Mechanisms as Ways to Build Technological Capabilities.

The thesis presents empirical evidence suggesting that the changes in the market environment that resulted from the regulations brought about by NAFTA, as well as the globalization strategy followed by the automobile assemblers, have impacted the production regime of automotive suppliers in Mexico, their innovation and their learning behaviors and capabilities.

From the analysis in Chapter 5, we see that under an open environment – in which domestic production is exposed to global competition and international production standards – the technological efforts by which firms engage in explicit and meditated processes aimed at technological learning and mastery differ significantly from those efforts made under a protected market. The ways and specific activities through which firms build and strengthen their technological capabilities (i.e., learning mechanisms) also differ over time.

The upper part of Table 8-1 presents a review of the mean averages and group means tests on changes in the adoption of learning mechanisms and technological efforts in the auto parts industry before and after the implementation of NAFTA. The bottom part of the table presents the results of the LR test suggesting that the effects of the firm-level characteristics and technological effects on the learning mechanisms analyzed were different before and under NAFTA. The results also justify the use of a general model over a restricted one for the econometric analysis conducted in Chapter 5.

Table 8-1 Adoption of Learning Mechanisms and Technological Efforts Adopted in the Auto Parts Industry Before and Under NAFTA (% of firms)

N = 192 firms	Before NAFTA	Under NAFTA
A. Learning Mechanisms		
1. Learning by training		
a) Quality control training activities	22%	40%***
b) Operational training activities	58%	58%
2. Learning by innovating[107]	68%	47%***
3. Learning by using[108]	57%	65%**
4. Learning by searching[109]	31%	38%**
B. Technological Efforts		
1. Adoption of mechatronics[110] in production	5%	13%***
2. Level of education of the workforce		
a) Participation of workforce with university degree	9%	12%***
b) Participation of managers/blue collar workers with graduate studies	21%	16%**
3. Adoption of lean production techniques (i.e., JIT and TQC)	16%	52%***
4. Adoption of Statistical Process Control	18%	42%***

LR Test Results	II (model)	No. parameters
General Model		
Before NAFTA (192 observations)	-551.559	65
Under NAFTA (537 observations)	-1723.831	75
Restricted Model (729 observations)	-2322.286	80

Source: Based on results found in the empirical analysis conducted in Chapter 5 (see Table 5-4).
***significant at 1% ** significant at 5% *significant at 10%.

Two important findings emerge from the empirical analysis illustrated in Table 8-1. The first one is that the adoption and types of learning mechanisms (and the signifi-

[107] Defined as: a) Design of new products, including increasing the variety of products; b) Quality improvements in process and/or product (including the adoption of new or improved productive processes that contribute to increased productivity and quality control); c) Design, improvement and manufacture of machinery.

[108] Defined as the acquisition of new machinery and equipment.

[109] Defined as the acquisition of technological packages and/or technology transfers.

[110] Use of robots and Computerized Machine Tools in production.

cance of the interrelationships among them) changes when market conditions and the economic environment undergo structural transformations. The second one is that the association between different technological efforts (TE) and learning mechanisms is influenced by the socio-economic environment of the firm and the changes to this environment over time.

Regarding the first finding, the methodology used in Chapter 5 allows us to analyze learning mechanisms as correlated actions that have direct influence on the adoption of other mechanisms. This methodology also permits us to compare the pattern of adoption of TE by the same set of firms at different periods of time (i.e., under different market conditions). From the econometric results, we deduce that TE that are relevant in one period of time are not necessarily significant under a different time frame or under different market conditions. The market environment in which the firm performs has an important influence on the significance of the TE engaged in and the intensity with which learning mechanisms are adopted.

One of the most important changes that NAFTA brought to the automobile industry was the homogenization of production requirements and the orientation towards export markets.[111] The results from the empirical analysis (i.e., Chapter 5) show that before the market-induced changes brought about by NAFTA, the adoption of techniques associated with lean production (e.g., JIT, QC and SPC) constituted significant TE that influenced the adoption of certain learning mechanisms through which firms built TC (see Table 8-1).

The econometric analysis also finds that with the market changes introduced by NAFTA, the association between learning mechanisms and TE changed. The significance of the relationship between TE and learning mechanisms shifted towards more technologically sophisticated efforts, such as mechatronics (i.e., CPC and robots), and towards the increasing participation of a more highly educated workforce and managers.

NAFTA brought about a new regulatory and operational framework in 1994, under which the assemblers required the auto parts suppliers to homogenize their production to international standards (including quality requirements). Under these new requirements, many auto parts firms increased efforts focused on the adoption of lean production techniques (e.g., JIT, TQC) in the years under NAFTA.

[111] Before NAFTA, the industry was divided into production towards the export market and production for the internal market, both with different production requirements and quality specifications.

The results indicate that although these TE were significantly important leading up to NAFTA, their significance reduced after 1994. We conjecture that although these efforts were new to many firms in the industry, they were no longer a novelty in the industry at the global level due to advances in the learning and technological frontier of the industry worldwide. This implies that these adoptions were seen as no more than a minimum requirement to keep auto parts suppliers in the market under the new competitive conditions. This phenomenon of lagging behind the organizational and technological common practices adopted in international industries is a problem faced by many developing countries and not limited to the automobile industry in Mexico.

Related to the second finding, the results show a robust and significant change in the association among learning mechanisms. We found that under the new market environment brought about by NAFTA, firms' learning by innovating was significantly reduced and an important shift towards more traditional (and less expensive) learning mechanisms (i.e., training and acquisition of new machinery and equipment) was observed. Also, there was a shift towards learning by searching, defined as the acquisition of technological packages or technology transfers from firms' headquarters.

In the case of the auto parts industry, the empirical results, complemented by the interviews conducted, indicate that when market conditions change, bringing uncertainty and greater openness to competition, firms tend to allocate a part of their economic resources to update themselves to the new requirements. From the interviews and the results in JICA (1996), we found that with the introduction of new market regulations and environment, firms develop an awareness that they have to invest in both technology and organizational changes. However, how well and how deeply they understand the importance of implicit learning efforts is not very clear. It seems that most firms (especially those domestically oriented) engage in this mainly because other firms seem to be doing so. This aspect is not within the objectives of this research but it constitutes a useful direction for further research.

8.3 Exports as a Performance Indicator

Under a globally competitive environment, only those firms with the accumulated knowledge and skills to recognize and adapt to market requirements are able to develop the innovation capacity required to compete internationally in a sustainable fashion. The research assumes that exporting firms have developed higher innovation capability levels that allow them to adapt to changing environments.

Considering exports as a proxy for learning, the econometric results in Chapter 6 conclude that exporting firms are those with a higher rate of adoption of more complex levels of automation than non-exporting firms. This is reflected in the sort of auto parts produced by these firms, namely engines and engine parts, as well as power-train and suspension systems).

Our findings are supported by those of JICA (1996), Jasso and Torres (1998) and Dominguez and Brown (2004) on export performance in the Mexican auto parts industry. We therefore found that *the production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms, and these firms differ widely in their internal knowledge, skills and experience base.* The adoption of modern production techniques implies that firms have a higher level of internal knowledge, suggesting a full understanding of the firm's processes by its managers and blue-collar employees. It implies knowledge of the process specifications followed internationally. We conclude that before being able to implement process techniques, such as QC, firms had undergone important learning processes that allowed them to use and exploit the adopted techniques and to continue adapting to international production requirements.

8.4 Local Content Requirements and Value Chain Integration

One of the key characteristics of the automobile industry is the level of interaction it develops with other industries, which promotes industrial development in general. In the case of Mexico, as found in our analysis and supported by JICA (1996) and Bancomext (2000), the level of development of the Mexican-owned firms was not adequate to cope with the international standard requirements in automobile production. This raises important questions about the levels of learning and innovating capabilities supporting automobile production in Mexico.

Without explicit institutional support in developing supporting industries, local integration has not developed, and the spillover benefits of having an international industry such as that of automobiles in the country are not optimally maximized. Empirical analyses in Chapter 6 and Chapter 7 point to the importance of imported inputs in the production of exporting and non-exporting firms. This may indicate that assemblers and auto parts suppliers find it increasingly more efficient and profitable to import parts and components than to produce them, thereby creating large assembly operations in which imported content plays a significant role. Also, empirical findings presented throughout all chapters of the thesis suggest that reduced output (substituted by a large amount of imports) slows down local learning, the acquisition of technological capabilities of local firms and knowledge spillover effects to other sectors of the economy. Based on these results, we conclude that *the domestic supply chain has not been strengthened under NAFTA, and that an important proportion of imported parts and components is significantly preferred in production over those that are domestically supplied, thereby weakening the domestic supply chain.*

As imports of parts and components with embodied knowledge take the place of investment in new machinery and local skills, acquisition of innovation capacity by domestic firms is reduced (Amsden 1989). The significance of imports of main inputs in exporting firms reflects a lack of domestic inputs that can compete with international standards in price and/or quality. The results support the findings both by JICA (1996) and Bancomext (2000), in which the poor development of the supporting industry – especially raw materials and high-tech components – is recognized.[112]

The descriptive statistics in the sample used in Chapter 6 suggest that about 40% of firms in the sample export their main products (data for 2002). When considering only firms manufacturing original equipment, we found that for the same year (2002) only about 24% of firms were exporting their products. This may suggest that the export orientation of auto parts firms in Mexico is inclined towards the aftermarket (requiring fewer technological and organizational arrangements) rather than the OEM market. The thesis does not explore this phenomenon in depth, but it points to avenues for further research in this area.

Taking elements from the value chain analysis and analyzing our findings from the perspective of the political elements regulating the chain, we conjecture that the learning and capabilities acquisition of exporting auto parts firms is strongly and significantly correlated with the disruption of the national supply chain, which raises important questions about the industry's levels of dependency on and integration with foreign actors (and inputs).

8.5 Networking Environment in Building and Enhancing Innovation Capacity.

Interactive linkages are one of the most essential elements of the systems of innovation perspective. The interconnection among the various elements and actors is an element influencing the internal dynamism of the SI. The innovative performance

[112] The Mexican government has established policies promoting local content requirements since 1962. Thanks to import protection (under ISI), the government succeeded in getting partial local content requirement for cars made for the domestic market by differentiating the rules for automobiles by market orientation (see Chapter 3 for more on this). While the changes in automobile production to systems such as the lean production system (i.e., JIT, TQC) might have created opportunities for local firms selling to the domestic market and abroad to upgrade their capacities to manufacture parts and components, they seem not to have done so.

of a country depends on the nature of linkages and relationships between the SI actors and their external and internal trajectories (OECD 1997). The historical character of these trajectories is important for the SI framework, in order to understand the political and legal regulatory regime that has influenced an industry over time.

To build innovation capacity, not only are linkages necessary, but the quality of the networking also plays a key role. Without the construction of high-level knowledge centers aware of the importance of interacting with other economic agents, firms are not motivated to establish such linkages.[113] Diverse Latin American authors have called attention to the weaknesses of the academic and institutional infrastructure in the region, as well as the lack of linkages between universities and firms, both before and after the implementation of the New Economic Model (Alcorta 2000; Arocena and Sutz 2003).

In Chapter 4, we present empirical evidence showing that the already weak linkages of firms and knowledge centers did not get stronger after the introduction of NAFTA. The evidence presented in Chapter 4 and the results found by other authors analyzing the auto parts sector suggest that *networking among Mexican auto parts firms has been weakened by the convergence of factors brought about by NAFTA.*

8.6 The Institutional Environment and the Strengthening of Innovation Capabilities

An important element of the SI is the role of history in shaping the nature of the system's institutions as "products of their environments" (Oyelaran-Oyeyinka and Barclay 2002) and "carriers of history" (David 1994). Institutions created under previous institutional settings, as well as the set of habits, routines, rules, norms and laws that regulated their behavior and interaction with other actors, have a strong effect on their actual political, institutional and regulatory nature (Mytelka 2000).

"Institutional memories" influence the people working in firms and, over time, also influence the routines that characterize the organizations affecting the environment in which individuals act and make decisions – as observed in the Andean metalworking and chemical firms, the Trinidad and Tobago gas industry and the Costa Rican

[113] Although knowledge centers and formal R&D in universities are important, the literature recognizes that other types of interaction, such as that between suppliers-producers and buyers-sellers, matter more (Lundvall 1988; Oyelaran-Oyeyinka 2004a). Being a mature industry, the auto industry depends even less than other economic activities on current R&D. The kinds of learning interdependencies required are within the machinery sector – which was poorly developed in Mexico and Latin America (Alcorta 2000).

electronics cluster, as well as the African textile industry (Mytelka 1978, 1985; Mytelka and Barclay 2004).

As Mytelka mentions in her multiple works, the environment in which firms operate and the institutions shaping that environment create an idiosyncratic kind of “tradition,” “tacit knowledge” or “environment” in the people involved therein. For this reason, learning behavior becomes an important factor shaping performance outcome in firms. In environments such as in Latin America where public servants are usually ”recycled” among different public organizations (i.e., ministries), this characteristic of the SI and its institutional setting has strong effects on policy-making and policy implementation by government agencies.

The research shows that the environment under which firms are created has a significant influence on their operational approach. Firms created under NAFTA are significantly more likely to export than those from previous economic regimes. We also found that although not significant, older firms have less probability of engaging in dynamic building of their TC, such as learning by innovating. The research finding is in line with those findings from the capability building literature in that the “memory” of organizations or firms plays a determining role in the way they learn (Oyelaran-Oyeyinka and Barclay 2002).

Institutions have memory, and history matters. Therefore, both the political regime and the economic climate under which firms were created or under which they have primarily performed is an important element of the institutional context that makes things work in certain ways. The historical review presented in Chapter 3 shows how the industrial development of the automobile industry is based on episodic industrial policies without long-term objectives. Macroeconomic short-term objectives (e.g., balance of payments deficits and employment) were the main motivations behind the policy decisions regarding automobile development. Building technological and innovation capabilities was never explicitly stated in the objectives of the automotive decrees. Therefore, it is not surprising that the outcome of these policies resulted in very poor learning and innovation in the auto parts and supporting industries.

The historical and contextual background presented in Chapter 3 helps us to understand the evolving role different actors have played over time in the development of the industry. The chapter establishes the routines and institutional learning that characterized the SI of the industry. The thesis presents evidence on how the political economy undermined integration among actors and thus undermined capability building.

A clear, in-depth understanding of historical patterns of development is important because such patterns condition routines, and these in turn condition linkages and learning. This is very relevant because it is not possible to deal with learning-based development if we do not go to the heart of the historical routines and institutional learning that are already established.

The institutionalization of a new regulatory framework reflecting changing market conditions represented by NAFTA brought the need for firms to adapt their production and organizational standards to international requirements. The historical review in Chapter 3 and the empirical results presented in this thesis tell us that this did not happen successfully for the auto parts industry, which still lags behind global requirements.

The development of global automobile production tendencies described in Chapter 4 led to the increasing global integration of automotive firms (i.e., the assemblers) and their supply base. As mentioned in Chapter 4, many of the organizational and production developments in Mexico, as well as denationalization patterns and the emergence of foreign linkages and content integration, have been determined by global automotive corporate strategies. NAFTA is not the creator of such trends, but merely the institutional instrument that officially positioned Mexico under the influence of such trends.

However, even within globalization, the movement of production from place to place is still determined by efficiency and cost variables. Therefore, a stronger domestic institutional structure for innovation and learning support would have probably helped Mexican auto parts firms to better face the challenges of NAFTA and the international requirements that implicitly came with the agreement.

The research does not attempt to state that NAFTA has been detrimental to the Mexican auto parts industry. It is noteworthy that the analysis presented in Chapter 5 is based on a substantial amount of firms (192) that existed before NAFTA and remained in business under the agreement, and that in Chapter 7 we find a slight increase in local content integration by exporting firms under NAFTA. These facts suggest that there are some firms finding their way through the new production requirements.

However, our findings revealing the types of learning mechanisms and technological efforts undergone by the industry as well as significant levels of imported inputs in production suggest that *the innovation support system for automotive firms has been inadequate under circumstances of market change*. The research also seems to show that the way new technologies are acquired is very passive and is less conducive to sustainability in the absence of continued licensing and less likely to give rise to local capacity for innovation.

8.7 Methodological Reflections

The conclusions reached in this thesis are based on the importance of historical shaping and the learning and institutional context that explain the changes in learning and innovation in the auto parts sector in Mexico. These are complemented by the results of the empirical analyses, conversations with policy actors in the auto industry in Mexico and the author's own experience through fieldwork and her implicit understanding of the country.

Considering the difficult and limited access to extensive micro data – especially panel data – we believe this research has made good use of the scarce resources available. The adaption of existing databases to address new issues is one of the strengths of this work. However, the fact that the data were not were not explicitly designed to cover the research topic implies that the research has to be adjusted in certain ways to work with the already existing data, such as the case of the selection of dependent over explanatory variables.

The author is aware that the election of proxies representing learning mechanisms and technological efforts has a high degree of subjectivity. The variables chosen to represent learning mechanisms could equally represent technological efforts. However, due to the availability of data, the author considered as dependent variables those representing more straightforward modes of learning mentioned in the literature (i.e., training, using, R&D). The author believes that the selection of these variables over others does not detract validity from the results here presented.

The findings presented in this thesis represent the learning and innovative behaviors of manufacturing firms under an environment in which the operating market conditions were undergoing deep-seated changes. There are about 400 auto parts suppliers registered in Mexico; after screening out retailers and those with less than 20 employees, we believe our sample gave a fair representation of the reality of the sector. The core of the thesis is based on the empirical analysis of a fixed set of 192 firms that were in operation before and under NAFTA.

By analyzing the same set of firms through both periods, the research presents a more accurate description of the learning and innovation trends adopted by firms when the market and operating environment in which they were created undergoes structural changes. We believe this set of data and the analysis thereof provided a more robust analytical platform than conducting entry-exit analysis (which, however, remains an interesting entry point for further research), in which we could not deeply appreciate how the same set of firms would react to changes in dynamic market conditions.

Chapter 6 analyzes critical differences between exporting and non-exporting firms in 2002. This chapter included OEM and after-market firms, making no differentiation among them. The sample contains 257 firms (including many of those firms analyzed in Chapter 5). Aiming to provide a perspective of how factors have changed under NAFTA for exporting firms, Chapter 7 analyzes a set of about 1,304 firms for the years 1995, 1998, 2000 and 2002. The results are in line with those found in previous chapters, which suggest that although we operate with three different databases, there is consistency in the findings.

The research is mainly based on the *meso* level and focuses strongly on firm-level innovation capacity. We recognize that this is only a node within the system. Therefore, it is important to supplement econometric results with the institutional, economical and political narratives and how events shaped the industry and the wider capacity of systems. After all, as the SI theory tells us, it is the behavior of systems that allow us to understand economic performance, not the behavior of individual components *per se*. This is only done in the present chapter, which harmonizes the individual results of each chapter and discusses their findings under the systems perspective.

8.8 Theoretical Contribution

The thesis makes two main theoretical contributions to the capability building literature in developing countries. First, in order to build, strengthen and upgrade technological, learning and innovative capabilities, it is necessary (though not sufficient) to have explicit policies targeting this goal. Second, if such capabilities are not built and absorbed by firms before changing the market conditions towards a more liberalized environment, and without these explicit policies, it is unlikely that they will be able to build such capacity along the way (which would be somewhat like fixing a broken-down vehicle in motion). When exposed to foreign competition and international industrial competitive requirements prematurely, firms are prone to exit or take the path of least resistance by turning to imports.

8.9 Policy Reflections

There are few systematic studies on the auto parts firms in Mexico. Two of the most relevant are those conducted in 1972 by Jorge Eduardo Navarrete Lopez (Permanent Mexican Representative at the United Nations, New York) and in 1996 by a team led by Mitsuhiro Kagami (IDE-JETRO, Japan). The empirical conclusions of this thesis are in line with the findings of these two pieces of research.

Table 8-2 summarizes the hypotheses analyzed in the various chapters of this thesis. It is only with the overall findings resulting from each chapter that we are able to make a definite statement concerning the overall guiding supposition. In other words: *The change in the market environment resulting from the regulations brought about by NAFTA, as well as the globalization strategy followed by the automobile assemblers, has impacted the production regime of automobile suppliers in Mexico, their innovation and their learning behaviors and capabilities.*

Table 8-2 Main Results of the Thesis

Hypothesis	Result	Chapter
Main Conclusion: The change in the market environment resulting from a convergence of economic liberalization and NAFTA, as well as the globalization strategy followed by the automobile assemblers, has impacted the production regime of automotive suppliers in Mexico, their innovation and their learning behaviors and capabilities.		Chapter 8
Supporting Statements: 1. The nature and direction of innovation and learning mechanisms adopted by automotive suppliers have changed since the introduction of NAFTA in 1994.	Not Rejected	Chapter 5
2. Domestic innovation and learning mechanisms of the auto parts industry are correlated with firm size, ownership structure and supplier tier level.	Rejected	Chapter 5
3. The production regime brought about by NAFTA has led to the segregation of firms into strongly and poorly innovating firms, and these firms differ widely in their knowledge, technological efforts and experience base.	Not Rejected	Chapter 6 Chapter 7 Insights from Chapter 5
4. The domestic supply chain has not been strengthened under NAFTA, and an imported proportion of imported parts and components is significantly preferred in production over those that are domestically supplied, thereby weakening the domestic supply chain.	Not Rejected	Chapter 6 Chapter 7
5. Networking among Mexican auto parts firms has been weakened by the convergence of factors brought about by NAFTA.	Not Rejected	Chapter 4 Insights from Chapter 3
6. The innovation support system for automotive firms has been inadequate under the circumstances of market change.	Not Rejected	Chapter 3 Insights from Chapters 4-7

Innovation capacity results from explicit and continuous technological efforts by firms over time. It involves technological efforts deliberately adopted to build, update and strengthen technological capabilities in firms. Innovation capacity is not only related to the construction of firms' internal knowledge, skills and experience base, but also, and most importantly, is the ability to build and strengthen firms' capacity to interrelate, adapt and react to changes in their environment. It is the result of fully understanding learning as a continuous and explicit process and not as an event that occurs just once.

Our conclusion from the research conducted is that there are insufficient technological capabilities in the auto parts industry in Mexico, and consequently innovation capacity in this sector is weak or undeveloped. The Mexican auto parts industry is clearly differentiated by the market orientation of the firm. In the years before NAFTA, export-oriented firms had significantly higher levels of innovative, technological and organizational capabilities, reflected in much higher levels of performance. And, like in the early years when the industry opened to foreign markets, exports have low levels of local content integration. In addition, imported inputs have accounted for a significant share of production for the domestic market.

The research shows important details of the contextual environment (e.g., political, economic and market factors) shaping the automobile industry in Mexico. This is an important element of the system of innovation – especially in developing countries – because it shapes the way policies that build learning and innovation capabilities are constructed (in this case, they were made haphazardly with few strategic goals in mind). In the case study of this thesis, the contextual historical settings led to a situation where the auto parts industry did not integrate either with the terminal industry or with the supporting industries.

The absence of an industrial development policy explicitly targeting science and technology in the industry and structured with a view to achieving long-term developmental objectives has also played a key role in the poor learning-based development of the auto parts sector. The automotive decrees were implemented as a short-term solution to resolve macroeconomic imbalances, basically balance of payments deficits and employment. This situation has been widely acknowledged by diverse authors in other Latin American countries (Macario 1999, 2000a; Macario, Bonelli, Ten Kate et al. 2000; Peres and Stumpo 2000; Reinhardt and Peres 2000).

The poor networking found among firms, knowledge centers and industrial associations is partly the result of an entrepreneurial culture that has been historically based on secrecy, lack of trust, poor communication with other agents in the system and short-term planning. The lack of institutional support and the disconnections between activities in industry and universities also explain the lack of interaction among the actors of the system. We can state that the third role of universities (i.e., the connection with the industry) is still underdeveloped in Mexico and in the Latin American region in general (JICA 1996; Arocena and Sutz 2000, 2002, 2003).

Another important factor that appears to have affected the development of the industry in an important way is the role of export promotion policies. When Mexico started to liberalize its economy, a great deal of attention was placed on export-based development lessons from the East Asian tigers (i.e., Korea, Singapore and Malaysia). Supporting institutions, such as Bancomext, were created with the specific mandate to promote exports. Years later, exports were no longer seen in Mexico as just one of many tools that would promote learning in order to achieve development. They were perceived as the ultimate goal, rather than the means. This is an important policy observation that should be seriously considered.

There is a large body of literature that analyzes exports as a means to build learning capacity in firms and as an output of an increase in firms' productivity. When the ultimate goal of a developmental policy is merely getting a firm to export, the richness of the approach is missed. If the policy effort is put on just the final outcome – exportation – we end up with exporting firms that have not developed sufficient learning and innovative capabilities and, as in the example of this thesis, firms that are not integrated with the national environment and that base their exports on a large amount of imports.

The same happens when we base our policy decisions on mere econometric research examining the role of exports in productivity growth. It is only when we complement econometric analysis with the historical and institutional context shaping the sector being analyzed that we can fully understand the dynamics determining sector performance and be able to make some policy recommendations. Therefore, another important point that other developing countries should take note of is the danger of adopting the "export orientation" approach as a model for development. It is true that we can build capacities to innovate through exports, but we can also destroy those capacities when we fail to first build a domestic base. The lesson for other developing countries would thus involve how to use the export approach to actually build this capacity to learn and innovate. Policy-makers in a developing context should seek explicit mechanisms for learning-based development rather than export-based development.

Reflecting on the type of policy that should be implemented is not an easy task. After signing several Free Trade Agreements (of which NAFTA became the most prominent), Mexico has limited the government's capacity to influence industries due to the already existing parameters specified in the FTAs. The production requirements and time frames established in NAFTA are non-negotiable and are a reality under which firms have to perform. From the research exercise conducted in this thesis, we deduce that if enough capacity is not first built under a more protective framework in which the government can act more dynamically, it is much more difficult (and requires an incredible amount of explicit effort) to build capacity under a framework strongly influenced by foreign actors.

In order to build innovation capacity in the country, all agents have to be involved and developed. The related ministries should not only be actively involved in the national developmental discussion but, most importantly, they should build relevant expertise on what is going on in the industry at the global level. What are the long-term plans of the assemblers? What technological developments are planned? What are other countries doing to face the upcoming challenges? What is our country doing? What type of TC do we need to master in order to keep ourselves competitive? What type of learning do we need to allow us to adjust to the new market changes that a potential technological change may bring? How high up are we (i.e., as an industry, and not as case studies of isolated firms) in the technological value chain?

The ability to handle processes of technological, organizational and technical change is a key difference between developed and developing economies. Only by making policy-makers and industry leaders aware of this and building the necessary knowledge to understand the implications of this and other issues can we engage in the institutional change necessary to design science and technology policies that will promote sustainable learning development in the industry.

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Curriculum Vitae

Bertha VALLEJO CARLOS was born in Guadalajara, Jalisco, Mexico on November 14th, 1975. Her main professional interest is processes and patterns of innovation, and specifically the process of building technological capabilities in SMEs and the policy measures needed to support that process. She is currently employed by Tilburg University in the Development Research Institute (IVO, for its Dutch acronym: Instituut voor Ontwikkelingvraagstukken). Although IVO is not focused on innovation systems, it carries out capacity building projects in developing countries. Ms. Vallejo is working in the area of Macro Accounting for Policy Analysis and as the coordinator of a 4-year project (2006-2010) in Central America. This has given her the opportunity to gain experience in project management, as well as in understanding from a closer perspective the ups and downs of knowledge transfer between north and south (particularly when the offer comes from the north). During her work in IVO, she has developed skills in the coordination and management of medium-sized units, as well as in teaching and workshop moderation.

Ms. Vallejo had the opportunity to pursue her studies in three different environments: Latin America, Asia and Europe. She joined the United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology (UNU-MERIT), Ph.D. program in The Economics and Policy Studies of Technical Change in winter 2001. The first 4 years of her PhD studies were financed by a scholarship of UNU-INTECH (United Nations University – Institute of New Technologies). Prior to joining UNU-MERIT, she completed her M.A. in International Political Economy at the Graduate School of International Political Economy (GSIPE), University of Tsukuba, Japan during 1999-2001 under the Joint Japan/World Bank Graduate Scholarship Program (JJ/WBGSP) with a scholarship from the Inter-American Development Bank (IADB). For her undergraduate studies, she took courses on Latin American Economy at the University of Santiago de Chile, as part of her Bachelor in Economics from the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) in Monterrey, Mexico (1993-1998). This gave her a strong multicultural and interdisciplinary background, as well as experience working in multicultural and international environments and good communication and language skills.

Ms. Vallejo's research specialization is in capability building and learning-based development in developing countries. Her work primarily employs the systems of innovation approach, with a particular emphasis given to issues related to SMEs' integration into the production chain in developing countries. Her practical experience in the area of innovation systems and innovation policy in developing countries comes from her doctoral dissertation and diverse assistance work she has done for UNU-MERIT and its various training and research programs. She understands systems of innovation as the set of principles that help us to adapt existing arrangements to context-specific [local] circumstances.

Ms. Vallejo acted as a resource person and facilitator at DEIP (Design and Evaluation of Innovation Policy in Developing Countries) in 2005 and 2006, under the supervision of Professor Dr. Banji Oyeyinka. Also between 2006 and 2009, she acted as a resource person and facilitator in the application of innovation systems perspectives in the design and implementation of agricultural research projects in the Andean region (in Lima, Peru) under the supervision of Prof. Dr. Andy Hall (LINK Ltd).