INTERNAL AND EXTERNAL SOURCES OF CAPACITY BUILDING IN THE MEXICAN AUTO-PARTS INDUSTRY

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I hereby declare that this thesis has not been submitted, either in the same or different form, to this or any other University for a degree.

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SUMMARY

This thesis is concerned with the study of technology upgrading in late industrialising countries. This research aims to understand the process of technology upgrading of SMEs in the automotive industry by looking at the internal and external sources of technology for these firms. To do so, the main bodies of literature of this research are i) technological capabilities and absorptive capacity, ii) global value chains, and iii) NLSs.

Technology upgrading has not been a well-developed notion in the literature. The literature has focused on technical change in industrialised economies and it has omitted the process of incremental changes and the shortcomings existing in the system of innovation for late industrialising countries. To observe technology upgrading in developing countries, I look at the transfer of technology from up-to-date firms (assemblers) to the less knowledgeable firms (SMEs) and the assimilation of this technology by the latter. To look at other sources of technology, I observed the country' context and the role of other actors in the industry. In this regard, National Learning Systems (NLSs) permit to understand and explain the differences of the process of technical change in late industrialising countries where they learnt through the diffusion of technology created somewhere else rather than the creation of it within the system. In this research, I offer new findings for the literature which has paid little attention to the process of technology upgrading and SMEs. I also confirm that the use of NLSs instead of NIS is more accurate for late industrialising countries and I offer new paths for future research in these issues.

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LIST OF ABBREVIATIONS

AERI	Programme of strategic alliances and innovation networks
AMDA	Mexican Association of Automotive Suppliers
AMIA	Mexican Association of the Automotive Industry
ANDELLAC	National Association of Suppliers of Tires
ANPACT	National Association of Producers of Trucks and Heavy cars
BANCOMEXT	National Bank of Export and Commerce
CANACINTRA	National Chamber of the Manufacturing Industry
CANIETI	National Association of the Electronic and Telecommunication Industry
CBU	Completely built vehicle
CKD	Completely-knocked down
CIDEC	Centre for Computer Research
CINVESTAV	Centre of Research Studies
CLAUT	Automotive cluster in Nuevo Leon
CMMI	Capability mature model integration
CONACYT	National Council of Science and Technology
CONCAMIN	Confederation of Industrial Chambers of Mexico
EPO	European Patent Office
FDI	Foreign direct investment
FUMEC	United States -Mexico Foundation for science in Mexico
INA	National industry of autoparts association
IPN	National Technical Institute
ITESM	Higher Technological Education Institute
MNCs	Multinational companies
NAFTA	North American Free Trade Agreement
NIS	National innovation systems
NLS	National learning systems
OEMs	Original equipment manufacturers

PCA	Principal component analysis
PCBs	Printed circuit boards
PRODIAT	Programme for the Development of High Tech Industries
PROMEXICO	Trade and investment agency
SKD	Semi-knocked down
SMEs	Small and medium-sized firms
SPICE	Software process improvement and capability determination
TechBA	Technology Business Accelerator
TC	Technological capabilities
UAQ	Autonomous University of Queretaro
US	United States of America
USPTO	US Patent and Trademark Office

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CHAPTER 1:
Introduction, research questions and literature review

1.1 Introduction

The basic objective that underlies this thesis is to understand how home-grown and -owned small and medium-sized companies in developing countries upgrade their technology through interactions with much larger foreign companies. This process of technology upgrading includes the acquisition of new tools and machines, as well as the development of new knowledge. My original motivation to study this phenomenon comes from my working experience in the Mexican automobile industry, where I observed that relations between foreign assemblers and their local suppliers stimulated learning and upgrading of technology, but to different extents for different firms. Some firms clearly profited from these relations more than others, and I have sought to ask why this is.

Therefore, my main research question is:

- How do SMEs in the Mexican automotive industry upgrade their technology?

Technology upgrading is not a well-developed notion in the literature, which has mainly focused on innovation in late industrialising economies. As noted by Viotti (2002) and many others, the extant focus on technological innovation is problematic for developing countries since it often foregrounds specific institutions' scientific and technical activities, especially R&D. This focus has largely overlooked the potential for a wide range of other activities, including production, training, maintenance and information access. By contrast, the notion of technical change avoids this bias, but is perhaps too general and overlooks a concern that is central to this thesis; namely, the process of upgrading the Mexican automobile industry. These activities can be seen as forms of incremental innovation, but should not be reduced to this, since they might result in more radical changes. Therefore, the notion of technology upgrading is defined here as all firms' technological improvement activities.

In the literature, a main technology upgrading determinant is the availability and further development of the capabilities of SMEs. The successful use of potentially under-used technological capabilities depends on firms' absorptive capacity, which is their capacity to recognise and internalise new knowledge (Cohen et al., 1990). As I explain in more detail below, absorptive capacity is not only dependent on firm characteristics, but is also shaped by the global automobile value chain, and by a wider set of factors, which are dealt with the literature of national learning systems (NLSs). Therefore, the theoretical framework of this chapter builds on three main bodies of literature: i) technological capabilities and absorptive capacity, ii) global value chains, and iii) NLSs.

Section 1.2 presents the literature review. Section 1.2.1 reviews the main contributions and definitions in the area of technological capabilities and acknowledges the different types of capabilities that can be accumulated at different economic levels (macro, meso and micro). Section 1.2.2 introduces the concept of absorptive capacity for the SMEs' successful learning from linkages with up-to-date firms. Section 1.2.3 studies technology upgrading in the supply chain and the car industry, and also reviews the impact of multinational companies in developing countries through technology transfer. Section 1.2.4 presents the structure of the automotive industry in developing countries. Section 1.2.5 examines the notion of NLSs, starting by introducing their origins from the concept of National Innovation Systems (NISs) and recalling the concept for those systems in which technical change is largely based on learning and diffusion rather than innovation. Section 1.3, which is based on the literature reviews, provides research sub-questions and an outline of the thesis.

1.2 Literature review

1.2.1 Technological capabilities

Since the early 1980s, scholars have explored the concept of technological capabilities (Bell and Pavitt, 1993b; Dosi, 1988; Lall, 1992), involving different levels of analysis, such as countries (macro systems), industries (meso systems) and firms (micro systems) (Acha, 2000; Alfranca et al., 2003; Archibugi and Coco, 2002; Eisenhardt and Martin, 2000; Helfat and Raubitschek, 2000; Winter, 2003). In addition, studies have distinguished between developing and developed countries (Romijn, 1997; Teitel, 1984) - in order to stress the differences that foster the development of technological capabilities in these contexts (Bell and Pavitt, 1993b, 1995). The review focuses on studies that deal with developing countries, but that also include all levels. At the macro and meso levels, technological capabilities are embedded in firms' responses or behaviours toward policies, markets (for example, producers, suppliers, consumers) and the institutional framework (for example, government) (Lall, 1992). At the micro level, technological capabilities are defined as the skills necessary to allow firms to engage in more complex activities of adapting, modifying, improving, creating new technology and, therefore, pave the way for a continuous upgrading (Bell and Pavitt, 1995). I first discuss capabilities at the micro level and then at the meso and macro level.

Several authors who have studied firm-level technological capabilities differentiate them according to functions involved. A systematic comparison of various capabilities is missing. In response, Table 1.1 compares various proposed taxonomies, making a distinction between the capability's concepts used as well as the resulting functions. From the table, it becomes clear that the most recognised functions are production, investment and innovation.

Table 1.1
Taxonomies of technological capabilities by function
Review of the existing literature

Author	Capability concept	Capability functions
Lall (1992)	Production capabilities: skills and knowledge required to carry out activities of the manufacturing or production area.	Quality control, operation, maintenance, adaptation and improvement of the equipment and machinery.
	Investment capabilities: skills and knowledge required to identify sources of technology and to invest in.	Selection of technology – machinery and equipment, cost of projects.
	Linkage capabilities: skills and knowledge required to transfer and diffuse technology.	Linkages with suppliers, subcontractors, consultants, service firms and technology institutions to support the firm's existing technological capabilities.
Bell and Pavitt (1993b, 1995)	Production capabilities: skills, knowledge and experience required to choose, acquire and adapt existing technologies.[1]	Improved layout, scheduling, and maintenance. Minor and major adaptations, process improvement, introduction of organisational changes. Adaptation to market needs and incremental improvement in product quality. Incremental new product design.
	Supporting capabilities: skills, knowledge and experience required to establish linkages with other firms and institutions.	Searching and absorbing new information from suppliers, customers and local institutions. Technology transfer to suppliers and customers and collaboration in technology development.
	Investment capabilities: skills, knowledge and experience required to acquire new technology.	Active monitoring and control of feasibility studies, technology choice/sourcing and project scheduling. Search, evaluation and selection of technology/sources. Detailed engineering, plant procurement, developing new production systems and components.
Viotti (2002)	Production capabilities: skills and knowledge required for the process of production.	Activities of routine maintenance, minor adaptation to firm internal local conditions; inventory control.

[1] Skills embedded in the process of diffusion technology (Bell and Pavitt, 1995).

Author	Capability concept	Capability functions
Viotti (2002)	Improvement capabilities: skills and knowledge required for the continuous and incremental upgrading of product design, process technology and performance feature.	Activities of preventive maintenance; major adaptation to firm internal local conditions; networking with suppliers and customers.
	Innovation capabilities: skills and knowledge required for the creation of new technologies.	Major changes in the design and core features of products and production processes.
Westphal et al. (1984)	Production capabilities: skills and knowledge required to operate productive facilities.	Production management, quality control, trouble-shooting, repair and maintenance of physical capital. Adaptations of processes and products.
	Investment capabilities: skills and knowledge required to expand capacity and establish new productive facilities.	Project engineering (including basic knowledge of process and equipment), project management. Choose, coordinate and supervise hardware suppliers and construction contractors. Plant erections, manufacture of machinery and equipment.
	Innovation capabilities: skills and knowledge required to develop less costly and more effective technologies.	New improvements, applied research and development, creation of pilot plants.
Romijn (1997)	Adaptive innovation capabilities: skills and knowledge required to adapt or create new technology and make changes to established plants	Capital stretching, making product or process adaptations to local factor prices, local materials and market demand.
	Investment capabilities: skills and knowledge required to acquire new equipment or machinery and to choose, acquire and install new equipment.	Preparation of feasibility studies, search of technology suppliers, comparison of the strengths and weaknesses of alternative technologies, bargaining with suppliers, drawing up of contracts, procurement of hardware, plant erection, process engineering, start-up, staff recruitment, organisation of staff, training and basic process design.

Author	Capability concept	Capability functions
Romijn (1997)	Production capabilities: skills and knowledge required to operate and established plants efficiently.	Quality control, raw material control, production scheduling, trouble-shooting and preventive maintenance.
Kim (1998, 1999)	Production capabilities: skills and knowledge required to use production facilities.[2]	See Westhpal et al. (1984).
	Investment capabilities: skills and knowledge required to set up new production facilities.	See Westhpal et al. (1984).
	Innovation capabilities: skills and knowledge required to create new technological possibilities.	See Westhpal et al. (1984).
Ernst et al. (1998)	Production capabilities: skills and knowledge used in plant operation.	Production management, production engineering (for example, raw material control) and repair and maintenance of physical capital.
	Investment capabilities: skills and knowledge required to prepare, design and set up a new industrial project or the expansion and/or modernisation of existing ones.	Feasibility studies, site selection, scheduling of investment, search of sources of technology.
	Minor change capabilities: skills and knowledge required to improve and adapt continuously products and processes.	Modify processes, improvement on the original performance standards.
	Strategic marketing capabilities: skills and knowledge required to build close links with customers and identify their needs and changing demands.	Collecting marketing intelligence, development of new markets, establishment of distribution channels and the provision of customer services.

[2] Production, investment and innovation capabilities are defined as elements of technological capabilities (Kim, 1999).

Author	Capability concept	Capability functions
Ernst et al. (1998)	Linkage capabilities: skills and knowledge required to transfer technology within the firm, with other firm and between the firm and the domestic science and technology infrastructure.	Activities of linkage capabilities within the firm are: management of interactions, information-sharing among different divisions. Activities of linkages capabilities with other firm are: exchange of information with suppliers, the sharing of marketing and distribution activities. Linkage capabilities with the science and technology infrastructure are: to screen and scan new technology development, and to apply close interactions with applied and basic science.
	Major change capabilities: skills and knowledge required to create new technology.	Development of new products, new ideas, patents.

Source: from material presented of the above authors and own elaboration

Among the important differences, Bell and Pavitt (1995) defined technological capabilities as those that also include experience. In this regard, experience, knowledge and skills are related. Second, Lall (1992) and Ernst et al. (1998) proposed the category of linkage capabilities; in a similar approach, Bell and Pavitt (1995) proposed the category of supportive capabilities to look at the interactions among actors within the system of innovation. In this regard, supportive capabilities include technology transfer that is necessary for a further diversification into new products and new industries. Third, Viotti (2002) is the only author who proposed the category of improvement capabilities to stress explicitly the importance of internal technology upgrading. This function may be encountered in other categories such as production capabilities. Fourth, Bell and Pavitt (1993b, 1995) did not propose innovation capabilities because these are functions of production, supporting and investment in advanced levels. By contrast, other authors such as Viotti (2002), Westhpal (1984), Romijn (1997) and Kim (1997) proposed the category of innovation capabilities to stress the novelty in the functions of these capabilities. Fifth, Ernst et al. (1998) proposed the categories of minor and major change capabilities to stress the different stages of late industrialised countries in adopting imported technology. Sixth, Westhpal et al. (1984) recognised that a specific category may involve other capabilities such as creating plants that include innovation, production and investment. Seventh, Ernst et al. (1998) proposed the category of strategic marketing capabilities to emphasise behavioural patterns related with suppliers as well as the importance of building close customer links as a competitive advantage.

Technological capabilities have also been categorised by their complexity or performance level. In this regard, Lall (1992) and Bell and Pavitt (1993, 1995) split technological capabilities into basic, intermediate and advanced levels. Basic capabilities refer to minor and incremental experience-based contributions that involve simple tasks and limited manufacturing experience. Intermediate and advanced capabilities include more ambitious contributions to learning; the main difference among them is the level of risk. Intermediate capabilities include the search for external solutions which then need internal adaptation. This is less risky than investing in internal research, which is addressed by advanced capabilities.

Although several scholars identify capabilities, in practice it is difficult to distinguish among types and levels. For instance, production capabilities also generate knowledge vis-à-vis choosing and investing in new technology. Similarly, several authors highlight that several sorts of firm-level technological capabilities are not captured by conventional measures, especially investment capabilities (Evenson and Westphal, 1994).

The capture and measurement of firm-level technological capabilities is even more difficult for developing countries. First, many small firms may not be legally registered and data gathering is not possible. Second, developing countries may not collect technological activity information for direct measures.

This thesis employs a comprehensive set of capabilities. This research emphasises production, innovation, and investment capabilities because they are used in activities related to competitiveness and most scholars recognise them. In addition, this research pays special attention to linkage or supportive capabilities and strategic marketing capabilities. Linkage capabilities are needed for establishing external relations and strategic marketing capabilities recognise the importance of building close links with customers.

Based on the literature above, production capabilities are defined as those skills and knowledge needed to undertake production activities. Investment capabilities are those skills and knowledge needed to acquire new equipment and machinery; innovation capabilities are those skills and knowledge needed to create new technological possibilities. Linkage or supportive capabilities are those skills and knowledge needed to establish linkages and collaborate with other actors to support the firm's existing technological capabilities; finally, strategic marketing capabilities are those skills and knowledge required to build up close linkages with customers.

I now move to a discussion of capabilities on the meso and macro level. Enos (1991, p. 10) analysed developing country technological capabilities at the industry and macro level and identified three main attributes: i) collection of human technical skills; ii) institutions such as industry associations or chambers of commerce that bring teams of people with complementary skills together; and iii) common purposes that permit combining and bringing together all the different types of knowledge within a productive framework. According to Enos, these attributes should be aligned to one or more national objectives.

Lall (1992) made a somewhat different capability list on the meso and macro level and proposed three main broad headings: i) the stock of physical technology investments needed to operate efficiently, ii) human capital; and iii) the collection of national efforts devoted to technology.

Much of the literature at the level of systems does not distinguish between macro and meso levels and implicitly assumes that capabilities at the macro level shape capabilities at the meso level. This is because meso-level capabilities are embedded in the national framework, and policies are external to the firm, but have effects inside the industry. In this regard, Lall (1992) claimed that in developing countries, the success or lack thereof for the development of technological capabilities is a function of the response of firms to the policy market and institutional framework.

Although macro-level capabilities shape meso-level capabilities, this thesis distinguishes between both levels. Chapter 2 provides empirical evidence of technological capabilities in the Mexican automobile industry and factors in the following main attributes: i) human skills, ii) institutions, and iii) a common purpose (Enos, 1991). Chapter 5 addresses the macro level by looking at technological indicators of education, acquisition, resources and associated national efforts.

1.2.2 Development of technological capabilities: Competencies and absorptive capacity

One not addressed issue is where do technological capabilities come from? How are they developed? Based on the discussed above, I can argue that at the firm level, the development of technological capabilities is observed through efforts of R&D investments and other forms of learning. At the meso and macro level, developing technological capabilities are through government efforts on education, training and acquisition of foreign technology (Lall, 1987; Ernst et al., 1998; Padilla, 2008).

To address the issue of development of capabilities von Tunzelmann (2009) stressed the differences between competencies and capabilities. Competencies are generally defined as, 'collective learning in the organisation, especially how to co-ordinate diverse production, skills and integrate multiple streams of technology' (Prahalad, 1993 cited in Javidan, 1998, p. 61). Some approaches suggest that competencies are firm routines (Augier and Teece, 2004), while others see them as having a technological knowledge component that results in the 'blending of technology and production skills' (Marino, 1996, p. 41). Based on these definitions, competencies and capabilities may be confused. This thesis adopts the definition proposed by von Tunzelmann (2009) in which competencies leverage resources (enhancements created outside the firm) and capabilities leverage services (in-house-developed enhancements).

At the micro level, competencies are introduced into the firm through staff recruitment and the acquisition of new technology, while capabilities are developed through the absorption of external knowledge. Thus, the development of capabilities is rooted in the firm.

Competencies such as static knowledge influence the development of further capabilities based on observation and empiric actions (for example, routines). For example, firm A acquires new and sophisticated technology; capabilities accrue in the skills developed in order to interact with and manage this technology.

In the literature of capability building, Lall (1992) and Enos (1991) did not differentiate competencies from capabilities. According to Lall (1992), capabilities are embedded in human capital; by contrast, von Tunzelmann (2009) stressed that training develops capabilities and the education system develops competencies. Enos (1991) paid more attention to technology acquisition without mentioning the interactions between the actors (skills embedded in individuals) at the industry level, and the technology. In this regard, von Tunzelmann argued that capabilities accrue in part from competencies. This thesis accepts von Tunzelmann's argument. I will also use both concepts: capabilities and competencies.

The development of technological capabilities not only requires the existence of competencies, but also needs the acquisition of new knowledge (Lall, 1987, 1992; Romijn, 1997). The capacity to acquire new knowledge has been termed absorptive capacity and determines how well the firm, industry or country level actors learn (Cohen and Levinthal, 1990; Giuliani, 2005; Keller, 1995). Subsequent sections explore the elements of absorptive capacity paying special attention to the firm level.

At the firm level, absorptive capacity is defined as the ability to recognise the value of new information (Cohen et al., 1990; Giuliani et al., 2005). Consequently, the ability to understand external know-how is largely a function of prior knowledge (hence competencies) (Cohen et al., 1990; Nieto et al., 2005).

Much of the work on absorptive capacity emphasises the effort required to enhance this capacity. (Cohen et al., 1990; Kim, 1997, 1998). Cohen et al. (p. 131) claimed that, 'to develop an effective absorptive capacity […], it is insufficient merely to expose an individual briefly to the relevant knowledge. Intensity of effort is critical'. The intensity of effort refers to the level of commitment and the energy expended to solve problems (Kim, 1998), acquire knowledge and learn new skills (Cohen et al., 1990). Keller (1995) also pointed out that successful technological development requires time and effort even when the technology has been only copied or imitated.

Analysis of these approaches suggests that enhancement of absorptive capacity at firm level requires a culture of learning (see the many discussions in the organisational learning literature – Garvin, 1993; Kim, 1997, 1998). In this context, Kim (1997) pointed to the importance of institutions and inter-organisational linkages to foster learning through industry growth and the importance of joint efforts (government and firms) in enhancing the firms' absorptive capacity in catching-up countries (Kim, 1998).

At the firm level, the process of absorption of knowledge is identified through six types of learning processes: *learning by doing* – internal to the firm and related to production activity; *learning by using* – internal to the firm and related to the use of products, machinery and inputs; *learning from advances in science and technology* – external to the firm and related to advances in science and technology; *learning from inter-industry spill-overs* – external to the firm and related to the work of other firms (competitors); *learning by interacting* – external to the firm and related to the establishment of downstream and upstream linkages with other firms (suppliers or users) in the industry; and *learning by researching* – internal to the firm and related to the R&D activities of the firm. Interactions among these types of learning can occur simultaneously (Malerba, 1992, p. 848).

The process of learning can be broken down into two distinct processes: i) knowledge acquisition, and ii) knowledge conversion (Figueiredo, 2003):

i) Knowledge acquisition is disaggregated into external and internal modes. External knowledge acquisition refers to the processes or mechanism through which individuals acquire tacit and/or codified knowledge from outside the firm (for example, overseas trainings, use of technical assistance, participation in conferences). Internal knowledge acquisition refers to the processes or mechanism through which individuals acquire tacit knowledge by doing different activities inside the firm (for example, daily production routines, improvement to existing processes or production organisation).

ii) Knowledge conversion is disaggregated into knowledge socialisation and knowledge codification. Knowledge socialisation refers to the process by which individuals share their tacit knowledge (for example, technical skills). This is observed through meetings, shared places, job rotation. Knowledge codification refers to the process by which individuals articulate their tacit knowledge into explicit knowledge. This process is observed through documentation, production procedures and internal seminars.

Both knowledge acquisition and knowledge conversion include a tacit component. This implies that the knowledge rooted in the firm is tacit and can be acquired only from experience. Howells (1996) provided a broad definition of tacit knowledge as intangible, non-codified, disembodied and acquired through informal common routines and procedures.

Tacit knowledge related to technology is not easily transmitted as it is embodied in the firm's tangible assets of new technologies, products and equipment, and its intangible assets of licences, patents, training programmes and R&D contracts. The former implies that tacit knowledge can be gained externally via collaboration with other supply chain firms (Howells, 1996).

Much attention has been paid to the process of absorptive capacity, but without differentiating between developed and developing countries. In fact, differences in access to technology and in spill-overs affect the availability of critical external resources. Dosi (1988, p. 252) pointed out that some of these differences emerge from, 'the asymmetries among countries in the production processes'. In this context, the literature argues that these asymmetries accrue from the determinants (for example, opportunities, incentives, R&D investments, innovative procedures, etc.) at both national and firm levels that are part of the interactions between government and market. At the macro level, government interventions to promote human capital development stress differences in learning between developed and developing countries. This thesis maps the absorptive capability of the Mexican automobile industry SMEs.

The absorptive capacity plays an important role in strengthening domestic capabilities and hence the technology upgrading of SMEs (producers of components) that are interacting with supply chain assemblers. In the next section, I detail more precisely the specific set of relationships that exist in the automobile industry.

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1.2.3 Technology transfer and technology upgrading: Relations in the supply chain

The objective of studying this second body of literature is threefold: i) to typify relations between assemblers and their suppliers in the automobile supply chain, ii) to explore how learning in the supply chain influences the component producer's domestic capabilities, and iii) to study the impact of foreign firms (product assemblers) in the SME's technology upgrading (component producers). This section summarises the main concepts and findings relevant to this research.

A supply chain is a system that coordinates people, information and organisations to move a product or service from suppliers to customers. Scholars have also defined a supply chain as a network of organisations due to the high level of mutual integration (Wu and Meixell, 2008; Mentzer et al., 2001). The members of a supply chain are: raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies.

Three different types of supply chain have been identified: i) direct supply chain, ii) extended supply chain, and iii) ultimate supply chain. A direct supply chain consists of a company, a supplier and a customer involved in the upstream or downstream flows of products. An extended supply chain involves suppliers of the immediate supplier and customers of the immediate customer. An ultimate supply chain includes all the organisations involved in the upstream and downstream flows of products/services (Mentzer et al., 2001, p. 4). Two types of supply chain integration are identified: vertical and horizontal. Vertical integration refers to the firm that develops the upstream supplier and downstream buyer links. Horizontal integration refers to the many firms who handle the same parts of the production process (Sandhya et al., 2002).
The importance of the supply chain lies in its involving relations, a necessary condition for activity coordination. Increased globalisation and production fragmentation have forced firms to look for more effective ways of coordination (Mentzer et al., 2001).

The relationships in the supply chain can be grouped under two broad headings: supplier-buyer and buyer-consumer. The structure of the supply chain is both internal and external. The internal structure includes purchasing, production and distribution activities which promote the external structure, that is, relationships with suppliers and consumers (other firms). These activities permit various types of information exchange to learn about the nature and reliability of suppliers and producers, the quantities to produce currently and in the future and the technical characteristics of products. The learning involved for effectively integrating activities between firms may result in the development of various types of capabilities (organisational, technological, etc.) in order to fulfil those tasks (Lall, 1980).

The automotive supply chain has been recognised as a complex structure in which firms must face higher levels of competitiveness. To do so, firms are organised in tiers; there can be multiple tiers of components (intermediate products) in the supply chain. The first-tier suppliers ship directly to the final product assembler (car assembler), the second-tier suppliers ship to the first-tier suppliers, etc. The products in each tier have their own components following the form of bill-of-material (BOM) structure. The BOM structures are embedded in the chain where firms may supply several other companies and are also served by multiple other suppliers. Given this, scholars refer to the automotive supply chain as a network of firms where the flow of information is bidirectional. Information of demand and production planning flows down and information to support upper-tier manufacturing processes flows up (Wu and Meixell, 2008, p. 4).

Establishing supply chain relations has been identified through formal activity linkages to support and provide information to downstream suppliers. Lall (1980) categorised these linkages into 10 categories: *Establishment* – direct assistance provided by enterprises to launch production; *locational* – assistance and encouragement to local suppliers to set up facilities near buyers; *informational* – long-term plans to facilitate planning and production; *technical* – provision of technical assistance; *financial* – grants and concessional loans to suppliers; *raw material* – assistance to buy materials; *managerial* – training related to management and organisational performance; *pricing* – setting up contracts to determine prices; *other distributional* – allocation of inventory and product development costs; and *diversification* – assistance to suppliers to find other customers (Lall, 1980, p. 208).

Various scholars have acknowledged the importance of establishing relations between firms in the supply chain for enhancing the absorptive capacity which might then lead to upgrading technological capabilities (Lall, 1980; Shandya et al., 2002). In this regard, Wu (2008) argued that creating supply chain knowledge requires interlinked processes that enable information sharing as well as associated information technology infrastructures. These interlinked processes have been observed in the development of collaborative relations (for example, R&D projects) between the supply chain members. Hence clear responsibilities, the buyer-oriented approach and the exchange of specific information are relevant for the process of inter-firm knowledge creation.

To develop knowledge, firms need to respond to the supply chain partner's new requirements. These new requirements can include 'customer and end consumer focus', 'technology adoption', 'relationships management' (customer relationship and supplier relationship) and 'styles of leadership'. (Wu, 2008). Table 1.2, presents the type of knowledge created vis-à-vis the new requirements that shape the supply chain management.

Table 1.2 Wu's view of the creation of knowledge in the supply chain

Requirements	Type of knowledge involved in:	Type of knowledge accrued from:
Organisational conditions	Customer requirements	Key domains knowledge
Technology adoption	Product information	Characteristics of products
	Trends of processes and products	Corrective and preventive actions
	Key documents of technical information	Ability to take further decisions
Customer relationship management	Customer requirement	Define product requirements
	Customer perception	Customer satisfaction index
Supplier relationship management	Specified requirements	Criteria for purchasing
	Technical documents	Supplier's ability

It is commonly acknowledged that developing supply chain relations requires mutual socialisation involving sharing tacit knowledge between individuals (Ivarsson and Alvstam, 2009; Wu, 2008). In this regard, I may refer to the earlier discussion and in particular the work of Lall (1990), who introduced the concept of supporting or linkages capabilities. In the automotive industry, important technology transfer channels have been identified in the relations that foreign manufacturing firms establish with their local suppliers. Here foreign manufacturing firms may provide assistance and technical specifications that help local suppliers to accumulate knowledge about the exchange products and their future improvements (Lall, 1980; Ivarsson et al., 2009). For this reason, Turnbull et al. (1992) argued that long-term relations between the buyer and supplier firms result in long-term technological improvements in which supplier firms learn from repetitive activities (Ivarsson et al, 2009).

It has been argued that Foreign Direct Investment and foreign multinational firms have played a very important role in the manufacturing industries of developing countries (Padilla, 2004, p. 19). In this regard, scholars have recognised the beneficial effects from foreign companies to domestic firms through helping them to improve their practices of supplying to global suppliers, allowing them to have access to international markets through exports and extending their geographical scope (Gentile-Ludecke et al., 2012). Similarly, spill-over literature has stressed the impact of foreign firms on the firm-level productivity of host country firms (Atallah, 2002; Bessant et al., 1999).

1.2.4 The structure of the automotive industry in developing countries

According to Humphrey (2003a, 2003b) the structures in the auto industry have been transformed by two major factors: i) 'the integration of developing countries into global auto production systems, and ii) the emergence of global component suppliers (first-tier firms) who are responsible for designing and delivering component systems at multiple locations around the world' (Humphrey, 2003a: 122). Subsequently, car assemblers have outsourced a major proportion of car complete functions (that is, modules, systems) and first-tier firms are greatly involved in the product/processes design. In this new outsourcing structure, car assemblers provide overall specifications of and information about of the car's interface and the suppliers design a solution using their own technology and adapting their own production processes to the customer's requirements. This shift has resulted in a major involvement of first-tier companies with car assemblers in which assemblers transfer research and product costs to suppliers; these also benefit the specialised manufacturing skills of their suppliers (ibid).

Based on the above, car assemblers and first-tier companies set the industry's organisational behaviour in terms of market structure, market conduct and market performance by assigning roles to other firms and assuring the integration of all supply chain firms. The tasks of these firms are beyond the scope of the chain and involve public and private institutions (Alternburg, 2000; Kaplinsky, 2001, cited in Alternburg, 2006). The prominent role of these firms shapes the chain structure and subsequent absorptive capacity; hence, capability development is determined in part by the transfer of technology, knowledge (elaboration of information to achieve *know-why)* and information (codified knowledge and *know-what)* (Lundvall et al., 2002) from these firms to the rest of the supply chain members.

In developing countries, technology acquisition is mainly observed through four major channels: i) in-house or indigenous R&D; ii) foreign technology transfer; iii) domestic technology transfer; and iv) inter-industry R&D spill-overs (Bin, 2007). In the automotive industry, important technology transfer channels are created through the relations established between assemblers and their local suppliers involving information exchange and learning from the assemblers' product quantities and qualities to satisfy their requirements. The main types of technology transfer are: i) product-related, and ii) process-related. Product-related technology transfer is observed through patents, licenses, product design and specifications, advice to help suppliers to master the customer's technologies and regular feedback on product performance. Process-related technology transfer is observed through the, 'provision of modern machinery and equipment, support in product planning, quality management, inspection and testing, advice on tooling and maintenance, production layout and operations' (Ivarsson et al., 2009a, p. 58). Similarly, different types of technology transfer from assembler to their suppliers are observed through training programmes, and the access to technical and market information, and transfer of organisational/managerial know-how through inventory management and logistical systems.

According to Sandhya et al. (2002), other types of car industry technology transfer involve subcontracting, including the role of government, the nature of the production technology, the level of industrial development; and historical industrialisation. Other channels of technology transfer include technical assistance, labour mobility, turnkey plants, etc. (Morrison et al., 2008).

Relations with assemblers help suppliers to upgrade their technology. In developing countries, the technology upgrading of domestic supplier firms has been observed through the introduction of new quality standards and performance requirements, the introduction of new management systems, and access to world-class raw materials and components. Moving downstream in the auto-car supply chain, technology upgrading in second-tier firms is observed through product's quality improvements, assistance in upgrading the firm's process technology and access to car's interface information (Ivarsson et al., 2009a).

The absorptive capacity of suppliers determines how well these firms learn and potentially develop further capabilities. According to Ivarsson et al. (2009b), the transfer of technology for the suppliers' upgrading enhances tacit learning. On this basis, a further development of technological capabilities occurs when suppliers are able to decode the technology received to adapt, improve, or reproduce it or create new processes or products. In other words, a deeper understanding of know-why allows firms to move up in the technology scale and, in the long-term, become autonomous in developing their own capabilities (Lall, 2000; Ivarsson et al., 2009a). In this regard, a deeper understanding of know-why requires close, long-term relations between assemblers and suppliers, assemblers' commitment to provide a high degree of technological assistance, and suppliers' efforts and commitment to master and decode the tacit elements involved. The weak capabilities in the suppliers may hinder the process of decoding the technology received; therefore, suppliers are dependent on their assemblers' technology (Ivarsson et al., 2009b).

Recalling the assembler's commitment to impact with the domestic suppliers, several scholars have argued that FDI and multinational firms are a relevant source for the technology upgrading, productivity growth, and higher export growth in developing countries (Atallah, 2002; Feldman and Kelly, 2006; Padilla, 2004, 2008). These benefits are observed through spill-overs and other mechanisms that multinational companies use to transfer technology (for example, supply chain relations). The literature on spill-overs emphasises multinational companies spreading tacit elements that enhance learning to other organisations (for example, firms, universities, institutions) in developing countries. In the supply chain, these spill-overs are observed through cooperative R&D projects. Examples of cooperation between firms and universities are technology transfer, hiring students and sponsored research (Atallah, 2002; Feldman and Kelley, 2006). In the supply chain, Bessant et al. (1999) pointed out that spill-overs are limited along tiers, with the most learning occurring from assemblers to first-tier firms.

Supply chain spill-overs are determined by first-tier companies. Veloso and Kumar (2002) claimed that the process of teaching and learning is determined by original equipment manufacturers (first-tier firms) who want to encourage best practices in manufacturing and design among their suppliers.

In contrast to the literature that emphasises spill-overs, Gorg et al., (2004) claimed that this literature relies mainly on econometric analyses where significant bias may be encountered. These studies usually measure foreign firms' short-run effects on domestic productivity; similarly, these studies do not consider other important factors that may emphasise the impact of multinational companies in developing countries. The factor that is not considered in most econometric studies is the industry type; multinational companies locate in high productivity industries (for example, electronics) where they may not cause such a high level of productivity. Taking this into consideration, the evidence of the effect of spill-overs is much weaker. In fact, studies on Mexico have shown negative spill-over effects such as those that force domestic firms to reduce production given the lack of competencies to compete with multinational companies. In the same line, there is no evidence of spill-overs when multinational companies use highly complex technology given domestic firms' lack of absorptive capacity. Domestic firms can benefit from multinational companies whose knowledge they can absorb. Nevertheless, in Mexico, Gorg et al. (2004) have found evidence of positive spill-over effects that force firms to improve their efficiency.

Taking into consideration the previous arguments, scholars have argued that government programmes should provide incentives for firms to establish formal linkages (Feldman and Kelley, 2006). Atallah (2002) argued that, horizontal R&D supply chain cooperation can mitigate competition and is often monitored by authorities; vertical R&D cooperation is likely to increase competition. However, if vertical and horizontal R&D cooperation are linked, strong policies to protect against competitors acquiring the knowledge could harm the vertical linkages (between firms). Drawing on the theory of technological capabilities and value chains, Morrison et al. (2008) claimed that the transfer and diffusion of knowledge and technology is effective insofar as the firm includes elements of capability building.

On the basis of policy to foster the exchange of knowledge in the supply chain, Bessant et al. (1999) stressed the development of policies focused on involving SMEs in the supply chain learning process. Most major firms develop linkages with their tier 1 and 2 suppliers, avoiding SMEs. For this reason, government must gear policies toward the needs of small and medium firms.

Most scholars have recognised the importance of transfer of knowledge through interactions established between assemblers and suppliers in the automobile industry in developing countries (Padilla, 2004; Ivarsson, 2009a, 2009b). These studies have also paid attention to the suppliers' resulting technology upgrading. However, these studies pay less attention to the suppliers' absorptive capacity and the role of other actors that may influence the involvement of domestic suppliers. For this reason, the following section focuses on the government's role in driving technology upgrading in developing countries.

1.2.5 National Learning Systems

According to the literature, the term *system of innovation* was originated in Lundvall's 1985 analysis of the interactions between user-producers of innovation. In this approach, user-producer relationships provide signals of innovation throughout the system to key institutions, such as universities, public agencies and firms, which respond and in turn influence the system (Lundvall, 1985). Similarly, Freeman (1987) alluded to systems of innovation to explain the astonishing progress of Japan after the Second World War. In this analysis, government policies and enterprises shaped this distinctive performance in the Japanese NIS. The term 'National Systems of Innovation' was used in Lundvall (1992a) to refer to the importance of nation-states, as they provide a degree of cultural homogeneity and of political centralisation.

Scholars have described the system of innovation as a set of components that work together to achieve an objective (Carlsson et al., 2002). Here, innovation is conceived as processes that firms master in order to develop new product design practices and manufacturing processes (Edquist and McKelvey, 2000; Fagerberg et al., 2005). Central to systems of innovation are their various dimensions which include physical (sectoral and technological, and geographical), national and regional aspects. Nelson (1993) focused on systems such as country capabilities and knowledge for bringing about technological change. More specifically, the NIS concept is used to study systems of innovation in countries.

In general, the *broad* NIS concept includes the production system (for example, relationships among producers), the marketing system (for example, relationships between producers and users) and the finance system (for example, financial relationships) which at the same time are subsystems where learning takes place (Lundvall, 1992b), as well as interactivity to exploit innovation (Chung, 2002). The *narrow* NIS definition considers both organisations and institutions in search of technological innovation (Lundvall, 1992a). The difference is important because, according to Edquist (1997, p. 6), organisations are structures with a specific goal, while institutions are a 'set of common habits, routines or laws', which regulate relationships and interactions between individuals.

This thesis adopts the NIS definitions proposed by Niosi et al. (1993, p. 212) and Freeman (1987, p. 1) as 'the system of interactive public and private firms (large or small), universities, and government agencies whose activities and interactions initiate, import, modify and diffuse new technologies within national borders'.

The definitions above encompass a large number of interconnected institutions and organisations that support and foster technical change within national boundaries. Institutions have been defined empirically and theoretically. The empirical definition of institutions refers to universities, research centres, R&D departments in firms, technological service institutes, patent offices, consulting agencies, etc. This is similar to the definition of organisations. The theoretical definition of institutions – embedded in the *sociological* meaning – refers to norms, routines, shared expectations, behaviour patterns (for example, economic behaviour), moral behaviour, etc.[3] Thus, institutions are, 'sets of common habits, routines, established practices, rules, or laws that regulate the relations between individuals and groups' (Edquist, 2006, p. 46). According to Edquist, there are three basic functions of institutions: i) to provide incentives, ii) to manage conflicts and cooperation and iii) to reduce uncertainty by providing information.

Organisations are formed partly by institutions, and, therefore, also differ in the way they emerge. Organisations are formal structures of groups with a common purpose and specific objectives. In attempting to achieve those goals, organisations follow institutions, in other words, the rules of the game; at the same time, however, they can influence those rules. By contrast, the development of institutions may occur, 'spontaneously and often is not characterised by a specific purpose' (Edquist, 2006, p. 47).

Drawing on the previous arguments, Carlsson et al. (2002) defined the *components*, *relationships* and *attributes* of a system of innovation. Components are agents such as organisations (for example, universities, banks, firms) that have relationships (for example, transferring or acquiring technology via markets), for which they incorporate properties or

[3] Economic behaviour is considered a, '"habit of thought" to describe uncalculated actions and behavior of people' (Edquist, 2006, p. 44).

attributes (for example, capabilities). Relations are links between the components and involve markets (for example, buyer-supplier) and non-markets (for example, informal channels of information) links. Attributes are the features that shape the system.

In a system, technology innovation does not emerge linearly from basic to applied research. Instead, it is characterised by feedback mechanisms and interactive relations that involve science, policy, learning and demand, meaning that firms 'almost never innovate in isolation' (Edquist and McKelvey, 2000, p. 1). Innovation requires technical knowledge which may be codified (embodied in manuals, blueprints) or uncodified (embodied in the experience of technical workers or engineers) (Niosi et al., 1993) (See also discussion on absorptive capacity and development of technological capabilities in Section 1.2.2). Therefore, firms require other agents in the system to innovate.

According to Lundvall (2002), innovation is rooted in learning and learning is rooted in doing, using and interacting among users and producers. In this respect, learning is a central activity of the system and involves social activity and implies processes of (tacit and codified) knowledge exchange. One result of this knowledge exchange is that elements in the system reinforce and combine learning feedbacks (Lundvall, 1992b); without such feedbacks the systems would be static. The feedbacks render the system dynamic in which capabilities change and grow over time, changing its configuration (Carlsson et al., 2002).
Niosi et al. (1993) grouped the interactions in the innovation system into four categories: *financial flows* (interactions among public and private financing of innovation and capital investment); *legal and policy links* (interactions between the national firms and the state that coordinates technology policy); *technological, scientific and informational flows* (market-driven and scientific and technical collaborations); and *social flows* (interactions among firms with firms, firms with universities and personal flows).

The success of innovation depends on long-term relations with external agents. In this context, interactivity transmits learning dynamics since firms draw from their own experiences of design, development production and marketing and from a broad variety of external sources at home and abroad (suppliers, customers) and many other organisations

(Lundvall et al., 2002; Freeman, 2008). In this picture, the set of relationships within the NIS determines the pace and direction of this process and the development of capabilities (Lundvall et al., 2002). Thus, relationships are crucial for the innovation process. Freeman (2008, p. 80) stated that 'The innovative success of individual firms and their rate of growth depend not only on their own efforts but on the national environment in which they operate'.

In focusing on how an NIS acquires industry-level technological capabilities, much attention has been paid to the case of Korea's rapid economic progress after the Korean War, identifying macro and micro factors that influenced this development (Kim, 1998, 1999; Nelson, 1993). The macro, or general, factors in the Korean system of innovation are the growth of government investment in education, the inflow of foreign technologies, and industry/science and technology and trade policies. As a result of these, the micro factors identified are firms' technological efforts, technical assistance agreements and transfer of foreign technology between local firms and leading foreign firms and substitution of foreign engineering by local engineering (Kim, 1999; Nelson, 1993).

According to Carlsson et al. (2002, p. 235), the function of a system of innovation, 'is to generate, transfer, diffuse and utilize technology'. To do so, the system requires agent capabilities, that is, the ability to make innovative choices, scanning and identifying technological opportunities, organising and coordinating the resources and economic activities, efficient executions of functions and learning to diffuse technology.

One of the most important types of relationships – considered a core activity – in innovation systems involves *technology transfer* or *technology acquisition*, which takes place via market or non-market interactions, intentionally or accidentally (Carlsson et al., 2002). Technology transfer is intentional for suppliers and receivers (Carlsson et al., 2002), with foreign firms in developed countries serving as an important source of new knowledge for firms in developing countries (Kim, 1999). Such transfers can occur in foreign direct investment, foreign licensing, and turnkey plants – all of which are considered formal channels (Kim, 1999; Radosevic, 1999). Foreign technology transfer may or may not be mediated by the market – without written agreements and payments (Kim, 1999). Technology acquisition usually involves a lengthy collaborative process (Carlsson et al., 2002).

Regular channels of technology transfer are foreign direct investment, licensing, joint ventures, import of goods, subcontracting, exports, technical services contracts, and cooperative alliances (Radosevic, 1999). Informal channels are reverse engineering, training of engineers abroad (universities, R&D institutes), hiring of foreign engineers, and recruiting from foreign subsidiaries (Hobday, 1995). All these processes produce technological spill-overs that require considerable investments of time and effort by recipients in order to obtain the knowledge involved (Carlsson et al., 2002; Mowery and Oxley, 1995).

Firms exposed to new technologies develop new skills in order to understand and unpack them; therefore, important spill-over sources such as reverse engineering may result in skill acquisition through learning by using. The extent of these spill-overs depends on several factors: level of indigenous capabilities, channel of transfer and the age of technology being transferred. Spill-overs are limited by the level of indigenous technical capabilities of the receiver firm and controls imposed by the transferring firm (Mowery and Oxley, 1995).

The role of NIS in technology transfer lies in strengthening spill-overs through mandates or requirements on specific production and national R&D activities. For instance, government FDI requirements strengthen linkages between foreign enterprises and local firms, while restrictive policies (for example, antidumping policies) induce foreign firms to locate specific activities locally. The importance of NIS is the ability to formulate policies to support local firms (for example, trade and economic policies), to provide stable macroeconomic structures and to support R&D (for example, development of human capital, industry-government technology programmes) (Mowery and Oxley, 1995).

In relation to technology transfer, Radosevic (1999) referred to the development of country (education skills) and firm (know-how) capabilities as contributing to acquisition of and changes (catching-up) in technology transfer. Successful technology transfer requires new investments in learning in order to acquire the tacit knowledge embodied in technology.

Technology transfer is not just acquisition of technology (equipment, machinery and information); other services are required (Radosevic, 1999) involving collaboration to induce more interactive learning (Palaskas and Tsampra, 2003). Poor learning processes are associated with technical change limited to simply assimilating capabilities (Viotti, 2002). Radosevic (1999) argued that transfer of technology involves know-how rather than the technical information to master the technology.

Knowledge can be transferred in different ways: face-to-face training, movement of equipment, and reproducing documentation. Knowledge is assimilated more efficiently if it involves physical contact between supplier and receiver (on-the-job training) (Grant and Gregory, 1997). The strength of technology transfer (Mowery and Oxley, 1995) depends on *national absorptive capacity*, which relies on investments in scientific and technical training along with economic and trade policies to encourage competition among firms. In this approach, the channel of technology transfer (licensing, joint venture, etc.) places different demands (higher level of complementarity between supplier and receiver) on the receiver's absorptive capacity.

NIS has been used for scholars to deal with developing countries in which industrialisation and economic growth that has resulted from the country's technical change is the core of analysis (Freeman, 1995; Lundvall, 1992). Similarly, these studies paid attention to the country's historical and cultural characteristics that contribute to the success of technical change. In contrast, NLSs are proposed by Viotti (2002) to deal with systems whose technical change processes are largely based on learning rather than innovation.

Viotti (2002) claimed that to refer to NISs in late industrialising economies could result in misunderstanding because economies from developing countries focus on absorbing knowledge rather than innovating. Similarly, scholars (Davenport, 1999; Intarakumnerd et al., 2002; Viotti, 2002) argued that problems related to the National Innovation System

(NIS) in developing countries are different from those in developed countries which involve learning-intensive catching-up. Developing countries often struggle to initiate learning-intensive catching-up because they lack the necessary government policy competences and capabilities.

In NLSs, the perspective of learning depends on the *capacity for absorption* of already-existing techniques. In this regard, technological capabilities are employed to acquire the knowledge involved in those techniques. Thus, technological capabilities address the process of technical change at firm, industry and country levels. Technological capabilities include production, improvement, and innovation.

In developing countries with passive learning strategies, firm-level technical change is based on production capability absorption.[4] In developing countries with active learning strategies, technical change is based largely on mastery of production capabilities in parallel with improvement capabilities (Viotti, 2002). With reference to absorptive capacity in NISs, Palaskas et al. (2003) grouped entrepreneurial learning into *intra-firm* learning based on internal R&D efforts, spill-overs, learning from the environment (clusters and industrial agglomerations) and institutional R&D, and *inter-firm* learning based on networks.
Several studies demonstrate the importance of technological capabilities in less-developed countries that require an appropriate national framework to generate innovation. Thus, the NIS includes how a nation manages the use, improvement and diffusion of new products and processes, which means that innovation cannot occur in isolation. The NIS needs to be supported by social capability, which emerges when a country is socially advanced (Olatunji, 2002).

There are differences between NLSs across developing countries. In this regard, Intarakumnerd et al. (2002) highlighted that systems problems in developing countries are

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[4] Viotti (2002) stressed the differences in NLS learning strategies (active versus passive) in NLS to distinguish technical change types. In passive learning systems, the technological efforts for technical change involve absorption; in active learning systems, the technological efforts are associated with higher commitments of investment in long-term strategies and technology capital. These differences are reviewed in more detail in Chapter 5.

different from those in countries with intensive technological learning (for example, South Korea, Taiwan, Singapore); the latter are involved in learning intensive catching-up, which developing countries (for example, Latin American countries) cannot engage in because of lack of linkages.

Using NLSs to build technological capabilities in developing countries requires building technical competence. Enos (1991) argued that basic education permits industrial workers to receive and transmit knowledge without other human intervention. Higher skills are restricted to the area of application; thus, the skills acquired in technical education (for example, vocational school) are transferable within sectors of a specific economy and the skills acquired through postgraduate university education are much more difficult to transfer. Basic education skills are easily transferable across all types of activities. However, it has been argued that the secondary (that is, manufacturing) and tertiary (that is, services) sectors require higher and more varied technical skills. Skills in the secondary sector are provided by firms (suppliers of medium-level skills) and research units (suppliers of higher-level skills). Firms supplement the education systems in developing countries by providing medium- and high-level skills (Enos, 1991). This is discussed more in Chapters 4, 5 and 6.

In developing countries, capability development faces market failures that hinder growth. Examples of these are lack of information, absence of suppliers, lack of or poor support institutions, exposure to strong competition and so forth. In this context, industry policies such as those related to protection may not succeed and could be harmful or ineffective and reduce the learning process in firms. Based on this, policies should be formulated to coordinate with factor markets. An example would be the building of local capabilities in firms by stimulating foreign investors to invest in R&D (Lall, 2003) by means of tax exemptions, financial grants, government procurement (that is, preferential financing) and so on (Chen and Sewell, 1996).

As pointed out by Nelson (1993b, p. 840), in systems of innovation, the, ‘level of coordination among different actors is a crucial aspect to foster technological change’.

Lessons from successful industrial countries show that close relationships between government and industry multiply innovation's effects and increase its diffusion. These interactions include those between government and large firms (national champions) or development of a common competition strategy (that is, small firms sharing their expertise) (Nelson, 1993b).

Most research on developing countries concentrates on multinational companies or those companies that can contribute significantly to technical change. However, small-sized companies constitute an important segment of the total developing country industrial structure. For this reason, in this thesis, I focus on studying domestic small and medium-sized companies in order to investigate how indigenous capabilities within the context of developing countries are affected by the presence of up-to-date technology companies (for example, foreign and domestic companies). In order to pursue this interest, as mentioned before, this thesis focuses on Mexican-owned SMEs that interact with foreign firms in the automotive industry. Hence, the following paragraphs introduce the peculiarities of small and medium-sized companies in developing countries.

The importance of SMEs is based on their heavy participation in markets, especially in developing economies (Bolaños, 2000). Because of the level of their participation, much of the discussion of small firms in developing countries focuses on clusters and the concepts of collective efficiency and upgrading to produce competitive advantage in geographically agglomerated firms in supply chains, market niches and sectors (Giuliani et al., 2005; Schmitz, 1995).

The literature on NLSs acknowledges the importance of firms in national economic growth; however, not all firm sizes show equal performance. In particular, SMEs rarely possess R&D resources and are, therefore, highly dependent on external technological information in which the development of external linkages is crucial for building competences and skills (Rothwell and Dodgson, 1994). More specifically, these external linkages are related to collaboration, which can involve R&D, manufacturing, marketing, etc. There are two types of collaborations, *horizontal* and *vertical*. Horizontal collaboration occurs between partners at the same level in the production process. Vertical collaboration occurs along the chains of activities involved in manufacturing, provision of raw materials, assembly, distribution and servicing (Dodgson, 1993). In approaching the interactions between firms in developing countries, Rothwell and Dodgson (1994) argued that relations with large firms push SMEs to increase their competitive advantage through innovation. These relations emerge as the result of joint ventures, subcontracting, producer-consumer relations, licensing, etc.

Rothwell and Dodgson (1991) grouped modes of interaction between small and large firms into: *manufacturing subcontracting relationships* – large companies transferring know-how to small sub-assemblers and suppliers of components; *producer-consumer relationships* – large firms transferring technological know-how to small suppliers of finished products; *licensing agreements* – large firms providing new technology (equipment or processes) to small firms who exploit it and provide a financial return; *contracted out R&D* – large firms contracting R&D services to small consultancy companies; *collaborative development* – small and large firms collaborating on a new project for the large firm; *large-small firm joint venture* – collaboration between small and large firms in which small firms provide the know-how and large firms provide financial, manufacturing and marketing resources. In spin-outs, the modes identified are: *sponsored spin-outs and venture nurturing*; and *independent spin-out assistance*.

In considering the applicability of the interactions between SMEs and large firms, it is important to stress their effectiveness. As Kimura (2002) pointed out, subcontracting relationships enhances both static and dynamic efficiency in SMEs. Note also that obtaining more benefits from the relationships with large firms requires the accumulation of knowledge resources in SMEs based mainly on entrepreneurs, firms and social or business networks. Here, learning progressing through absorptive capacity is crucial. Hence it is necessary to improve the institutional context by promoting applied learning that exploits earlier firms' learning (Macpherson and Holt, 2007).

The literature based on NISs has ignored the process of learning and absorbing dominant in developing countries and studies focused on developing countries have highlighted the failure of NISs in such countries (Padilla, 2004; Yoruk, 2009). For this reason, to understand the process of technology upgrading in developing countries, this thesis adopts the concept of NLSs proposed by Viotti (2002).

1.3 Research questions and outline of the thesis

The main research question for the thesis is:

- How do SMEs in the Mexican automotive industry upgrade their technology?

This question is addressed in the literature by introducing the notions of technology capabilities, competencies and absorptive capacity, and by analysing technology transfer between firms in the global supply chain. This leads to the first sub-question:

- How do SMEs in the Mexican automotive industry upgrade their technology through interactions with larger firms in the global value chain?

However, other actors are also important and are captured in the literature through the notion of the National Learning System. This leads to the second sub-question:

- How do SMEs in the Mexican automotive industry upgrade their technology through interactions with other actors in the National Learning System?

The thesis is comprised of seven chapters. This first chapter has introduced the research questions and reviewed the theoretical literature. Chapter 2 will look at the process of technology upgrading in various countries, including South Korea, Japan, Taiwan and Brazil, in order to identify differences and similarities with Mexico. Chapter 2 also provides additional background information about the Mexican automotive industry. Chapter 2 complements the theoretical overview of factors influencing the process of technology upgrading with a more broad-brushed empirical analysis, bringing a comparative dimension to the thesis. Chapter 3 discusses in more detail the empirical research that has been conducted, specifically in the Mexican industry, and detail the methodology used. In Chapter 4, I focus on the first sub-question and discuss the internal sources of capacity building, such as those internal to the relationships between large firms and SMEs. In Chapter 5, I move to the external sources for technology upgrading and, therefore, also to the meso- and macro-levels of the industry as a whole and the inclusion of other actors in the analysis, such as chambers of commerce, governments and universities. This is prompted by the use of the notion of national learning systems. I also deepen this analysis by again comparing the developments in the Mexican industry with those in other countries mentioned above. In Chapter 6, I look at both sub-questions again and re-analyse my data using a more quantitative approach. Chapter 7 discusses the answers given to the research question and offers a research agenda.

CHAPTER 2
EMPIRICAL LITERATURE: COMPARATIVE CASES

2.1 Introduction

This chapter's main objective is to provide a larger comparative context to technology upgrading in the Mexican automobile industry by analysing this process in the cases of Japan, South Korea, Taiwan, and Brazil. In addition, this chapter presents the historical and contemporary context of the development of the Mexican automobile industry. The aim is to collect insights about the role of various actors and factors in the process of technology upgrading. It is not a systematic comparison, but a selective one, aimed at identifying some key lessons.

Section 2.2 presents the global value and supply-chain relationships among firms. These relationships were presented in Chapter 1 to look at technology transfer and technological learning among interacting firms. For Chapter 2, this section presents a more detailed description of the hierarchical structure of the automobile industry, stressing the role of each firm in the different tiers. Section 2.3 presents the size of the global automobile industry, based on statistical data. Both sections provide a context for a discussion of various countries' experiences. Section 2.4 examines successful cases of automobile industry technology upgrading in Japan, South Korea, and Taiwan. The cases present various relevant aspects of technology upgrading. For South Korea, it focuses on the role of the government in developing technological capabilities for large firms (*chaebols*). For Japan, it focuses on developing science and technology in the NIS. For Taiwan, it focuses on the role of the government in upgrading the technological capabilities of SMEs auto parts. Section 2.5 and 2.6 examine the historical context of the development of the automobile industry for Brazil and Mexico. Section 2.7 presents the size and importance of the automobile industry in Mexico through economic indicators.

2.2 Overview of the automotive and auto-parts industries

The automobile industry and the auto-parts sector are internationally recognised as among the most capital-intensive industries that majorly affect related industries (such as textils and plastics). In developing countries, these industries provide a path to technological and economic development (Jan and Hsiao, 2004). The case of the automobile industry was selected for two main reasons: The automobile industry in developing countries represents acquisition of foreign technology and rapid industrialisation; and the automobile industry provides a channel for local firms to absorb new information and compete with foreign firms in the home country.

2.2.1 Automobile and auto-parts industries: Structure and relationships

The automobile industry consists of car-assembly firms and the auto-parts sector, which produce or assemble original vehicle components.[5]

Generally, the auto-parts sector includes: bodywork (such as body mouldings, plastic parts), trims (such as carpets, seat parts, seat adjusters), accessories (such as radios, wheels), electrical components (such as harnesses parts, embedded systems), engines parts (such as oil pumps, monoblocks) (Bancomext, 2004) among others parts presented in Table 2.1.

[5] The auto-parts sector has two consumers: The terminal sector and suppliers of original equipment (in other words, spare parts).

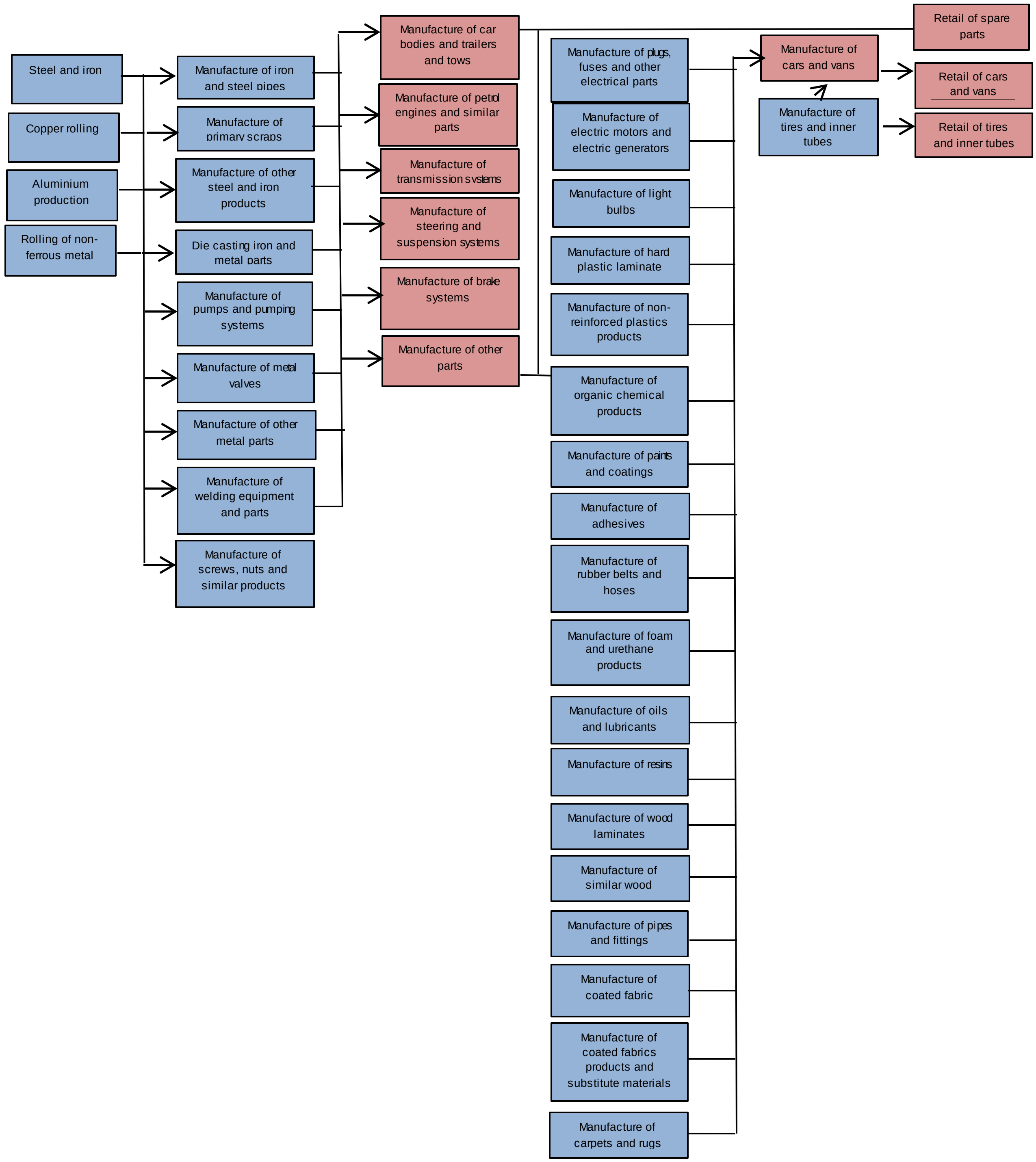
Table 2.1
Taxonomy of vehicle parts

Group	Category
Automotive wheels and tyres	Pneumatic tyres for cars
	Pneumatic tyres for trucks
Rubber automotive products	Hoses
	Rubber products
Plastic parts and accessories	Plastic parts and accessories
Glass, windows, and automotive windshields	Glass, windows and automotive windshields
Electronic components	Automotive electrical harnesses
	Spark plugs, breaker points, and automotive condensers
	Batteries
	Embedded systems
Vehicle bodywork	Bodywork
Car engines	Engines for vehicles
	Engines for trucks
Engine parts	Car bearings
	Crankshafts
	Monoblocks
	Oil pumps
	Oil filters
	Air filters
Transmissions and clutches	Transmission and clutches
Car suspensions and steering	Car dampers
	Car steering
Brakes	Brake pads
	Brakes
Fabrics, carpets, and seats	Carpets
	Car seats
Metal Parts	Car dies
	Metal parts
Cooling parts	Radiator
Other	Oils, lubricants and other fluids

Source: Own elaboration based on the National Auto-parts Institute, Mexico INA

Figure 2.1 depicts the main activities and components of the automotive supply chain and their relationships. The first and second columns (from left to right) belong to suppliers of the fourth and third tier, respectively. The third column belongs to suppliers of the second tier and the fourth column belongs to first-tier suppliers. Components in red are main production activities, and components in blue are secondary production activities. The arrows represent the relationships among those activities.

Figure 2.1
Manufacturing linkages between the automobile industry and auto-parts sector



Source: Ministry of the Economy-SIEMhttp://www.siem.gob.mx/siem/portal/cadenas/CadenasProductivas.asp

With regard to the relationships between the automobile industry and auto-parts sector, the following subsections present the global value-chain and supply-chain relationships in the automobile industry to examine the process of technology transfer and technological learning among firms.

2.2.2 The automobile industry global value chain and supply chain

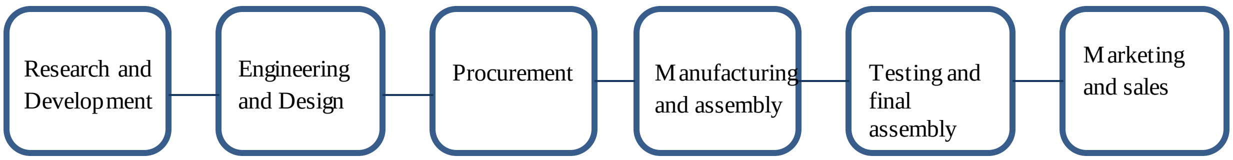
Distinguishing features of the auto industry are global production and the widespread diversity of the sectors and firms involved. The supply chain is characterised by global interaction among firms to lever engineering efforts (at the vehicle design and development levels) across products sold in different end markets (Sturgeon et al., 2008). The high degree of division in the global auto industry value chain (in other words, different parts of the value chain are developed separately) allowed developing countries (such as Mexico) to enter into the global auto industry value chain with vehicle-assembly plants and components. The changes in the global assembly sector influenced the auto-parts sector, where relationships between assemblers and suppliers changed considerably due to the impact of assemblers' global reach (Humphrey and Memedovic, 2003). The concept of the global value chain is used to analyse how auto-parts firms are involved in the industry and how changes to the chain affect the auto-parts sector, especially in developing countries in which the auto-industry has encouraged developing the auto-parts sector.

More specifically, the structure of the value chain in the automobile industry consists of six main segments (see Figure 2.2).

- R&D, comprising basic research (theoretical work to acquire new knowledge without application), applied research (developing investigations to acquire new knowledge, and experimental development (work developed on the basis of the existing knowledge gained from research and/or practical experience)(OECD, 2002, p.30)
- Engineering and design are related to design activities to adapt and develop products and processes. This stage requires knowledge of materials (such as quantity, quality, and aesthetics), standards, manufacturing facilities (in-house), and process knowledge (Pugh, 1991).
- Procurement refers to intra- and inter-firm agreements (such as sourcing activities) of manufacturing processes and services activities.

- Manufacturing and assembly activities comprise intensive human capital and activities, mainly located in various developing countries.
- Testing and final assembly activities
- Marketing and sales activities

Figure 2.2
Segments of the value chain in the automobile industry

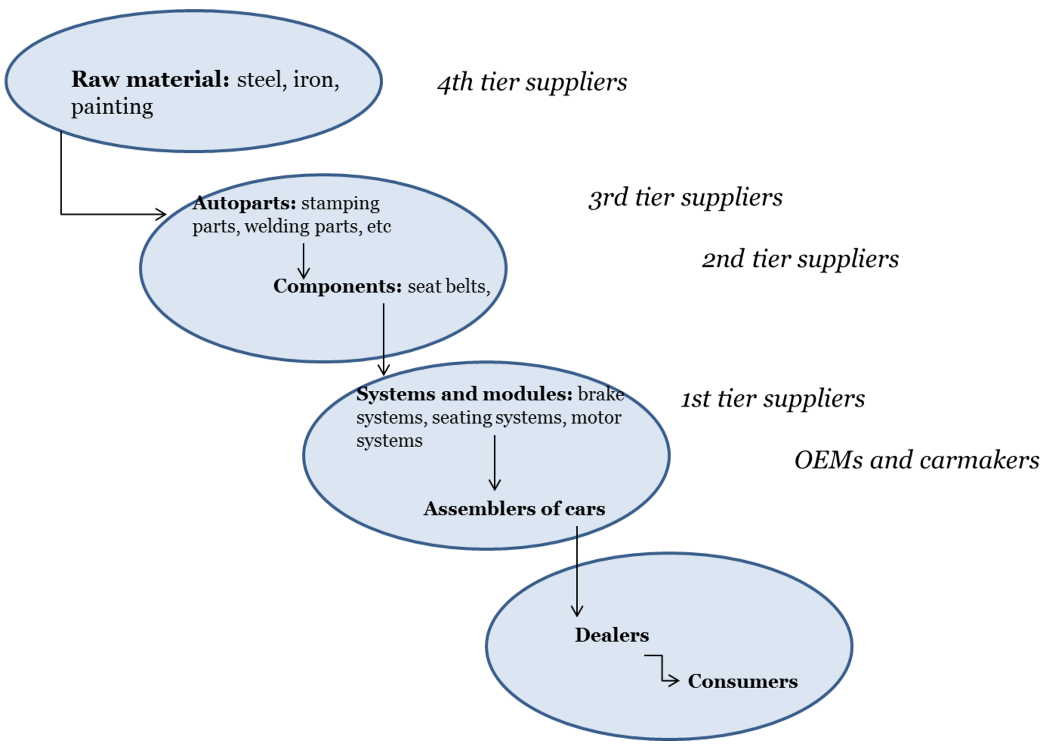


Source: Adapted from multiple secondary sources (see Humphrey, 2003; Luchi, 2000)

The relationships between assemblers and suppliers are analysed within the supply chain framework (see Chapter 1). The automobile industry comprises different actors: Assemblers, global mega-suppliers, first-tier suppliers, second-tier suppliers, and third-tier suppliers. *Assemblers* refers to auto makers (such as Ford, Chrysler, Toyota, Nissan), *global mega-suppliers* refers to those firms that supply major systems to assemblers (such as seating systems). These firms have global coverage and are closer than first-tier suppliers to the assemblers. They are responsible for managing the second-tier suppliers and developing supply systems in different locations. *First-tier suppliers* directly supply assemblers. They supply tooling, logistics systems, modules, and so forth (Ochoa, 2005). *Second-tier suppliers* supply less-sophisticated components and parts than first-tier suppliers. Second-tier firms work with designs provided by assembler or global mega-suppliers and first-tier suppliers. *Third-tier suppliers* supply basic products such as aluminium, plastic, and glass products. They supply products that do not require sophisticated engineering and design.

Within the structure of suppliers to the automobile industry, second- and third tier suppliers do not have direct linkages with assemblers. The tier in the supply chain is determined by the closeness of the relationship between assembler and supplier (Humphrey and Memedovic, 2003; Miranda, 2007; Ochoa, 2005). With respect to the relationships between the different parts of the automobile industry, the supply chain focuses upstream on integrating supplier and customer processes to improve efficiency. The supply chain includes the efforts involved in producing and delivering a final product, from supplier to supplier-customer or consumer to customer (Feller et al., 2006). Figure 2.3 depicts the different tiers of suppliers in the automotive supply chain and their relationships. This figure stresses the differences between the different tier suppliers as producers of parts, components, systems and modules. The differences among parts, components, systems, and modules are based on the level of complexity in manufacturing or assembling and the function of the different parts, as mentioned above.

Figure 2.3
Tiered suppliers in the automotive supply chain



Source: Jímenez, 2006; Ochoa, 2005; Miranda, 2007.

2.2.3 Barriers to entry

The high concentration of a small number of powerful lead firms that drive the automotive industry has been a barrier to the entry of firms who lack capabilities in this industry. The high levels of technology and strict requirements in the automobile industry increased the tendency for global relationships between assemblers and their suppliers. Assemblers in different locations are more likely to use the same suppliers to assure quality standards, level of technology, and ease of communications for more complex, technologically advanced products. This preference for familiar suppliers hinders the involvement of domestic suppliers, especially for firms lagging behind these standards. The growth of car production and acquisition of brands by auto makers has reduced the number of suppliers to the auto industry. The auto-parts sector has increased restructuring. There are three main components to this restructuring: Suppliers have moved toward greater customisation of their products to fit customer needs; greater supply of complete functions (such as systems or modules); and greater involvement of assemblers in specifying quality and production. Assemblers and first-tier suppliers are expanding their reach by acquiring and establishing component manufacturers (Humphrey and Memedovic, 2003).

In essence, the barriers/challenges identified to entering the automobile industry are:

- Production related to economies of scale. Because the automobile industry involves large-scale production, component suppliers require high investment in production facilities (such as machinery, equipment, and manufacturing plants) to assure production at low cost (Follis and Enrietti, 2002).
- Development of technological capabilities. Auto-parts firms must implement high quality standards, quality systems (such as the Kaizen system), and control systems (such as just-in-time systems) to supply parts to assemblers. Intangible investments are also necessary to develop sufficient capabilities related to product design and engineering (Follis and Enrietti, 2002; Ochoa, 2005).
- High level of competitiveness. The globalised environment of the automobile industry creates barriers related to high levels of investment by auto-parts firms to be part of the industry (Miranda, 2007).

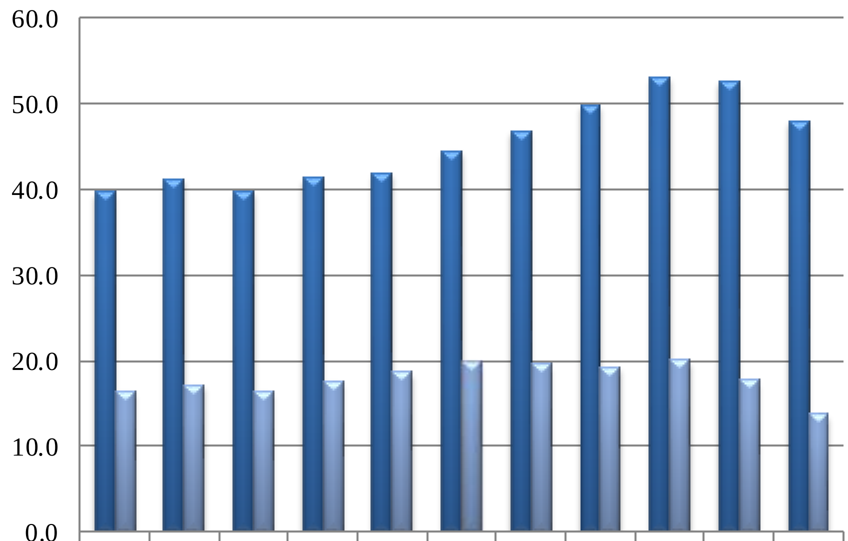
2.3 The size of the global automobile industry

Focusing on the auto-parts industry requires a corresponding focus on the automobile industry, since a typical vehicle comprises more than 10,000 components.[6] According to the International Organization of Motor Vehicle Manufacturers (OICA), world production of cars in 2008 was more than 52 million units and world production of commercial vehicles was more than 17 million units, for a cumulative total of more than 70 million units.[7–8] The global financial downturn in late 2008 and early 2009 hindered growth in the

[6] 'Global engineering for the automotive industry'. Siemens PLM Software. www.siemens.com/plm
[7] Production refers to a completely built vehicle (CBU), rather than assembly of completely knocked down (CKD) or semi-knocked down (SKD) sets. OICA: http://oica.net/wp-content/uploads/stats-definition.pdf.
Commercial vehicles are light commercial vehicles, heavy trucks, coaches, and buses OICA: http://oica.net/wp-content/uploads/stats-definition.pdf

automobile industry and produced an automotive recession in late 2009.[10] In 2009, world production of cars was almost 48 million units, and the world production of commercial vehicles was more than 13 million, for a total of more than 61 million vehicles (OICA; 2008, 2009) (See Graph 2.1).

Graph 2.1
World motor vehicle production (millions)



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cars	39.8	41.2	39.8	41.4	42.0	44.6	46.9	49.9	53.2	52.7	48.0
Commercial vehicles	16.5	17.2	16.5	17.6	18.7	19.9	19.6	19.3	20.1	17.8	13.8

Source: International Organization Motor Vehicle Manufacturers (OICA)

Table 2.2 shows the world's largest auto makers in 2009. The largest is Toyota, with production of 7.2 million cars and commercial vehicles, followed by General Motors, Volkswagen, and Ford.

Table 2.3 shows the world's largest manufacturing countries in the automotive industry. China is the largest global producer, followed by Japan and South Korea. In Europe, Germany is the largest producer, followed by Spain and France. In the Americas, the largest producer is the US, followed by Brazil (in South America) and Mexico and Canada (in North America).

'Cars are motors vehicles with at least four wheels, used for the transport of passengers and comprising no more than eight seats in addition to the driver's seat.' OICA: http://oica.net/wp-content/uploads/stats-definition.pdf.

[10] Vlasic and Bunkley (2008) 'Hazardous Conditions for the Auto Industry', *New York Times*. http://www.nytimes.com/2008/10/02/business/02sales.html?_r=1&partner=rssnyt&emc=rss

Table 2.2
The world's largest auto makers in 2009
(Millions)

Rank	Auto maker	Nationality	Cars	Commercial Vehicles	Total
1	Toyota	Japan	6.14	1.08	7.22
2	General Motors	United States	4.99	1.45	6.44
3	Volkswagen	Germany	5.9	0.16	6.06
4	Ford	United States	2.95	1.73	4.68
5	Hyundai	South Korea	4.22	0.32	4.54
6	PSA	France	2.76	0.27	3.03
7	Honda	Japan	2.98	0.03	3.01
8	Nissan	Japan	2.38	0.36	2.74
9	Fiat	Italy	1.95	0.47	2.42
10	Suzuki	Japan	2.1	0.28	2.38
11	Renault	France	2.04	0.25	2.30
12	Daimler	United States	1.05	0.34	1.39
13	Chana Automobile	China	1.42	0.00	1.42
14	B.M.W	Germany	1.25	0.00	1.25
15	Mazda	Japan	0.92	0.06	0.98
16	Chrysler	United States	0.21	0.75	0.96
17	Mitsubishi	Japan	0.71	0.09	0.80
18	Beijing Automotive	China	0.68	0.00	0.68
19	Tata	India	0.37	0.28	0.65
20	Dongfeng Motor	China	0.66	0.00	0.66

Source: The International Organization Motor Vehicle Manufacturers (OICA) (2009)

Table 2.3
Global motor vehicle production by country 2008–2009
(Number of cars and commercial vehicles)

Country	Rank (total production 2008–2009)	2008	2009
Europe			
Germany	4	6,045,730	5,209,857
Spain	8	2,541,644	2,170,078
France	9	2,568,978	2,047,658
United Kingdom	12	1,649,515	1,090,139
Italy	13	1,023,774	843,239
Belgium	14	724,498	537,354
Sweden	16	308,299	156,338
Portugal	17	175,155	126,015
America			
United States	3	8,693,541	5,708,852
Brazil	6	3,215,976	3,182,617
Mexico	10	2,167,944	1,561,052
Canada	11	2,082,241	1,490,632
Argentina	15	597,086	512,924
Venezuela	18	135,042	111,655
Asia			
China	1	9,299,180	13,790,994
Japan	2	11,575,644	7,934,516
South Korea	5	3,826,682	3,512,926
India	7	2,332,328	2,632,694

Source: The International Organization Motor Vehicle Manufacturers (OICA) (2009)

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Table 2.4 shows the main firms in the auto-parts sector. In 2007, the leading firm was Robert Bosch GMBH, which manufactures headlights, brake systems, batteries, wiper blades, starters, and air filters. Second was Denso Corporation, which manufactures systems such as engine management (such as gasoline and diesel engine management, starters, alternators, and radiators), climate control, body electronics (such as head-up displays, instrument clusters, parking-aid systems, and remote keyless-entry systems), driving control and safety (such as airbag-sensing systems, adaptive cruise-control systems, adaptive front-lighting systems, and electric power-steering systems). Johnson Controls was third in the auto-parts sector, with revenue of more than US$ 27 million, and manufactures seating systems (such as metal structures and mechanisms, climate subsystems, safety subsystems, and foam and trim), interiors (such as cockpit and instrument panels, door panels and systems, and floor consoles), and electronics (such as body-control modules, access-control systems, tyre-pressure monitoring systems, interior control modules, and energy-management systems) (see Appendix 1).

Table 2.4 Worldwide auto-parts industry: Tier 1 suppliers (2007)

Global revenue (US$ Millions)

Company name	Nationality	Revenue (million US dollars)	System
Robert Bosch GmbH	Germany	51,328	Art lights, brake systems, batteries, wiper blades, starters and air filters.
Denso Corporation	Japan	29,132	Engine Management, Climate Control, Body Electronics, Driving control & safety, Hybrid vehicle components, Info & Communication
Johnson Controls Inc.	United States	27,479	Seating, Interiors, Electronics
Delphi Corporation	United States	26,947	Body & Security, Driver interface, Entertainment & Communications, Electrical and Electronic architecture, Fuel Cells, Hybrid and Electric vehicle products, Powertrain systems, Sensors, Thermal systems
Bridgestone Inc.	Japan	24,340	Tyres
Magna International Inc.	Canada	22,811	Body & chassis systems, Powertrain systems, Exterior and interior systems, Seating systems, Exteriors & Interiors, Vision systems, Closure systems, Roof systems, Electronic systems, Fuel systems
Goodyear Tire & Rubber Co.	United States	19,723	Tyres
Aisin Seiki Co. Ltd	Japan	19,376	Drivetrain related products, Brake and chassis related products, Body related products, Engine related products, Information related products
Michelin Group	France	19,300	Tyres
Continental AG	Germany	17,130	Chassis and safety systems, Interiors, Powertrain systems
Lear Corporation	United States	17,089	Seating systems, Electronic systems, Environmental systems
Visteon Corporation	United States	16,976	Climate Control, Electronics, Interiors, Lighting
Toyota Industries Corporation	Japan	13,760	Engines, Compressors, Electronics, Stamping dies
Faurecia	France	13,592	Acoustic package, Seating systems, Door system, Cockpit, Emissions control systems, Front / End systems
ZF Group	Germany	13,411	Transmissions, Driveline components, Axle systems, Chassis components, Steering, Electronic components
TRW Automotive Holdings Corporation	United States	12,643	Cognitive safety integration, Steering systems, Braking systems, Occupant safety systems, Electronic systems
Valeo SA	France	12,297	Powertrain systems, Thermal systems, Comfort and driving assistance systems, Visibility systems
Eaton Corporation	United States	11,115	Engine valves, Lifters and Valve actuation, Superchargers, Differentials and locking differentials, Gears, Advanced machining products, Powertrain controls, Fluid conveyance, Fuel emissions controls, Plastics
Arvin Meritor Inc.	United States	8,903	Axles, Brakes and safety systems, Drivelines, Suspensions, Light vehicle body systems
Dana Corporation	United States	8,699	Drivetrain related products, Sealing products, Thermal systems
GKN plc	United Kingdom	6,612	Driveline, Cylinders, Powder metal components, Land systems
Federal-Mogul Corporation	United States	6,286	Powertrain energy, Powertrain sealing and bearings, Safety and protection systems
Autoliv Inc.	Sweden-United States	6,205	Safety and protection systems, Electronics, Steering wheels

Source: PricewaterhouseCoopers Automotive Institute. Global Automotive Financial Review. 2007 Edition

2.3.1 Trends in the auto-parts sector

Trends in the auto-parts sector relate to technology and innovation, which are strategic elements. The automobile and auto-parts sectors have focused on environmentally friendly products since 2007 (PWC, 2007). Here, I summarise the features of the global automobile and auto-parts industries.

- Cost reduction: The automobile and auto-parts industries are characterised by high levels of competitiveness (PWC, 2007). Auto makers and first-tier suppliers reduce costs by investing in production facilities and design centres in low-cost countries (emerging markets). Activities such as outsourcing, improvements in labour productivity, partnerships, and new production methods are important to control costs. Auto makers forged joint ventures and technology agreements in which suppliers are aligned to the automotive companies (SpencerStuart, 2006). In relation to cost-efficiency, auto-parts suppliers consolidate their base through innovation, redesigning components and parts, and development capacity (PWC, 2007).
- Rapid response and flexibility: The automobile industry is characterised by high flexibility and rapid response to market requirements. The supply chain has benefited from outsourcing activities and suppliers offering 'flexible modular solutions' to concentrate on specific core capabilities and functions. This flexibility in the auto-parts industry allows these companies to respond quickly to shifts in demands by streamlining production and flexible cost structures. Auto-parts suppliers require operational experience and financial acumen (SpencerStuart, 2006).
- Large scale innovation: Given the high level of technology involved in car systems and mass-production of cars around the world, this industry is characterised by large-scale innovation in which intensification and acceleration of R&D is impelled by a shift from mechanical to electro-mechanical car systems and product variety. The latter is due to market fragmentation into regional markets in which auto makers must design new models and adapt them to regional market requirements. As a result of this shift, auto makers are focusing on core areas to master the technology. These areas include: combustion, electronics, software, artificial intelligence, and communications. (Miller, 1994). There is a need to share the development of capabilities effort along the supply chain. Auto makers and first-tier suppliers assess which responsibilities can be assigned to smaller suppliers (Veloso and Kumar, 2002).
- Global networks: The globalised structure of the automobile industry promoted development of supply networks to ensure better, faster interactions within auto makers and their auto-parts suppliers. Developing and integrating suppliers in the global value chain resulted in the emergence of global suppliers able to deliver component systems to any location in the world (Humphrey, 2003). Suppliers adopted different strategies, including developing a global perspective and planning operations on a global scale. Similar models were simultaneously launched in different locations. As a result of this global structure, auto firms are replicating the

supply-chain structure and requiring suppliers to be located in the same region (Veloso and Kumar, 2002).

- Hierarchy in the automobile supply chain: The automobile industry is clearly identified by its structure. First-, second- and third-tier suppliers are grouped according to product complexity levels. First-tier suppliers manufacture highly complex products, second- and third-tier manufacturers produce less complex products. Suppliers at all levels must operate with just-in-time production and have appropriate quality standards and manufacturing processes. In second- and third-tier suppliers, these conditions are assessed by auto makers and their first-tier suppliers (Ochoa, 2005). Auto makers and first-tier suppliers set the pace and direction of technology in components and parts.
- Importance: The high-scale production and large revenues related to the automobile industry are an attraction for developing countries trying to achieve industrial upgrading. Typical incentives, such as reduced standard tax rates and accelerated depreciation, are practices such countries use to attract the industry (Altenburg, 2006).

2.4 Empirical evidence on technological capability building: Asian countries and Brazil

The first subset of literature on rapid industrialisation and development of technological capabilities in the automotive industry in Asia offers important lessons for analysing the auto-parts industry in Mexico. Although there are differences among these countries in terms of the role of the government, idiosyncratic features, capabilities and competences, and relative importance of small and large firms, there are some common features related to active policy in developing human capital, indigenous efforts to absorb technology, impressive and aggressive policies oriented to acquire, assimilate and create technology, and import- and export-oriented strategies.

The second subset of the literature focuses on developing countries in Latin America, particularly the automotive industry in Mexico and Brazil. Studies of Brazil's automotive industry present the achievements and shortcomings of policy reforms for developing the automobile industry based on the presence of foreign firms. The Brazilian case is important due to similarities to Mexico in the role of government on diffusing technology. The subset of the Mexican automobile industry presents in more detail the automobile industry development, as well as the stages of the automobile industry's growth. This section also examines auto-parts technology upgrading by developing technological capabilities and the role of the government.

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2.4.1 The case of South Korea's automobile industry

In the empirical evidence leading to development of technological capabilities in developing countries, the South Korean automobile industry shows the importance of Korea's car makers' efforts and ambitions to lead the industry and the role of the government in growing the Korean car industry. The literature acknowledges South Korea's astonishing industrial development (Kim 1997, 1998; Nelson, 1993, Rim et al., 1998). South Korea's rapid industrialisation is attributed to many factors (such as the role of government, competences, and car makers' efforts) in industries such as electronics and automobiles, which were central to technological development and industrial growth (Kim 1997, 1998; Rim et al., 1998).

In relation to developing technological capabilities in the automobile industry, Kim (1997) identified two main avenues for technology upgrading relating to both developed and developing countries. The main difference between them is if the development is endogenous to the innovation system, or comes from the outside. The process of upgrading covers the emergence, consolidation, and maturity of product and process innovations. In developing countries, knowledge is acquired from industrialised economies. The upgrading process includes acquisition, assimilation, and improvement of technology acquired from foreign firms (Kim, 1997).

Several scholars (Cardoza, 1999; Kim, 1997) argue that acquiring foreign technology is necessary for the technological change process. Developed countries acquire and assimilate technology based on mature foreign technology. Hobday (1995) identifies some mechanism of foreign technology acquisition in developing countries: Direct foreign investment, joint ventures, foreign and local buyers, licensing, overseas acquisitions, strategic partnerships for technology, subcontracting, and foreign and local buyers.

According to Kim (1997), assimilating general production technology in developing countries permits local firms to develop production capabilities (technological capabilities) to unpack foreign technology and apply it for manufacturing products. The process requires technological efforts from local engineering firms. Diffusing technological skills (related to production and process design) acquired from foreign technology is achieved by moving experienced personnel among early acquirers of the technology.

The relatively successful assimilation of general production technology in developing countries lies in firms' learning processes to understand and duplicate foreign technology. Firms may need to repeat this process for higher-level technology. When the developing country firms have accumulated indigenous technological capabilities, they can generate new technologies. An example of this process is SMEs in the automobile industry in South Korea, in which experienced engineers played pivotal roles in emergence of new firms (Kim, 1997; Nelson, 1993).

The literature generally argues that Asian firms followed a learning-by-imitating path, in which firms begin assembling simple components under subcontract to foreign firms. Engineers and technicians assimilate key production skills, and gradually gain control over everyday production processes. Based on the accumulated knowledge and mastery of reverse-engineering practices, firms concentrate on strengthening quality controls. Once firms have standardised routines and processes in place, R&D activities are introduced to develop new products. Along this path, technological skills are upgraded to move from the early to the final stage (Amsden, 1989; Kim, 1997, 1998; Cardoza, 1999). In this context, subcontracting acts as a vehicle to spread progressive, modern practices to develop technological capabilities, especially for SMEs (Amsden, 1989; Cardoza, 1999).

In terms of government roles, the Korean government played a significant part in rapidly developing the automobile industry by supporting and imposing ambitious goals that allowed firms to achieve outstanding growth in response to some particularly challenging government goals. The implementation of the creative crisis through incentive policies developed firms' technological capabilities. As result of these policy incentives, the assembly operation of foreign-designed automobiles with semi-assembled parts (SKD) and components supplied by foreign firms transformed to assembling fully disassembled parts (CKD) and components involving more complex technical tasks (Kim, 1997, 1998; Lee and Lim, 2001).[11] In addition, firms' dynamic industrial activities and intense technological efforts allow them to accumulate and develop technological capabilities (Kim, 1998). Government mechanisms, such as providing market protection, permitted Korean firms to accumulate extra profits to invest in R&D (Lee and Lim, 2001) and develop capabilities. The literature stresses the role of NIS in promoting development of technological capabilities in Korean manufacturing industries (Nelson, 1993a; Rim et al., 1998; Kim, 1998, 1999). A good example of the importance of government was the establishment of the Automotive Industry Production Law in 1962 to provide tariff exemptions for imports parts, incentives, and local market protection. This policy led to the establishment of other large, domestic, assembly car firms (Kim, 1997).[12]

In focusing on the role of the firms, the Korean car makers pushed harder by imposing internal changes and chaos to reap tremendous growth in a short timespan by assimilating general production technology and enhancing competences. For instance, Hyundai (the largest Korean car maker) set an ambitious goal to acquire production capability in the shortest possible time. Hyundai's engineering teams mastered operations by disassembling and reassembling two passenger cars, a bus, and a truck multiple times. Repeating procedures with this internalisation transferred explicit knowledge (production manuals) into tacit knowledge (Kim, 1997: 112). Similarly, Hyundai Motor Company sent many of its employees for short- and long-term training that involved learning by observation (Amsden, 1989; Kim, 1998).[13] Hyundai illustrates how Korean car makers acquired their initial production capability.

The South Korean car industry acquired technological capabilities by the roles played by the firms, government, and the technological environment of the innovation system that promoted by developing human sources at all levels (firms, academics, and senior government staff were involved in observation and overseas training), diffusing imported technology within industries (such as policies that favoured capital goods imports to strengthen learning by reverse engineering), and acquiring foreign technology by Foreign

[11] SKD, in which parts and components are semi-assembled. CKD, in which parts and components are fully disassembled.
12 Daewoo Motor, Hyundai, Asia Motor, and Kia Motor are car firms that emerged after the establishment of the Automotive Industry Promotion Law (Kim, 1997).
[13] See Kim, 1998.

Direct Investment (FDI), licensing, and technical assistance (Amsden, 1989; Kim, 1997, 1998; Viotti, 2002).

By 2009, South Korea has six domestic auto makers with firms worldwide, such as Hyundai Motor Company, which manufactured and assembled more than 3 million vehicles, and was the fifth largest producing country. [14][15] In the same period, Mexico assembled 1.5 million vehicles and was the 10th largest producing country with foreign assemblers (OICA, 2009). South Korea's development of technological capabilities in the automobile industry is also reviewed in the literature on catching up (Lee, 1997; Kim, 1998).

Despite the overall dramatic development of Korean automobile firms, not all firms benefited from the government incentives. Korean manufacturing industries failed to develop network links with SMEs. Therefore, the Korean economy is dominated by vertically integrated large firms (*chaebols*), with few ties outside each group. SMEs were unable to work with the latest technology to produce high-quality components and parts (Biggart and Guillén, 1999).

2.4.2 The case of Taiwan and Japan: SMEs in developing and developed countries

Taiwan provides other effective lessons for developing technological capabilities in SMEs. In contrast to South Korea, Taiwanese industrial development was dominated by SMEs. In the automobile industry, Taiwan is a well-known auto-component exporter in the global economy. SMEs linked to each other in horizontal networks and by their ability to meet global quality standards impelled export prosperity. This ability to produce high-quality components relies on a cooperative economic organisation, in which manufacturers collaborate to produce an order (for a specific product or service) by relying on personal relationships (family networks). In this context, government mechanisms established

[14] Asia Motor Company, Hyundai Motor Company, Kia Motor Company, Daewoo Company, SsangYong Motor Company, and Samsung are examples of Korean auto makers (Lee, 1997).
[15] This data includes trucks, buses and coaches, and light commercial vehicles (OICA, 2009).

demand-responsive connections (the ability to receive an order and produce it for foreign firms) and supported small independent firms (Biggart and Guillén, 1999).

The Taiwanese government introduced three mechanisms to nurture the automobile industry: Local content regulation to ensure that certain a percentage of parts were produced locally; market protection; and R&D policies. These mechanisms enforce technology transfer from foreign partners to Taiwanese firms and encourage firms to invest in R&D to upgrade their design and manufacturing technological capabilities (Jan and Hsiao, 2004). SMEs benefited from these mechanisms through trade-promotion activities, financial credits, training programmes, and so forth (Schive, 1995). In short, the factors involved in Taiwan's automotive sector were: Governmental role, SME dominance, and firms' ability to achieve global quality standards (Biggart and Guillén, 1999).

In developed countries, the involvement of Japan's automobile firms in subcontracting networks provides a successful case of developing technological capabilities in SMEs. The government implemented policies to promote SMEs, including financial arrangements, tax concessions, managerial and technology advice, and competition protection for weak small firms (Biggart and Guillén, 1999; Kimura, 2002). Because subcontracting activities involve long-term relationships, suppliers of subcontracting activities must develop relationship-specific skills (that allow suppliers to efficiently respond to subcontractors' requirements) to assure continuity of relationships with their subcontractors. Developing such skills requires accumulated learning acquired through transactions with subcontractors and general technological capabilities (Asanuma, 1989; Asanuma and Kikutani, 1992).

One of the drivers in the early growth of the suppliers' network in Japan was the transfer of capital and technology from assemblers to the less-knowledgeable suppliers. In this regard, the relationships established between assemblers and suppliers included close, trusted links. A clear example of this was the Keiretsu system, which is a network of suppliers that is organised into a hierarchical form of parts-supply transactions. This network includes long-term purchasing relationships, intense collaboration, cross-shareholding, and the frequent exchange of personnel and technology (Christina et al., 2001:688). There is also evidence of the government's role in enhancing absorptive capacity at the industry level. This was demonstrated by its promotion of science and technology by establishing institutions to launch cooperative schemes between universities and industry. Similarly, SMEs benefited from government mechanisms (such as laws and plans to build new institutional frameworks for NIS). Provision of support for SMEs concentrated on improving innovation, performance, and the competitiveness of these firms. One example is the development of research centres to provide training, testing, and technology guidance for SMEs. These centres are administered by local and central government. In addition, developing a 'triple-helix' model, including links between universities and industry and government, tied technology goals to policy projects (Edgington, 2008).

2.4.3 Technology upgrading and absorptive capacity in the Asian car industry

The empirical evidence shows the role of firms and government in Asia's industrial development. In this regard, several studies discuss the technological environment and highlight the importance of the system of innovation (Freeman, 1987, Nelson, 1993).

In terms of firms' roles, the process of learning by latecomer firms in Asian countries comes from three main sources: The international community, the domestic community, and in-house efforts at a firm level. *International community* refers to those firms able to establish networks with international actors (such as institutions, firms, and universities). These links strengthen firms' abilities to identify and learn from other firms to build their own technological capabilities. *Domestic community* refers to interactions between firms and local institutions, government R&D institutions, private research centres, universities, and other firms in the community. These interactions are major sources of imitative reverse-engineering, which enables firms to build technological capabilities by exploring complementary expertise in the community. *In house-efforts*, as already mentioned, refers to interactive mechanisms between production experience and R&D efforts. Practised firms are more capable at existing activities, and R&D efforts enable firms to accumulate and assimilate codified knowledge (Kim, 1997).

In terms of the system of innovation and government, Kim (1997) highlights the technological environment and the role of government in introducing measures to promote technological learning in industry. He points to three main components of industry policy related to technological development: Policies designed to strengthening the demand side of technology development by creating market needs for technology; policies to strengthen the supply side of technology development by developing science and technology institutions; and policies to provide and strengthen effective linkages between both sides to ensure successful implementation of public actions. [16]

Viotti (2002) claims that the success of Asian countries (such as South Korea) is related to specific characteristics of an active learning system. These characteristics are: Education and training (such as the increase in the number of students registered at a university); technology acquisition (such as capital goods imported from advanced industrial countries); and technological efforts (such as overseas training of engineers).

Despite the rapid industrial growth of the car industries in Asian countries, not all firms were favoured the same way. Kim (1997) claims that South Korea's success was not evenly distributed across firm sizes. SMEs were disadvantaged by policies that favoured large firms, especially in the automobile and electronics industry in which large firms provided limited technical assistance to suppliers that were acquiring technology with minimum know-how and competing in a pressured environment (Amsden, 1989). [17] In Taiwan, industrial growth was based on policies for SMEs to provide assistance, market promotion, strategic alliance promotion, business cooperation, and technology and labour training. In this context, factors such as entrepreneurial incentives and diffusion of technology favoured SMEs that were more flexible, adopted technology, and competed within their industry (Schive, 1995). In Japan, the Keiretsu system favoured technology transfer between few firms (such as car assemblers and closer suppliers).

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[16] In developing countries, external changes are imposed by government, which sets goals for firms (see Kim, 1998).

[17] *Chaebols* (large firms) are instruments designed to promote mature technologies and lead export activity. In turn, these large firms develop strategic industries (Nelson, 1993).

2.5 The case of Brazil: Technology upgrading in the car industry

The review of empirical cases in the Latin American countries focuses on Brazil, which is well-known for its automobile industry.[18] Brazil's automobile industry was established in 1919 with the first Ford assembly plant, followed by a General Motors plant in 1925 (Saphiro, 1991). In the 1950s, the automotive sector's goals focused on import substitution and policies to reduce auto imports. These policies led to the 104 groups of auto components and parts domestically produced (Mukherjee and Sastry, 1999; Saphiro, 1991). By 1954, CKD parts were being imported as a result of prohibition on importing assembled cars (Saphiro, 1991). In the 1960s, the Brazilian government demanded auto makers purchase 95 per cent of their components locally. This resulted in a more cooperative relationship, in which auto manufacturers invested in their suppliers' capacity (Rachid, 2001). In 1990, the government opened up the market to imports (Mukherjee and Sastry, 1999). At the end of the 1990s, existing vehicle manufacturers (such as Fiat, Ford, Volkswagen, and General Motors) heavily invested in building new plants for assembling components and parts (Humphrey and Memedovic, 2003).

In the 1990s, the auto industries of developing countries were transformed due to liberalisation policies. This change led to the major auto assemblers investing in emerging markets, building new capacity, and modernising existing plants (Humphrey, 2003).

According to Humphrey (2003), interactions between assemblers and suppliers are characterised by complexity and long-term relationships. The complexity is due to shifts associated with two important trends: higher specialisation of components suppliers, and global competence. The trend towards technology transfer in the late 1990s consisted of acquiring and selectively transferring activities between companies (major assemblers and their parent companies). In this context, SMEs were integrated with the largest components manufacturers as a result of takeovers and mergers.

In the Brazilian automobile industry, the vertical and horizontal interactions between large multi-nationals and their suppliers show little cooperation, and horizontal interactions are

[18] In 2009, Brazil was the sixth largest global producer of cars and commercial vehicles (International Organization of Motor Vehicle Manufacturers).

hindered by high levels of competition among auto-parts firms. Domestic competition is enhanced in part by multi-nationals to reduce their suppliers. When vertical interactions take place, suppliers developed strong tiers with their customers. In contrast, when horizontal interactions take place, these are limited to the exchange of market (Mesquita et al., 2007). With regard to developing technological capabilities in the supply chain, vertical interactions greatly depended on technology transfer almost exclusively from foreign firms (Lemos et al., 2003).[19]

The government plays a determining role in the Brazilian auto industry. The auto-parts firms cultivated long-term relationships with government at all levels. Major multi-national firms took advantage of institutional services and resources to maximise their performance (Mesquita et al., 2007). Small and medium suppliers are under strong pressure from their large customers to adhere to quality standards and reduce costs due to global sourcing. In order to compete, suppliers must improve their performance by reducing their costs, increasing their quality, and providing more reliable delivery. The large firms are the reference for new organisational standards (Abreu et al., 1998). In fact, Brazilian auto-parts suppliers face problems in trying to enter and compete in international networks and markets (Lemos et al., 2003).

Contracts with small and medium suppliers are usually informal (such as buying orders) rather than formal (such as short-term contracts). Formal written contracts usually apply to first-tier firms (Abreu et al, 1998). SMEs (some first-tier suppliers) are also involved in outsourcing by large companies. Most of these firms usually outsource to second-tier or independent suppliers (Lemos et al, 2003). Examples of these outsourcing activities related to manufacturing processes include: Equipment design, die-stamped parts, plastic injection, machining, foundry, and injected aluminium (Rachid, 2001).

Competition in the Brazilian automotive industry transformed the skills of workforce. In the late 1990s, the automotive industry increased its productivity performance and established an educational qualification requirement to work in the industry. First-tier firms

[19] As a result of the process of economic liberalisation, in Brazil, the share of foreign firms increased in the auto-parts sector (Lemos et al., 2003).

require 12 years of schooling, and small firms require their workers to have a minimum of five years schooling (primary school). Some small firms provided training (Abreu et al, 1998). In addition, evaluation of suppliers (such as the Supplier Evaluation Manual) by first-tier firms was introduced in Brazil, followed by other Latin American countries. Suppliers are assessed for ownership profile, quality systems, global skills, finances, product and process competences, and management structure, among other factors. Suppliers receive oral feedback/suggestions and written documents on how to improve their internal operations (Ivarsson and Göran, 2005).

In the context of developing countries, Ivarsson and Göran (2005) argue that technological transfer through relationships between first-tier firms and their suppliers upgrade suppliers' performance. Brazilian suppliers took advantage of this relationship to improve their manufacturing operations, based on a long history of operations in the Brazilian automotive industry and long-term relationships between customers and domestic suppliers (Ivarsson and Göran, 2005). The Brazilian government involves assemblers in the process of technology transfer to local firms. Assemblers transfer technology via three main routes: Exchange of technical workforce and licensing with foreign firms; joint ventures with local firms; and establishment of foreign suppliers in Brazil (Posthuma, 2005). More specifically, the government focused on import substitution policies and exports via financial incentives for exporting to develop capabilities in the Brazilian automotive industry (Posthuma, 2005).

In relation to the NLS in Brazil, policy concerns focused on creating science and technology institutions (such as Secretaria de Tecnologia Industrial [STI]) to carry out R&D programmes, supply technological information to firms, fund technological projects in the public and private sectors, and regulate technology transfer through other institutions. [20] Following this approach, some successful cases in the automobile industry of domestic firms in the system of innovation reveal close interactions between firms and public institutions. Firms effectively use the public support infrastructure (such as fiscal and credit

[20] Secretaria de Tecnologia Industrial (STI), belonging to the Ministry of Industry and Commerce was established in 1972.

incentives) and the institutional system to support innovation (such as collaborative projects with research and technical institutions and universities) (Nelson, 1993).[21]

More generally, Latin American countries experienced industrial growth based on a strong presence of multinational corporations in manufacturing sectors. Automotive and electronics are prominent examples of these sectors. In 2009, Brazil was the sixth largest producer of cars, and Mexico was the 10th largest producer, both with foreign assemblers (OICA, 2009). Diverse factors favoured establishing those MNCs in Latin America. According to Mortimore and Vergara (2004), cheap labour costs and better access to the US market were factors favouring establishing MNCs in Mexico.

The case of technology upgrading in Brazil differs from South Korea, Taiwan, and Japan. The growth of the car industry in Brazil was based on the strong presence of foreign firms that established strong barriers to enter into the industry. Domestic and SMEs that overcame these barriers were later purchased or merged with foreign firms. The transfer of technology was largely based on selective activities that only involved major assemblers and their parent companies. Domestic firms lacked ambitious goals to achieve significant technological learning. In addition, the government's role has been more oriented toward diffusing technology, rather than creating it.

2.6 The case of Mexico: The growth of the car industry and technology upgrading

This section reviews the historical context of the automobile industry in Mexico, focusing on the policies that shaped this industry since its establishment. According to Moreno et al. (2005), Mexican industrial growth consisted of two main phases: Import substitution and trade liberalisation. The import substitution phase (1940 to 1970) was characterised by the state's intervention in the economy and its role in leading industrialisation. This phase was characterised by the government's protectionist role in the economy. The government's focus was on fostering industrialisation through import substitution and industrial policies

[21] One example of public support is involvement of the public sector in establishing Fiat in Betin, Brazil. The government provided fiscal and financial incentives, as well as physical infrastructure to locate Fiat in that area. The government also invested financially to become a Fiat shareholder. As a result, Fiat launched a project to develop the auto-parts suppliers, with the government providing the physical infrastructure and financial incentives (Lemos, 2003).

aimed at protecting the manufacturing sector through trade protection measures, fiscal incentives, and regulations on FDI. These policies focused on specific sector programmes (such as automotive, computer, and pharmaceutical). In order to assure employment and prevent bankruptcies, several public firms were created. The 1966 *maquiladora* programme is an example of this government intervention.[22] Government support for the manufacturing sector consisted of tax incentives, tax exemptions on imports of machinery and equipment, financial credit, and price controls (Moreno et al., 2005).

The trade liberalisation phase was characterised by reduced state intervention in the economy. In this phase, the government focused on foreign commerce and encouraging local and foreign investment to export, mainly to the US. Industrial policies were aimed at privatisation, deregulation of FDI, trade, and financial liberalisation. These reforms eliminated several incentives and subsidies in the manufacturing sector. In particular, they removed FDI restrictions and liberalised the automobile industry in 1984. The government reduced the domestic vehicle content in exports and local production. The establishment of NAFTA was an example of these reforms (Moreno et al., 2005).

Studies on the automobile industry show that the Mexican automobile industry was established in 1925 with the first assembly plant of Ford Company. In 1935, General Motors set up a second assembly plant in Mexico, followed by Chrysler in the same year. In this period, the goal was assembling cars to export to the US. Low productivity due to lack of physical infrastructure and scant investment was a feature of these early plants. Auto-parts plants were established as a result of government reforms aimed at 20 per cent of domestic components and parts in Mexican car production (Miranda, 2007, Vieyra, 1999, 2000a, 2000b).

The Mexican government established the first automotive law in 1962. This plan restricted imports of vehicles and core components (such as motors and transmissions) and required existing plants to assemble using 60 per cent domestic components and parts. This plan limited foreign ownership in auto-parts plants to 40 per cent, and prices were controlled

[22] The *maquiladora* programme solved the problem of rising unemployment along Mexico's northern border. This programme arose at the end of the Bracero programme (Moreno et al., 2005).

(Brown, 1997; Miranda, 2007). According to Moreno (1996), the automobile industry at that time only consisted of assembly. The law forbade importing CKD vehicles, and components and parts.

The first automotive law promoted the emergence of the auto-parts sector in Mexico, and existing assembler firms set up auto-parts plants in different regions in collaboration with domestic firms.[23] The development of technological capabilities for auto-parts firms was based on knowledge transmitted by foreign partners (such as technical information and technology transfer), rather than being rooted in endogenous technical capabilities. The manufacturing processes and products of these firms lacked higher-technology skills (such as glass, batteries, and internal auto parts) (Brown, 1997; Miranda, 2007). In 1964, Volkswagen set up an assembly plant in Puebla City, which was followed in 1966 by a Nissan assembly plant in Cuernavaca City (Saphiro, 1991).

In 1972, the second automotive law required auto assemblers to export 30 per cent of their production. In particular, this law promoted exports. It protected the auto-parts sector by establishing a minimum of 50 per cent of domestic vehicle content (components and parts) representing foreign exchange. These export-oriented reforms were strengthened in 1983 with the law to rationalise the auto industry. In essence, the government paid more attention to export promotion than auto-parts manufacturing (Moreno, 1996; Miranda, 2007, Vieyra, 1999). In 1971, Mexico had two of its own auto-maker firms (VAM and DINA-Renault).

In the 1980s, the assembly firms reduced the share of components and parts suppliers by a process of vertical disintegration of the supply chain. This led to alliances between existing auto assembly firms and foreign auto-parts suppliers. The growth in exports by auto assembly firms attracted several foreign components and parts suppliers, and exposed local firms to more foreign competition (Brown, 1997; Miranda, 2007).

By 1989, the third automotive law of modernisation and promotion of the automobile industry favoured the auto-parts sector setting a minimum of 36 per cent of domestic

[23] By 1964 and 1965 respectively, Chrysler and GM set up plants to assembly motors in Toluca (Miranda, 2007).

vehicle content (parts and components) and reducing import taxes on parts and components. Some claim that this reform enabled strong linkages between the auto industry and the auto-parts sector (Moreno, 1996; Miranda, 2007; Sosa, 2005).

In 1994, the North American Free Trade Agreement (NAFTA) increased the levels of foreign competition. In 1993, VAM and DINA-Renault were sold to Renault France (Barragan and Usher, 2009). To reduce the cost of supplying American automobile firms, the auto-parts sector in northern Mexico grew with the establishment of *maquiladoras*. In 1994 and 1995, Mercedes Benz and BMW set up the sixth and seventh assembly plants in Mexico City. In 1995, Honda had an assembly plant in Jalisco City, and Hyundai and Renault both established plants in 2001. The policy regulations on restricting foreign ownership in auto-parts firms were reduced, and the new auto-parts firms had more than 40 per cent of foreign ownership specifically from the US (Brown, 1997; Carrillo, 1997; Moreno, 1996).

In 2003, the government established the law of competitiveness for the terminal automobile industry and development of the internal automobile market. This law represented a shift in the state's concern to stimulating foreign investment to improve the physical infrastructure and develop new infrastructure. This law also aimed to benefit local firms by requesting that automobile firms develop and support local suppliers through training programmes and transfer of technology to first- and second-tier systems suppliers (Miranda, 2007).

The auto-parts sector started with the establishment of diverse automotive laws. In particular, the first automotive law established in 1962 led to the birth of the auto-parts industry. Before this, parts and components were mostly imported. The first law "established strict foreign exchange balancing requirements" (Moreno, 1996:8), including imports of vehicles and core components, and components manufactured in Mexico. The assembly plants were required to manufacture with 60 per cent of domestic parts. The second automotive law, established in 1972, protected the auto-parts sector by requiring assembly plants to export goods with a minimum of 50 per cent of domestic components and parts. Foreign auto-parts firms were allowed into Mexico to upgrade domestic firms' technology. These foreign firms were focused on export. The third automotive law, established in 1989, reduced taxes on parts and components and protected the auto-parts industry by setting a minimum of 36 per cent of domestic content (Barragan and Usher, 2009; Moreno, 1996; Miranda, 2007; Vieyra, 1999).

The development of the auto-parts industry was based on the transfer of knowledge and technology from multinational companies (such as assembly plants) to domestic firms. The first domestic auto-parts firms were involved in manufacture of batteries, glass, and interiors (Moreno, 1996; Miranda, 2007; Sosa, 2005). By 1958, cars manufactured in Mexico were completely assembled from CKD kits. The automobile industry was dominated by two foreign automobile firms (Ford and General Motors) and one Mexican firm (Fábricas Auto-Mex), which later sold one-third of its equity to Chrysler. There were other wholly Mexican-owned assembly plants operating under foreign manufacturers' licences. Government policy impelled development of the automobile industry in Mexico.

By 1959, the government focused on the automobile industry as a candidate for investment following the phase of import substitution. These new policies were informed by research and visits to countries with recent automobile industries, such as Brazil and Argentina, but without consultation with the transnational automobile firms in Mexico (Bennett and Sharpe, 1979).

Several scholars note that establishing market-oriented reforms opened Mexico to the outside world, forcing the existing auto-assembly firms to improve and upgrade their physical infrastructure and competences. In the 1970s, the automobile industry lacked a technological production infrastructure and was producing locally made vehicles of low quality at higher production cost than their foreign counterparts. However, this context did not concern the government, due to the closure to international markets (Moreno, 1996; Miranda, 2007). The second automotive law induced the automotive companies to modernise and invest in physical infrastructure in Mexican assembly plants. Therefore, American firms built new plants in northern Mexico.[24] Here, technology transfer was

[24] At that time, almost all auto-assembly firms were established in Mexico City.

significant and occurred in relation to establishing those new plants, which embodied up-to-date technologies (Moreno, 1996).

By the end of 1980, the auto-parts industry was dominated by a few foreign firms. First-tier suppliers included a few Mexican firms (see Table 2.5). These firms forged joint ventures and alliances with foreign auto-parts firms and auto makers. Second-tier suppliers consisted of small and medium indigenous suppliers. The first-tier suppliers involved small and medium foreign firms (Barragan and Usher, 2009). In the 1980s, three assembly plants were set up in Nuevo Leon, Hermosillo, and Aguascalientes. At the same time, five motor producers were set up in Chihuahua, Nuevo Leon, and Mexico City (Carrillo and Ramirez, 1997).

Table 2.5
Large Mexican-owned auto-parts firms

Company	Year of foundation	Products	Tier
VITRO	1909	Glass, glassware and glass container	3rd tier
Grupo industrial Saltillo	1928	Monoblocks and engine head covers	2nd tier
San Luis Rasini	1929	Brake systems, suspension systems	1st tier
Industrias de Hule Galgo, S.A de C.V	1952	Interiors, rubber and tyres	1st tier
Condumex (Grupo Carso)	1954	Electronics systems, wires and cables	1st tier
Metalsa (Grupo Proeza)	1956	Suspension systems, chassis systems	1st tier
Grupo DESC Automotriz	1973	Engine related products and rubber products	2nd tier
Grupo ALFA	1974	Monoblocks and engine head covers	2nd tier
Grupo QUIMMCO	1994	Engine related products, break systems	1st tier

Source: Barragan and Usher (2009) and own elaboration.

At the end of the 1980s, as a result of foreign competences, the auto-parts sector developed technological and organisational capabilities through investment in physical infrastructure, machinery, equipment, and control of processes. The export-oriented economy in Mexico entailed high investments by the existing assembly plants. New auto-parts plants (*maquiladoras*) were built in northern Mexico. These *maquiladoras* were fully export-oriented, equipped with modern technology, and employed young highly qualified workers. Up to this point, the Mexican automotive industry was concentrated in a few subsidiaries of foreign auto makers, with an auto-parts sector dominated by few large firms (Brown, 1997; Moreno, 1996). [25]

The *maquiladora* programme was launched in 1966 to solve the problem of unemployment along the northern Mexican border and attract FDI through tax incentives (Moreno et al., 2005). The auto-parts *maquiladoras* were set up in Chihuahua in the late 1970s. Chrysler, General Motors, and Ford set up firms focused on exports to the US. First-tier suppliers, such as Yasaki and Essex International, also set up plants in northern Mexico. In 1995, there were 180 *maquiladoras*, of which approximately 45 were owned by Ford, General Motors, or Chrysler. These firms originally started manufacturing cables and wire harnesses. Subsequently, other plants were established to manufacture radiators and engine-related products. All these *maquiladoras* were more heavily involved in vertical integration with terminal companies in the US and less involved with American subsidiaries in Mexico. There were almost no relationships between domestic firms and those *maquiladoras* (Carrillo and Ramirez, 1997).

NAFTA entailed high investments by the automobile and auto-parts firms. The automobile industry and the auto-parts sector modified their learning processes in order to compete under the new economic conditions (NAFTA) by, for instance, changing their recruitment strategies. Before NAFTA was set up, and owing to the existence of protectionism laws, the auto-parts industry was only involved in vertical integration with terminal companies (Carrillo, 1997; Moreno, 1996). The automotive laws fostered the development of the automobile and auto-parts sectors in Mexico. As many scholars argued, the second automotive law induced foreign firms to invest in physical infrastructure for their subsidiaries in Mexico (Moreno, 1996, p.7; Miranda, 2007). These firms employed personnel with basic education and skills, and benefited from workers' past learning experience.

[25] By 1992, Chrysler, Ford, General Motors, Nissan and Volkswagen between them had 14 assembly plants in Mexico (Moreno, 1996).

The implementation of NAFTA entailed heavy investments by auto-parts firms in Mexico to reduce the cost of supplying the American automobile firms (Miranda, 2007). New auto-parts plants were built in northern Mexico. Foreign auto makers established auto-parts plants in Chihuahua, Sonora, and Durango. General Motors and Chrysler established motor manufacturing plants in Coahuila. Similarly, Ford established plants in Chihuahua and Sonora, and Renault established plants in Durango (Moreno, 1996; Brown, 1997).

Under NAFTA, firms' strategies were focused on hiring well-educated personnel (those with a university education) to rapidly and steadily build up and strengthen firms' capabilities. In addition, the free-trade agreement put auto-parts firms under pressure to comply with new standards (such as quality standards) in order to compete in international markets, or standards imposed by the supply chain (Moreno, 1996; Vallejo, 2005). Vogel (1997) states that NAFTA intensified Mexican environmental controls during the early 1990s, putting pressure on multi-national firms to improve their environmental practices and those of their subcontractors in less-developed countries.

Overall, NAFTA promoted the development of technological capabilities. Subsidiary firms benefited from technology transfer from parent companies, equipment, and technology. Under NAFTA, firms were less likely to learn from universities. This was explained on one hand by the role of the universities in developing countries as skills-providers rather than knowledge-creators. On the hand, foreign firms (terminal firms) were keen to locate R&D centres at home rather than in foreign countries (such as Mexico) (Vallejo, 2005). However, the free trade agreement did not benefit all firms. It endangered the survival of a majority of local small and medium auto-parts firms by increasing FDI flows and stronger competition.

In 2003, the Mexican government introduced the law of competitiveness for auto makers. This law enforced the development of a local market for the automotive industry and development of international competitiveness among auto makers in Mexico (Miranda, 2007). However, the development of the automotive and auto-parts industries in Mexico failed as compared to other automotive industries in emerging economies (such as South

Korea), due to the failure of automotive regulations (the first, second, and third automotive laws) and the lack of industrial organisation (the growth of the automotive industry was unplanned) (Miranda, 2007; Sosa, 2005).

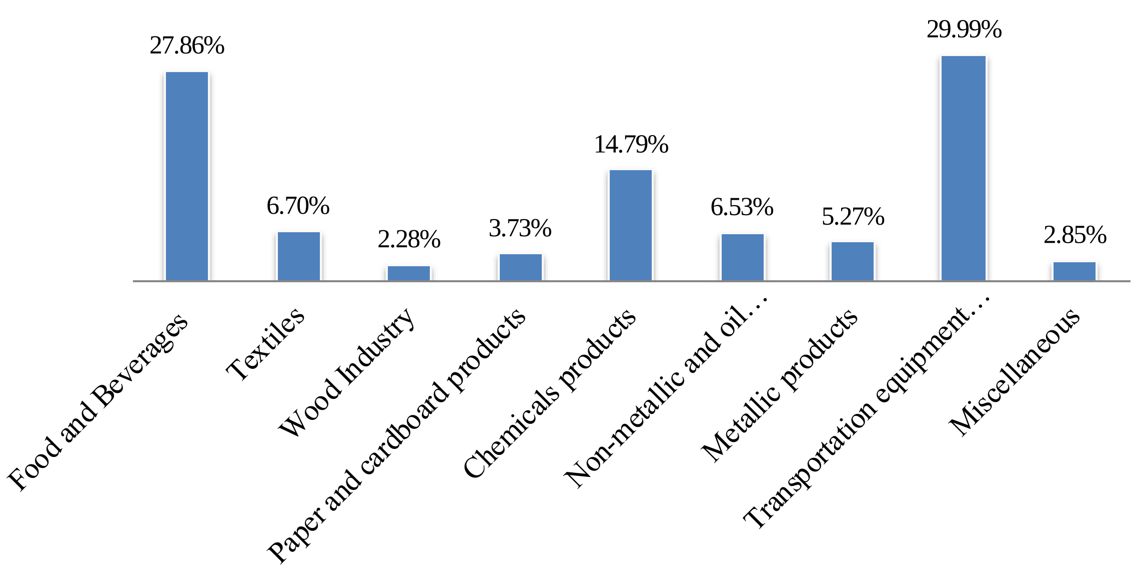
2.7 Today's automobile industry in Mexico: Main economic indicators

To understand the growth of the car industry and its technology upgrading, this section provides statistical data (from 1994 onward) of the automobile and auto-parts industries in Mexico.

From 1998 to 2007, the manufacturing industry made an average GDP contribution of 27 per cent with respect to total economic activity.[26] The greatest contribution was from the service industries, with 71 per cent. Within manufacturing, transportation equipment contributed an average GDP of 30 per cent (see Graph 2.2).

Graph 2.2

Transportation equipment industry in Mexico: Gross Domestic Product (1998–2007)



Source: Own elaboration based on INEGI

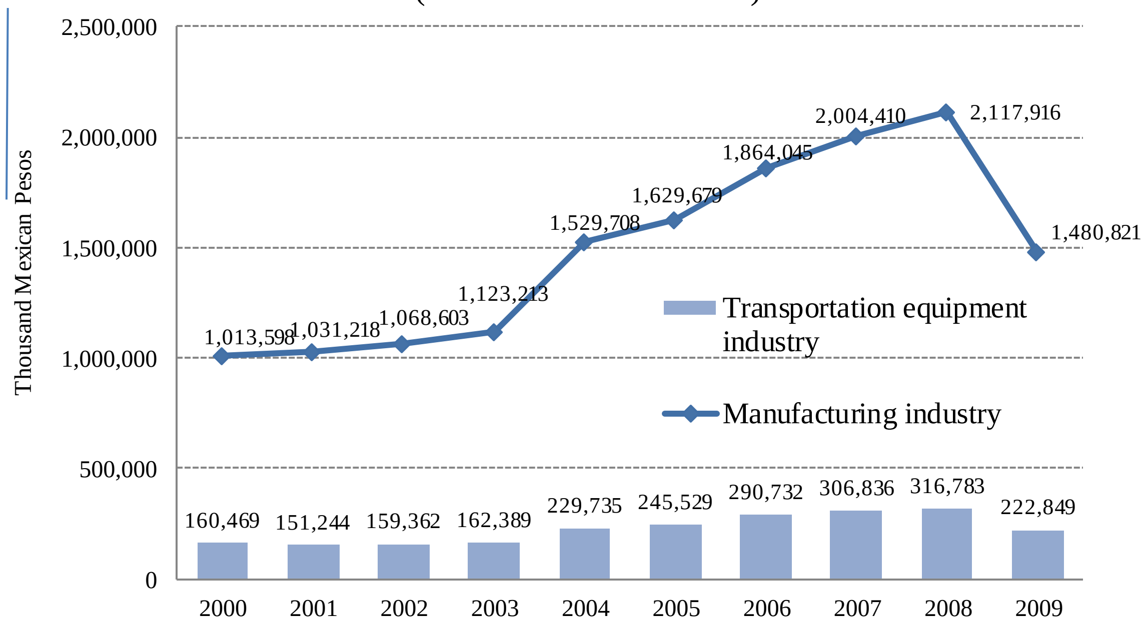
[26] The data was calculated using information on GDP based on 1993 prices. The figures obtained from INEGI does not count 100%

Between 2000 and 2008, valued added for the transportation equipment industry[27] showed an average annual growth of 11 per cent. In 2009, this industry experienced a major downturn due to the financial crisis. At the same time, the manufacturing industry produced an annual average growth in value added of 9 per cent. The constant price was 2003 based (see Graph 2.3).

In 2009, value added in the automotive industry (passenger cars and buses) represented almost $MNX 83 million. In 2009 the auto-parts industry (auto parts and accessories) represented value added of more than $MNX 125 million. Graph 2.4 provides a picture of value added in the automotive and auto-parts industry for 1994 to 2004. In 2004, value added in the transportation equipment industry was more than $MNX 357 million (at constant prices). The automotive industry contributed more than $MNX 172 million (at constant prices). The automotive subindustry contributed more than $MNX 84 million (at constant prices), and the automotive accessory subindustry contributed more than $MNX 88 million (at constant prices). The overall automotive industry accounted for a share of 48.37 per cent and 23.64 per cent for the automotive subindustry (passenger cars) and 24.72 per cent for the auto-parts subindustry.[28]

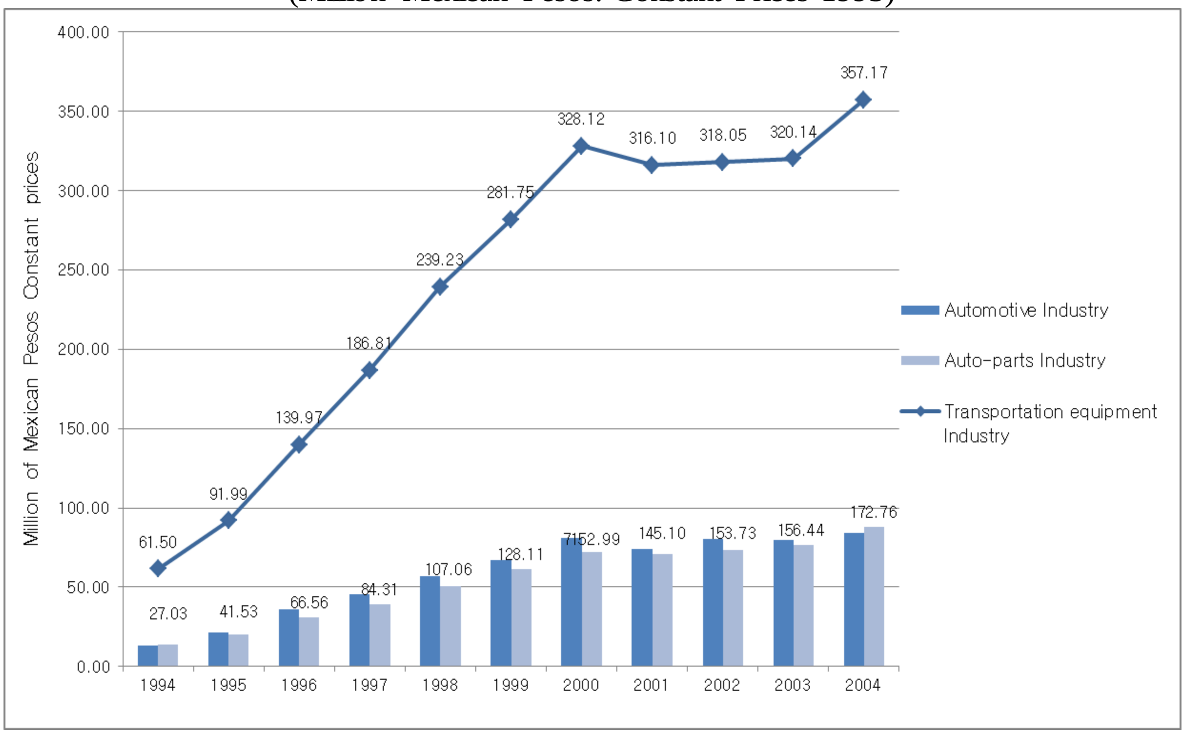
[27] The transportation equipment industry includes passenger car and buses, auto parts, aircraft parts, ship and boat parts, railroad equipment, truck bodies and trailers, and miscellaneous transportation equipment (INEGI).
[28] INEGI Economic census 2004

Graph 2.3
Transportation equipment industry in Mexico: Value added (2000–2008)
(Thousand Mexican Pesos)



Source: Own elaboration based on INEGI (2004, 2009, 2010)

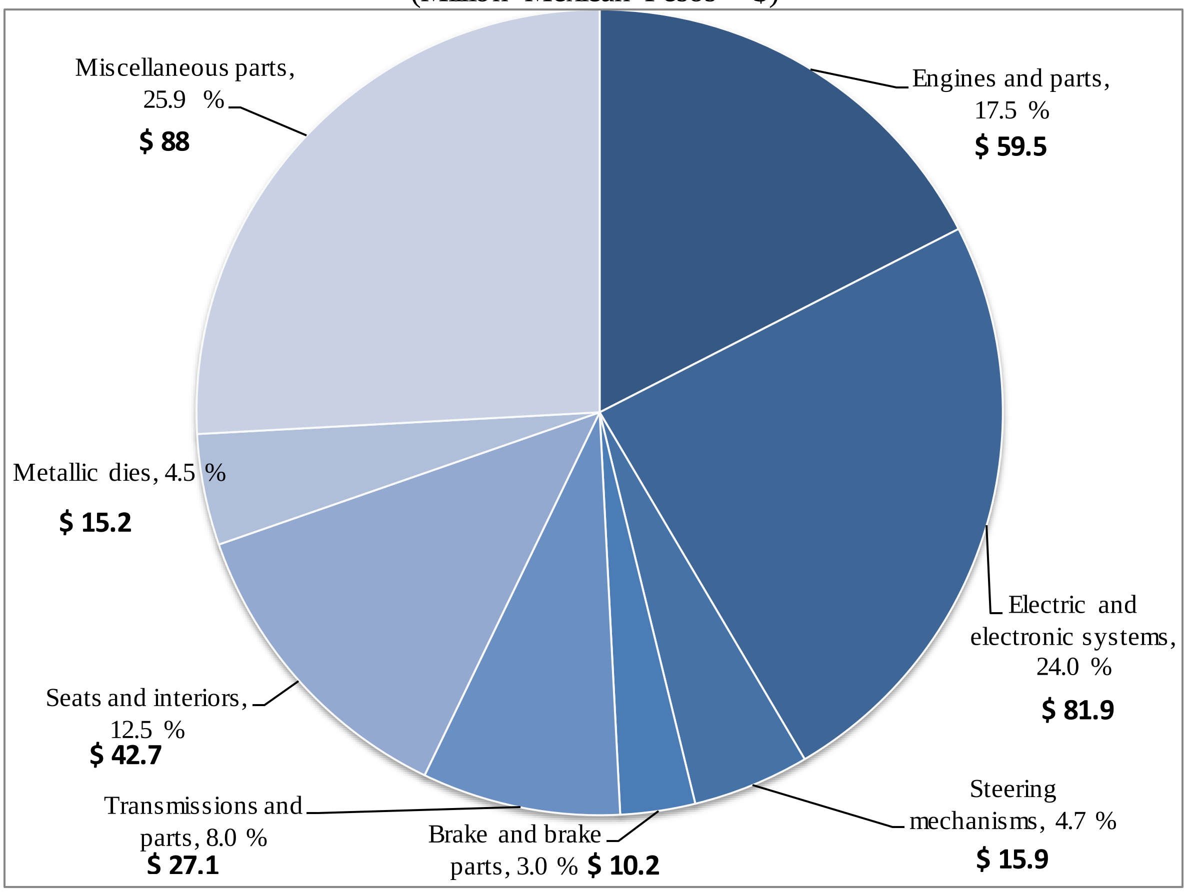
Graph 2.4
Automotive and auto-parts industries in Mexico: Value added (1994–2004)
(Million Mexican Pesos: Constant Prices 1993)



Source: Own elaboration based on INEGI- Economic census 2004

From 1998 to 2007, GDP in the auto-parts industry was 7.41 per cent of the manufacturing industries as a whole.[29] According to the National Institute of Auto-parts, annual auto-parts production in Mexico for 2007 reached more than $MNX 21 billion. In 2008, this declined to more than $MNX 16 billion.[30] These figures only include what is reported by Association members and are not totals. In 2009, the auto-parts industry accounted for total production of more than $MNX 340 million. The highest production was in electric and electronic systems, at more than $MNX 81 million, followed by engines and engine parts with more than $MNX 59 million (see Graph 2.5).[31]

Graph 2.5
Auto-parts subindustry in Mexico: Total production (2009)
(Million Mexican Pesos = $)

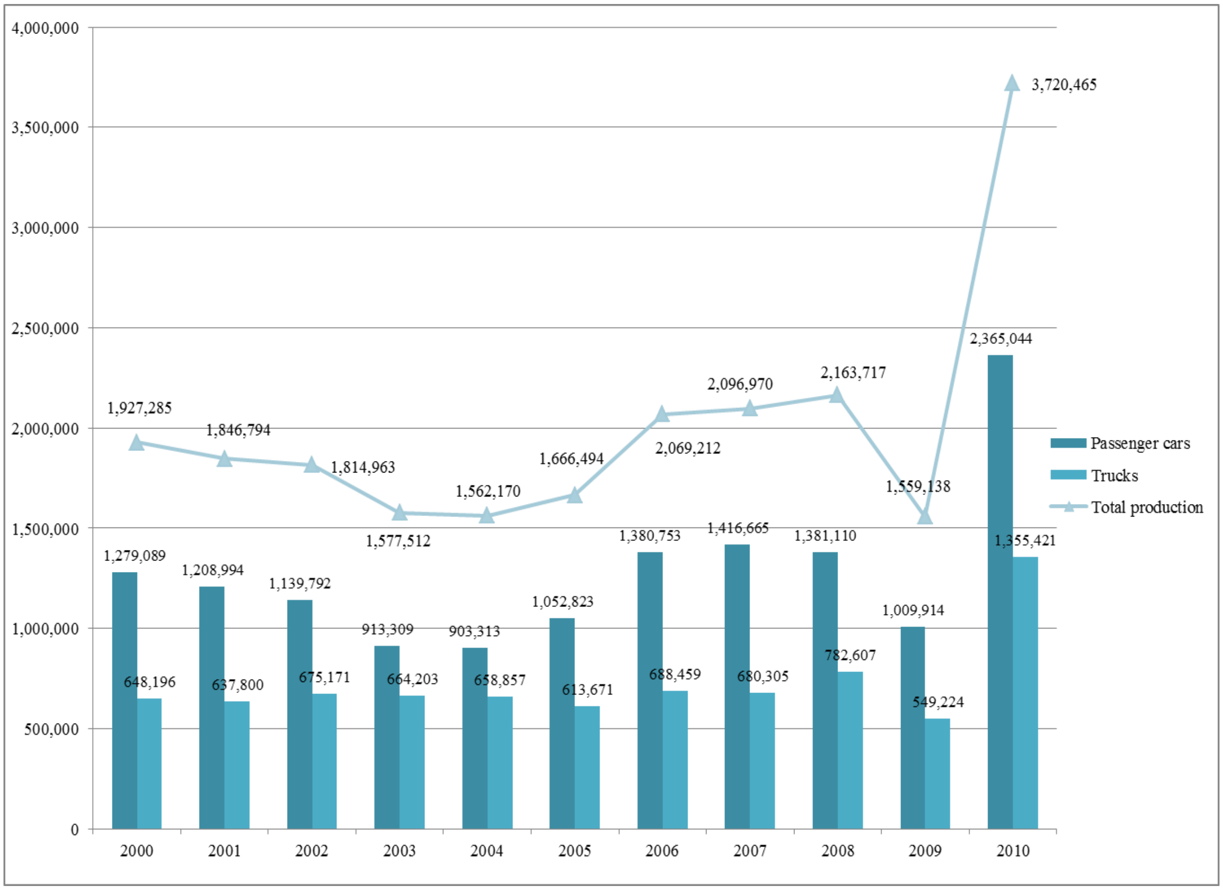


Source: Own elaboration based on INEGI Economic census 2009

[29] INEGI, Economic census 2004
[30] National Industry of Auto-parts Association INA
[31] INEGI, Economic census 2009

According to INEGI (2010), overall 2010 Mexican production (for national and international markets) of passenger cars was more than 2 million vehicles.[32] Production of passenger cars decreased between 2001 and 2004, and rose slightly again in 2005 (see Graph 2.6).

Graph 2.6
Automotive industry in Mexico: Production of passenger cars and trucks (2000–2010)
(Units of vehicles)



Source: Own elaboration based on INEGI Database (2010)

In 2007, the auto-parts industry exported more than $MNX 198 billion and the whole automotive industry exported more than $MNX 279 billion. Total global exports (automotive and auto parts industries) from Mexico from 1995 to 2007 were more than $MNX 6,465 billion (see Graph 2.7).[33]

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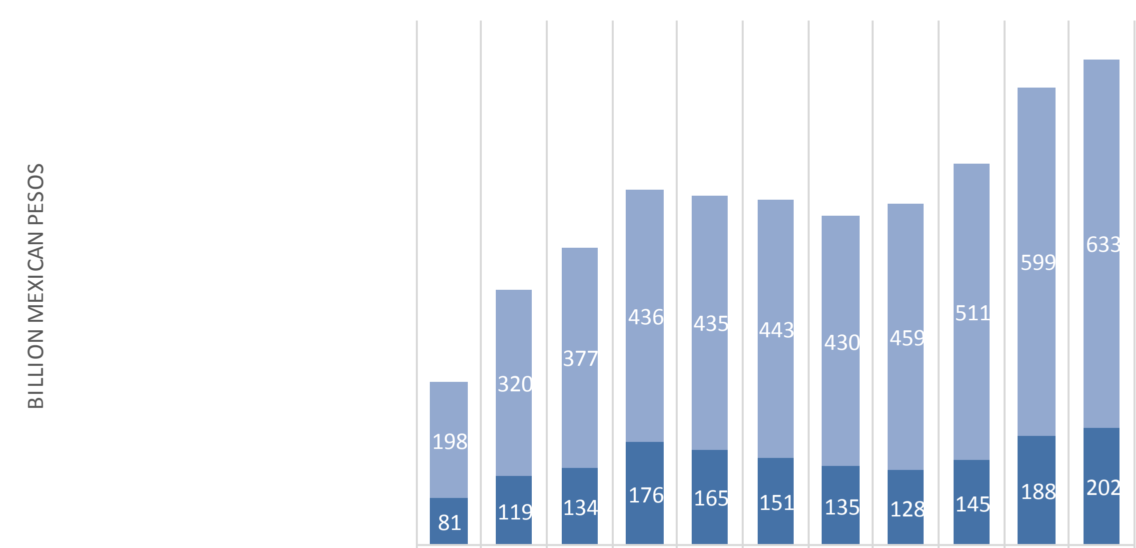
[32] This figure excludes production of trucks and buses.
[33] World Trade Organization. Statistics database: http://stat.wto.org/Home/WSDBHome.aspx?Language=E

In 2009, the automotive industry exported more than 1 million vehicles (passenger cars and trucks), rising to almost 2 million in 2010, with a growth of 56.6 per cent.[34] The main North American partners were the US, and Canada, and Guatemala, Brazil, Chile, Colombia, Panama, Dominican Republic, Costa Rica, El Salvador, Argentina, and Venezuela in Central and South America (See Graph 2.8).[35]

Graph 2.7
Automotive and auto-parts industry: Exports from Mexico to the world
(1995–2007 Billion Mexican Pesos)
Exchange rate (2003) $US 1 = $MNX 10.80



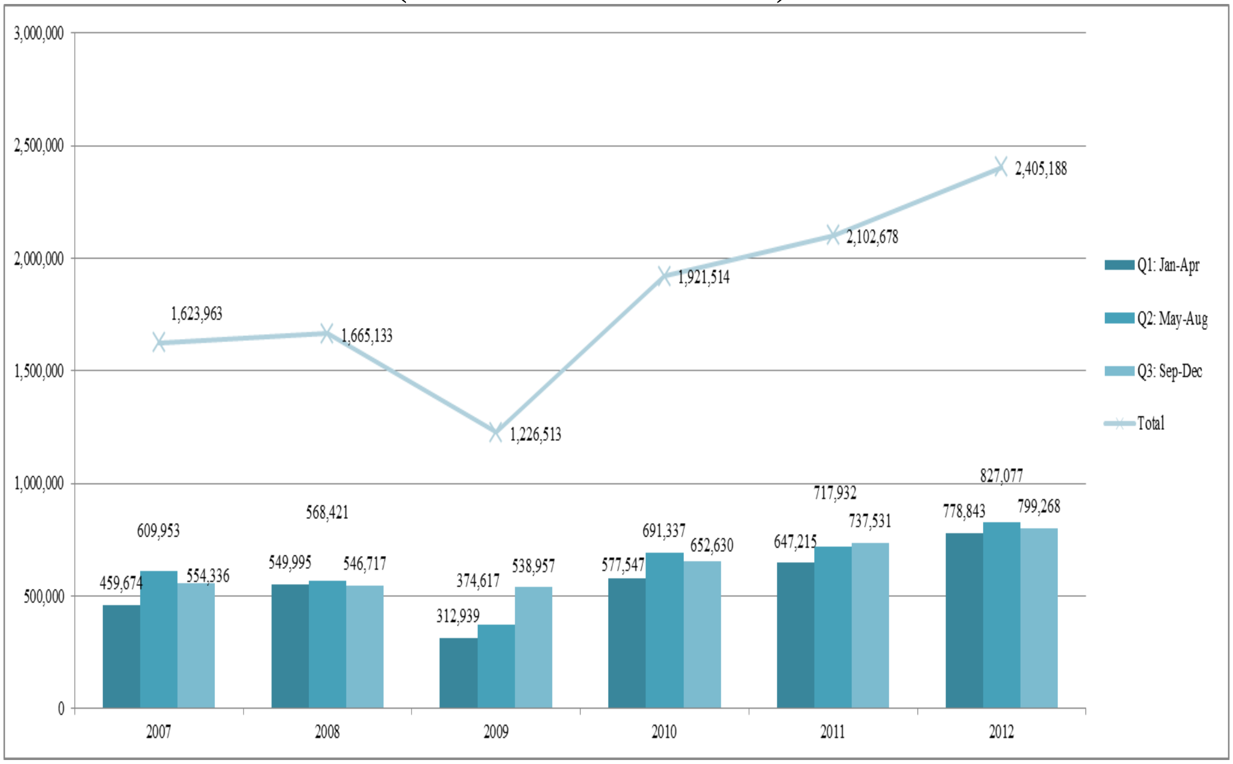
	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Automotive accesories sub-industry	198	320	377	436	435	443	430	459	511	599	633
Automotive Sub-industry	81	119	134	176	165	151	135	128	145	188	202

*Automotive accessories includes wholesale and retail sale of all kinds of parts, components and accessories for motor vehicles, when not combined with sale of such vehicles themselves (see group of auto-parts in table 2.7 and 2.8)

Source: Own elaboration based on United Nations Commodity Trade Statistics Database

[34] Mexican Association for the Automotive Industry AMIA (Asociacion Mexicana de la Industria Automotriz). *Automotive Review 2010.*
[35] World Trade Organization. Statistics database

Graph 2.8
Automotive industry: Exports from Mexico to the world
(2007–2012: Units of vehicles)



Source: Own elaboration based on the Mexican Association for the Automotive Industry AMIA

Worldwide exports by the Mexican automotive industry include 40 countries, such as Germany, France, Spain, Saudi Arabia, Switzerland, Japan, Australia, China, and the UK.[36] In 2007, Mexican auto makers' exports to Germany were more than $MNX 32 billion and exports to the Russian Federation were more than $MNX 1 billion. In 2007, exports to the US reached $MNX 141 billion, while auto-part exports to the US were more than $MNX 526 billion.[37]

From 1999 to 2008, the automotive industry attracted more than $MNX 174 billion in FDI, with manufacturing and assembly of vehicles receiving 26.11 per cent. The highest share was for manufacturing and assembly of parts and accessories (see Table 2.6). In 2007, the auto-parts industry had FDI stock of more than $MNX 15 billion.[38]

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36 PROMEXICO
37 United Nations Commodity Trade Statistics Database
38 Ministry of the Economy. FDI Statistics

Table 2.6
Automotive and auto-parts industry: Foreign direct investment (1999-2008)
(Million Mexican Pesos)

Sub-Industry	Years										Accumulated Value	
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	%
Manufacturing and assembly of automobiles.	14,908	4,972	1,245	3,666	2,189	12,765	2,377	440	3,021	97	45680	26
Manufacturing and assembly of bodywork and trailer for automobiles and trucks.	21	65	751	30	0	0	0	0	0	0	866	0
Manufacturing and assembly of motor and parts for automobiles and trucks.	809	1,070	440	651	528	488	698	638	174	118	5614	3
Manufacturing and assembly of transmision system for vehicles and trucks.	406	24	95	117	208	2,324	935	403	1,428	91	6031	3
Manufacturing and assembly of suspension system for automobiles and trucks.	-6	2,204	261	419	300	1,116	226	527	-129	12	4930	3
Manufacturing and assembly of brake system for automobiles and trucks.	191	175	416	99	151	130	379	499	698	593	3331	2
Manufacturing and assembly of other parts and accesories for automobiles and trucks.	7,380	8,899	12,025	9,053	9,658	9,819	17,436	12,915	15,070	6,254	108509	62
Total											174,960	100

Source: Own elaboration based on the Minister of Economy FDI statistics

In terms of employment, the transportation equipment industry employed 540,436 workers in 2009. This includes 89,184 workers in the automotive industry (passenger cars and buses) and 441,179 workers in the auto-parts subindustry.[39] In auto parts, the highest employment was in electric and electronic systems (185,722 workers), representing 42.1 per cent of total employment in the auto-parts industry, followed by miscellaneous parts (91,053 workers), and seats and interiors (63,293 workers), representing 20.6 per cent and 14.3 per cent, respectively (see Table2.6).[40] SMEs employed 43,348 workers, and large firms employed 397,831 workers.[41] Among SMEs, the highest share of workers was employed in miscellaneous parts (30.4 per cent), followed by electric and electronic systems (22.8 per cent), and brake and brake parts (12.3 per cent). Among large firms, the highest share of employment was in electric and electronic systems (42.1 per cent), followed by miscellaneous parts (20.6 per cent) and seats and interiors (14.3 per cent) (see Table 2.7).

The auto-parts sector provided an average of 439,112 jobs per year between 1993 and 2003. This figure represents 27.56 per cent of the total share of employment in the transportation equipment industry. Large firms and multi-national subsidiaries employed 302,870 workers, and SMEs employed 136,242 workers. From 1993 to 2003, large firms and multi-national subsidiary firms achieved a sales volume of more than $MXN 140 million, and the auto-parts SMEs reached more than $MXN 3 million (see Table 2.8).[42]

[39] INEGI (2009) Economic census
[40] INEGI (2010) Economic census
[41] According to the Mexican Ministry of the Economy, small manufacturing firms are those with fewer than 100 workers, medium firms have between 101 and 250 workers, and large firms have more than 250 workers. DOF 06-06-2006.
[42] INEGI (2004) Economic census

Table 2.7
Auto-parts industry in Mexico: Total employment (2009)

Group of auto-parts	Number of workers	Percentage
Engines and engine parts	39163	8.9
Electric and electronic systems	185722	42.1
Steering mechanisms	13336	3
Brake and brake parts	15130	3.4
Transmissions and parts	18637	4.2
Seats and interiors	63293	14.3
Metallic dies	14845	3.4
Miscellaneous parts	91053	20.6

Source: INEGI Economic Census 2009

Table 2.8
Auto-parts industry in Mexico: Total employment by size of firm (2009)

Group of auto-parts	Number of workers			
	SMEs	%	Large firms	%
Engines and parts	3865	8.9	35298	8.9
Electric and electronic systems	9888	22.8	175834	44.2
Steering mechanisms	2916	6.7	10420	2.6
Brake and brake parts	5344	12.3	9786	2.5
Transmissions and parts	1460	3.4	17177	4.3
Seats and interiors	2988	6.9	60305	15.2
Metallic dies	3699	8.5	11146	2.8
Miscellaneous parts	13188	30.4	77865	19.6
Total	43348	**100.00**	397831	**100.00**

Source: Own elaboration based on INEGI Economic census 2009

The Mexican auto-parts industry consists of 789 SMEs and 447 large firms and multi-national subsidiaries (INEGI, 2009). Table 2.9 summarises the number of auto-parts firms by group of auto-parts. The highest share belongs to miscellaneous parts (328 firms), followed by electric and electronic systems (297 firms).

Table 2.10 summarises the number of firms by size. SMEs represent 63.8 per cent (789 firms), and large firms and multinational subsidiaries represent 36.2 per cent (447 firms). Among SMEs, the highest share of firms belongs to miscellaneous parts, followed by electric and electronic systems. Within large firms and multinational subsidiaries, the highest share belongs to electric and electronic systems, followed by miscellaneous parts.[43] The majority of MNC subsidiaries are American and Japanese firms (such as Navistar International, Alcoa Fujikura). Some large enterprises are local firms that export to the US and Canada (such as Condumex, Enermex). Firms registered as belonging to a different trade are not included. For instance, the Mexican Institute for Regulation and Certification claims that the Mexico City region has 2,500 auto-part SMEs, which is the largest number of enterprises in Mexico.

Table 2.9
Auto-parts industry in Mexico: Firms by group of auto-parts
(2009)

Group of auto-parts	Number of firms	%
Engines and parts	130	10.5
Electric and electronic systems	297	24.0
Steering mechanisms	67	5.4
Brake and brake parts	105	8.5
Transmissions and parts	47	3.8
Seats and interiors	126	10.2
Metallic dies	136	11.0
Miscellaneous parts	328	26.5

Source: INEGI: Economic census 2009

[43] INEGI (2009) Economic census

Table 2.10
Auto-parts industry in Mexico: Total firms by size (2009)

Group of auto parts	Number of firms			
	SMEs[44]	%	Large firms	%
Engines and parts*[45]	82	10.5	44	9.9
Electric and electronic systems	134	17.2	163	36.6
Steering mechanisms*	47	6	16	3.6
Brake and brake parts	88	11.3	17	3.8
Transmissions and parts	23	3	24	5.4
Seats and interiors	66	8.5	55	12.4
Metallic dies	118	15.2	18	4
Miscellaneous parts	220	28.3	108	24.3
Total	778	**100**	445	**100**

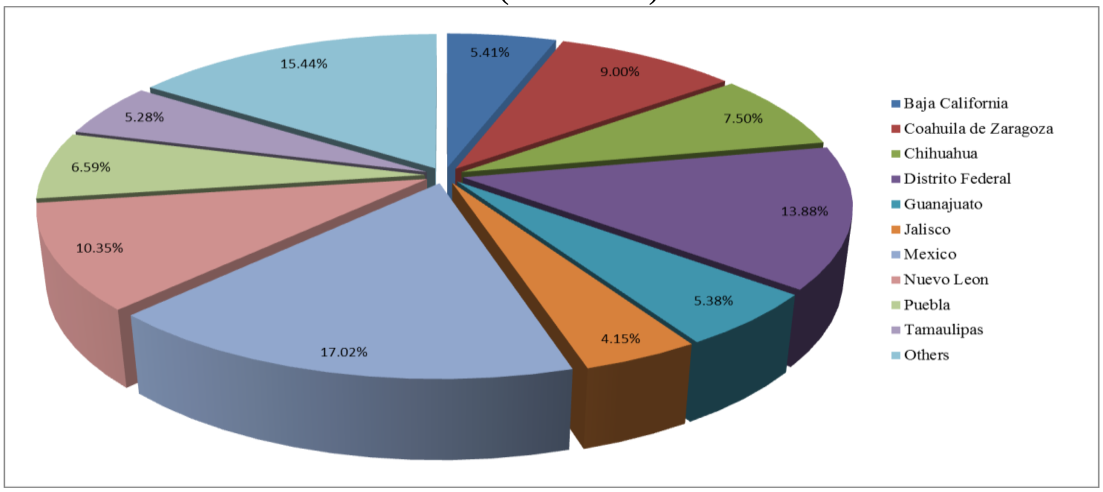
Source: INEGI: Economic census 2009

Graph 2.9 shows the average share of GDP from 1993 to 2007. Almost all these states are located in two main regions: the northern Mexico that shares a border with the US, and the centre of Mexico.

[44] The group of SMEs includes both foreign- firms and Mexican-owned firms

[45] *The groups of engines and parts, and steering mechanism do not have accurate data on SMEs

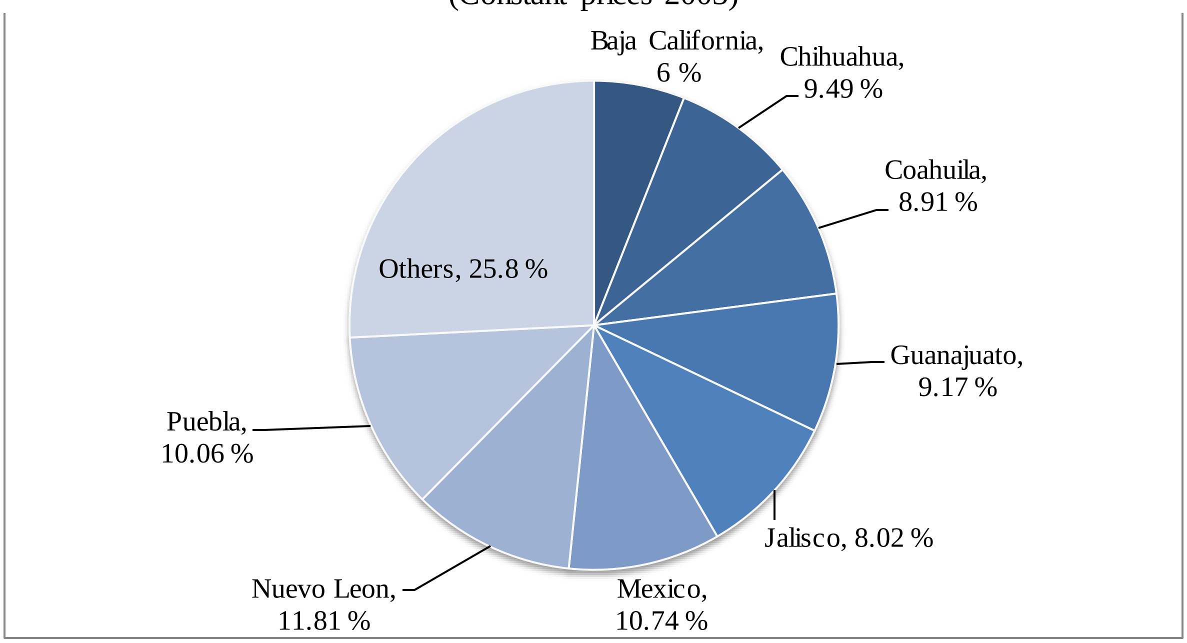
Graph 2.9
Transportation equipment industry: Gross domestic product average share by states
(1993-2007)



Source: INEGI Statistics Database

Graph 2.10 shows the locations with the highest share of GDP (constant 2003 prices) in 2009. Four states are located in the northern region (Baja California, Chihuahua, Coahuila, and Nuevo Leon), two are in the centre region (Puebla and Mexico), and two are in the north-west region (Guanajuato and Jalisco).

Graph 2.10
Transportation equipment industry: Gross domestic product by states (2009)
(Constant prices 2003)

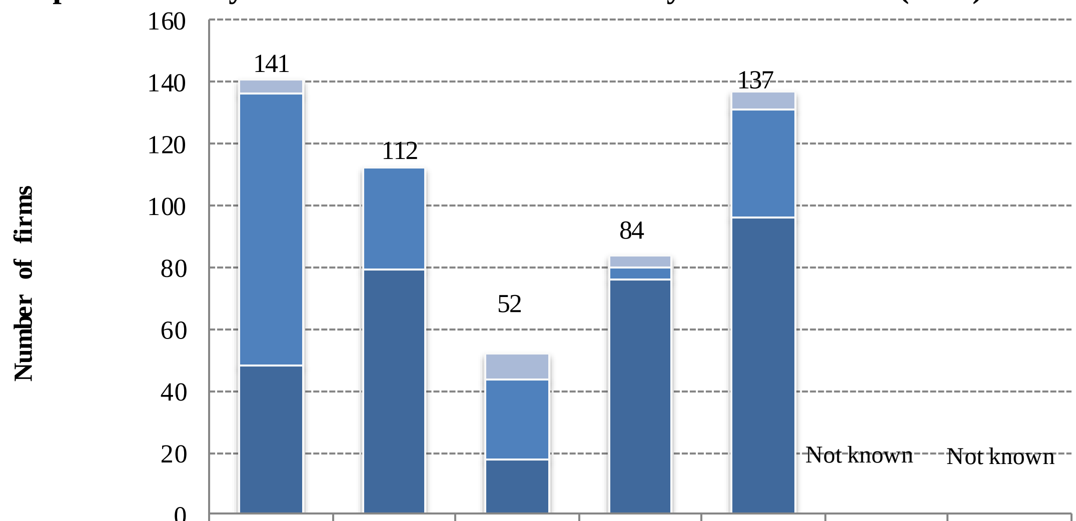


Source: INEGI Statistics database

Mexico City and Nuevo Leon have the highest number of firms in the transportation equipment industry, followed by Jalisco, Puebla, and Chihuahua.

Mexico City has 137 auto-parts subindustry firms, 96 of which are SMEs and 35 are large firms.[46] Nuevo Leon has 79 small and medium auto-parts firms and 33 large firms. Jalisco has 84 firms, 76 of which are SMEs and four are large firms. Chihuahua has 141 auto-parts firms, 48 of which are SMEs and 88 are large firms (see Graph 2.11).[47] The highest shares of firms in these locations belong to the electric and electronic systems, engines and parts, and brakes and brake parts.

Graph 2.11
Auto-parts industry in Mexico: Number of firms by selected states (2009)



	Chihuahua	Nuevo Leon	San Luis Potosi	Jalisco	Mexico City	Puebla	Tlaxcala
Not known size	5	0	8	4	6	0	0
Large firms	88	33	26	4	35	0	0
Small and medium firms	48	79	18	76	96	0	0

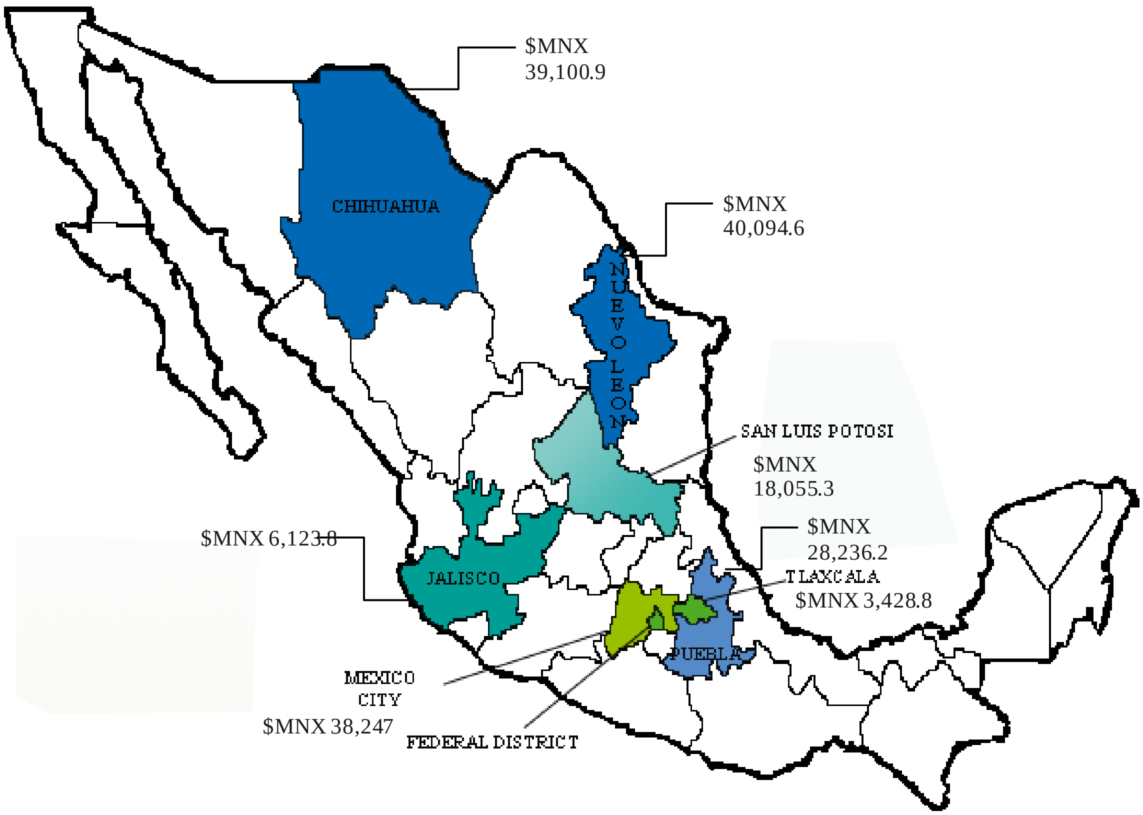
Source: INEGI: Economic census 2009

Overall, 70 per cent of auto-parts production is directed to car assembly. The other 30 per cent goes to spare auto-parts suppliers.[48] In relation to production in the auto-parts industry,

46 This data is from INEGI Economic Census 2009. There are missing values for some SMEs, or large firms.
47 INEGI lacks information on the number of firms in Puebla and Tlaxcala.
48 BANCOMEXT, 2006

Nuevo Leon had the highest production in 2009 (more than $MNX 40 million), followed by Chihuahua and Mexico City (more than $MNX 39 million and more than $MNX 38 million, respectively) (see Graph 2.12).[49]

Graph 2.12
Total production: Auto-parts industry (2009)
(Million Mexican Pesos)



Source: INEGI: Economic Census 2009

NAFTA encouraged export activity in the automobile industry. Exports of cars grew by 271 per cent from 1994 to 2004. In 1994, exports represented more than $MNX 98 billion. In 2003 the figure was more than $MNX 353 billion.[50]

The phase of trade liberalisation increased auto-parts production in Mexico. From 1994 to 2005, production of auto-parts grew by approximately 60 per cent. In 1994, production of

[49] INEGI (2009), Economic census
[50] Ministry of the Economy (2006), NAFTA and the automobile and auto-parts industry

auto-parts represented more than $MNX 150 billion. By 2005, this was more than $MNX 253 billion (Ministry of Economy, 2006).

Liberalisation of the automobile industry exposed domestic auto-parts firms to foreign competition. According to the Ministry of the Economy (2005), NAFTA favoured FDI in the auto-parts industry. From 1999 to 2003, Mexico attracted investments of more than $MNX 68 billion in different auto-parts production areas (see Table 2.11).

Table 2.11
FDI Attraction in the automobile and auto-parts industries

Auto-parts production	FDI %
Interiors	54
Production of cars	36
Terminals and connectors	4.4
Engines and parts	3
Brake systems	1.3
Transmission systems	1.1
Assembly of body systems	0.2

Source: Ministry of the Economy: NAFTA and the automobile and auto-parts industry

In terms of types of firms NAFTA favoured, the *maquiladoras* (registered under the NAFTA regime) reached production of $MNX 222 billion in 2000. At that time in Mexico there were 246 *maquiladoras* located in Chihuahua, Coahuila, Nuevo Leon, Sonora, and Tamaulipas. Non-*maquiladora* auto-parts firms reached production of $MNX 219 billion. From 1994 to 2000, the non-*maquiladora* firms grew annually by 10 per cent (INEGI, 2004).

2.8 Conclusions

This chapter reviewed the process of technology upgrading in different countries. It also examined the role of government and the innovation system for developing technological capabilities at the firm level. Korea focused on building large firms. Taiwan focused on developing capabilities in SMEs by establishing regulations and policies to enforce technology transfer from foreign firms. As an industrialized economy, Japan provided some insights into the internal and external sources that influenced technology upgrading in its automobile industry by stressing SMEs. The empirical evidence on the Brazilian automobile industry highlighted government mechanisms related to technology upgrading in the automobile industry. It revealed similar characteristics to the growth of the car industry in other Latin American countries.

For Brazil and Mexico, the growth of the automobile industry was characterised by the strong presence of foreign firms that established and imposed high barriers to entering the industry. In these countries, the transfer of knowledge was limited and exclusive between car assemblers and closer suppliers or parent companies.

The automobile industry is characterised by the establishment of linkages with suppliers worldwide. This results in a structured supply chain made of different tiers. The suppliers of carmakers are grouped in different tiers, according to the level of technology of their products. Suppliers in the first tier have strong linkages with carmakers and dominate the market. These firms are global-mega suppliers.

The barriers to enter into the automobile industry hamper firms that lack capabilities to compete in this industry. The automotive industry in Mexico is grouped in geographical agglomerations. Firms specialise in other sectors, such as electronics. This industry is dominated by foreign firms and a few large local firms. In this context, SMEs are a minority.

The review of the empirical literature offers lessons for the Mexican case regarding the role of government and firms for technology upgrading. Mexico contrasts with cases in Asia in terms of technological accumulation and capability building. In Asia, the government's role of deliberate efforts to support technological learning and the industry's achievements in terms of technological capabilities is a major difference from the situation in Mexico. The literature on South Korea focuses on an outstanding case of capacity-building, promoted by government impelling rapid growth in industry and the learning process in firms. The literature on Japan and Taiwan presents an automobile industry with a high presence of SMEs that have succeeded in technological capability building. In Taiwan, the main mechanisms were: Government support for technology transfer from foreign partners to locally owned firms; and development of R&D policies. In Japan, strong linkages and trust between assemblers and suppliers played an important role for technology transfer in the car industry.

The case of Brazil presents similarities with Mexico. An in-depth comparative analysis would be an interesting direction for future research.[51] The role of government in favouring export-oriented firms (NAFTA) through privatisation, FDI deregulation, and trade and financial liberalisation eliminated all incentives and subsidies for the manufacturing industry (Moreno et al., 2005), which were core to the Asian countries' process of technological accumulation at the firm level. The case of Brazil permits a better understanding of the automobile industry in the Mexican context and might provide recommendations for future policy based on the following issues:

- Lack of market protection hampered the process of technological accumulation of locally owned firms in Mexico.
- FDI-led policies do not guarantee rapid absorption of technological knowledge.

Based on a review of the empirical literature, the most relevant factors for developing technological capabilities in the automotive industry are:

- The role of system of innovation is core to technological capability-building, in which government plays an important role.
- The absorptive capacity in an interactive process. Agents in the system play an important role in developing deliberate efforts to absorb and spread knowledge.
- The process of technology upgrading at the firm level accrues from absorbing foreign technologies and strong, intense efforts in organisational learning.

This chapter reviewed the main features of the automobile industry and the auto-parts sector by investigating the empirical literature on important cases of technology upgrading in Asia and the Mexican automobile industry. Chapters 4, 5, and 6 analyse the empirical

[51] Because the main purpose of this research is the study of capacity-building at the firm level through interactions between SMEs and foreign firms, developing an in-depth comparison between the Brazilian and Mexican automobile industries is beyond the scope of this thesis.

evidence gathered through direct interviews in those industries. Chapter 3 focuses on methodology.

CHAPTER 3: METHODOLOGY

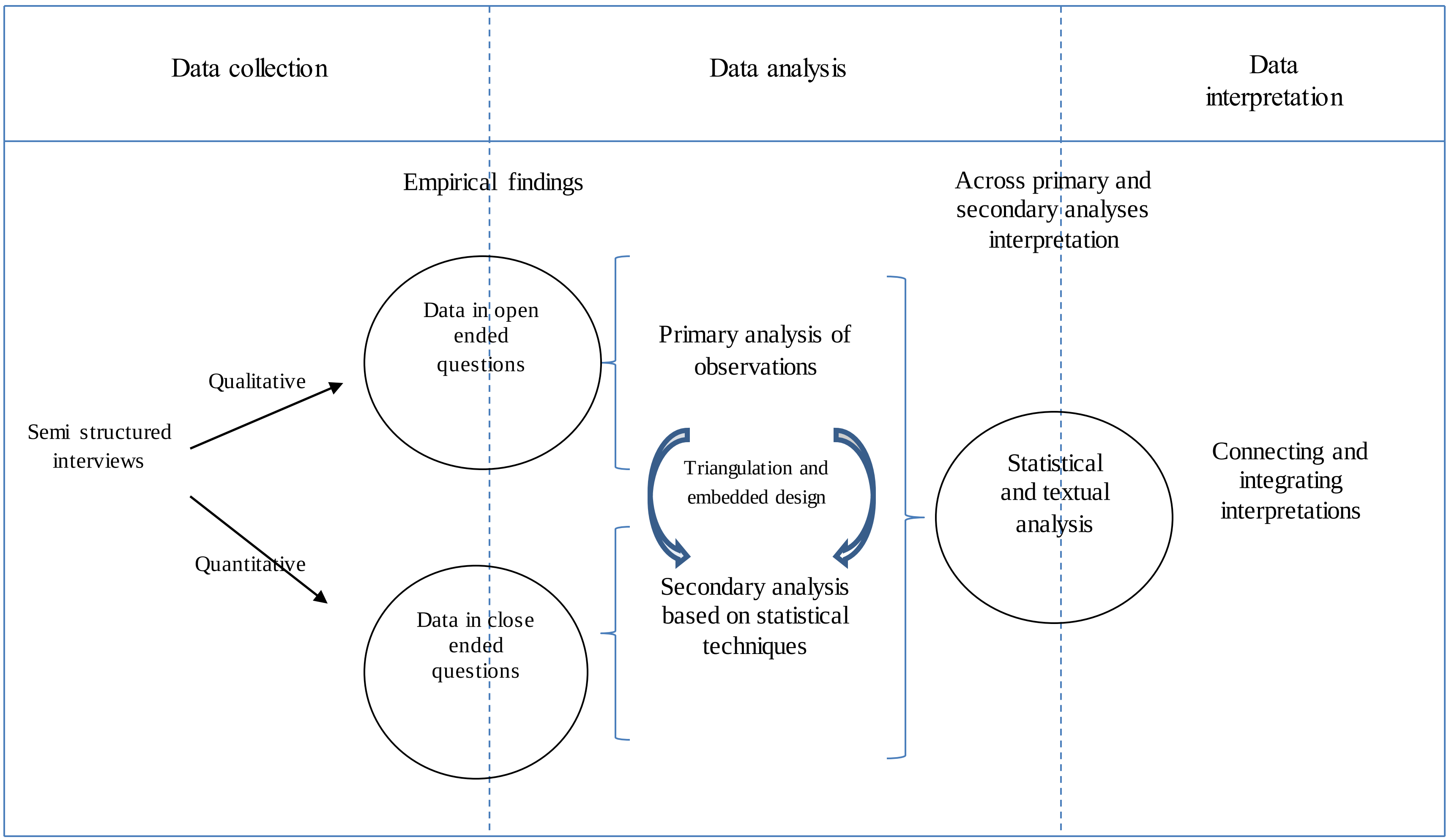
3.1. Introduction

This Chapter describes the methodology used to analyse data collected for this research. The first main part (Section 3.2) introduces the analytical approach and methodology. Section 3.3 describes the research design in more detail. The methodology and the interview design. The fieldwork is described in Section 3.4 and it also discusses the role of sponsorship. Section 3.5 presents the sample and describes the regional economies of the interviewees in Mexico.

3.2. Analysis: Mixed method approach

The analysis in this thesis adopted a mixed-methods approach, which involves qualitative and quantitative analysis. Data was collected during fieldwork and through semi-structured interviews and secondary sources. The empirical analysis involves the following stages: i) exploratory analysis of the empirical data collected during the fieldwork (qualitative and quantitative); ii) mixed techniques analysis to understand the factors that influence the outcomes from the exploratory research (Creswell, 2003); and iii) mixed-methods procedures for interpreting and validating the data (see Graph 3.1).

Graph 3.1
Qualitative and quantitative methods: Mixed methods procedures

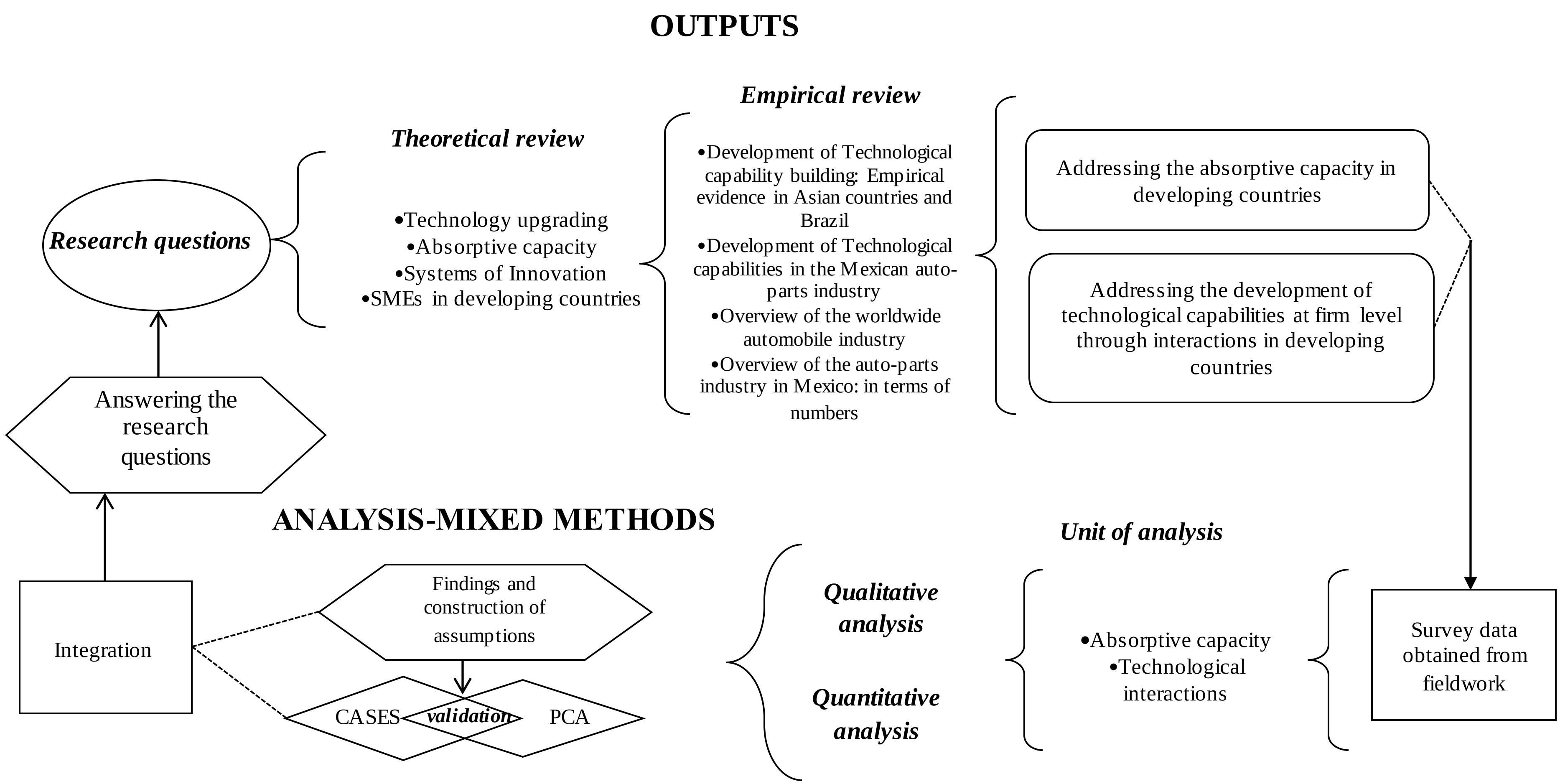


Adapted from Creswell (2003).

The rationale for the use of mixed methods is that they allow multiple approaches to data collection and also reinforce the results obtained from both forms of data collection. The mixed-method strategy in the analysis was concurrent (qualitative data was embedded in the quantitative analysis via the variables) (Creswell, 2009), and triangulation (empirical findings from the qualitative analysis were confirmed by the findings from the quantitative techniques) was used to provide validation. Graph 3.2 visualises the different stages of the research design, which depicts the stages of data collection, analysis and integration of this research. The different stages of research design includes the development of the theoretical and empirical framework based upon the criteria of the development of technological capabilities in the auto-parts industry in developing countries. Accordingly, the theoretical concepts of absorptive capacity and NIS in developing countries were identified to build up the research questions of this research. The main interest in exploring the technological interactions among firms (Mexican-owned-SMEs and large firms) was considered designing the semi-structured interviews for data collection during the fieldwork. The semi-structured interviews aimed to collect data to observe and study the main interactions among firms, considering the theoretical concepts of absorptive capacity and technological interactions as unit of analysis. The analysis of this research is based on qualitative methods and quantitative techniques to analyse and integrate the results to answer the research questions. These stages are further detailed and discussed in section 3.3.

Chapters 1 and 2 addressed absorptive capacity at firm level as the unit of analysis for developing technological capabilities. Firm-level absorptive capacity includes the competencies of the firm’s founder and employees. The first two parts of the semi-structured interviews were aimed at collecting this type of information. The development of technological capabilities in developing countries can be influenced by multinational firms that upgrade the level of their technological capabilities. Interaction among agents is the next unit of analysis for developing technological capabilities. These interactions were explored in-depth, and their impact was analysed through semi-structured interviews conducted during fieldwork, which focused on the influence of those interactions in the surveyed SMEs. Data validation was based mainly on triangulation among the different interviews. The analysis was based on observation of the data collected with secondary analysis on the basis of qualitative evidence, triangulation, and embedding the qualitative results in quantitative analysis (Creswell, 2003). Similarly, I conducted a macro-comparative analysis to locate the Mexican system of innovation in the literature. This is in line with Viotti (2002) according to whom the NLS approach is suited to countries that fail to innovate. The analysis was validated through the data collected from the interviews with agents in the Mexican learning system.

Graph 3.2- Research Design



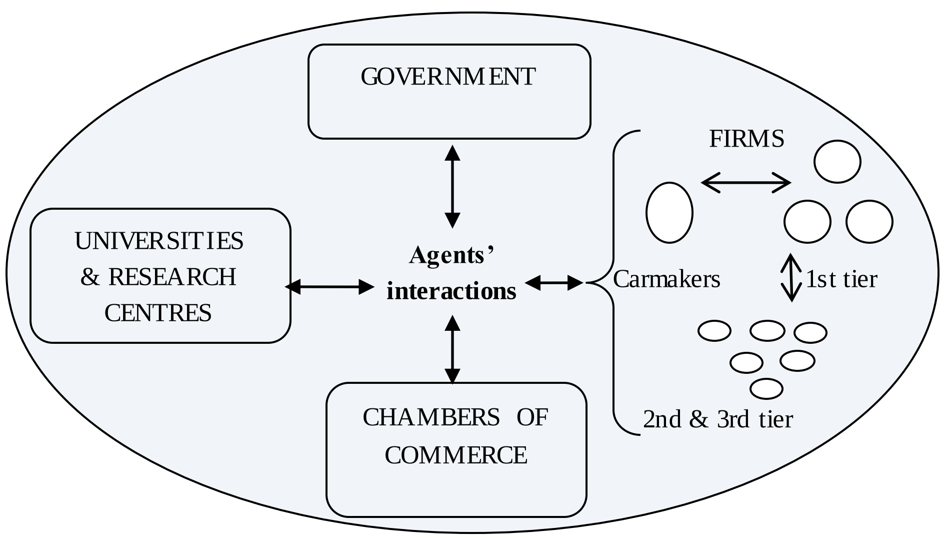
3.3. Research design

The research design in this thesis comprises several stages (see Graph 3.2) following the review of theoretical and empirical literature, collection, analysis and interpretation of the data collected during the fieldwork as well as validation and integration of the qualitative and quantitative approach. The following sections explain the research design of this thesis and the data collection process.

3.3.1. The research actors

I identified the main actors as: i) small and medium suppliers; ii) large producer firms; and iii) agents in the NIS - universities, local government agencies, central government agencies and chambers of commerce (Graph 3.3). To address the research questions, I studied different locations in Mexico to identify the acquisition of technological capabilities in SMEs. Next, I designed the interview protocol for each group of agents.

Graph 3.3
The agents and their interactions



3.4. Fieldwork and data collection

3.4.1. Development of the fieldwork

The fieldwork included 33 face-to-face, semi-structured interviews, lasting one to two hours. The interviews included a sample of local small and medium firm owners and representatives from large producer firms and senior officers in government agencies, universities and chambers of commerce. Two focus group discussions were organised. The interviews involved six large firms or multinational subsidiaries, five central government agencies, three local government agencies, four industry associations (such as chambers of commerce), five universities and 10 SME owners. The focus group discussions each involved between 12 and 16 participants (Table 3.1).

Table 3.1
Sample of the automotive industry in Mexico

Agent in the automotive industry	Number of interviews applied
Small and medium-sized firms	10
Multinational and local large firms	6
Universities and research centres	5
Chambers of commerce and industry	4
Central and local government agencies	8
Total	33

The fieldwork began on 15 February 2010, and corresponded with the timing of the annual *Programa de Alianzas Estratégicas y Redes de Innovación* (AERI) meeting, as part of the FUMEC automotive project (which sponsored this research), FUMEC gathers together SMEs involved in the auto-parts industry. [52] [53]The fieldwork finished on 22 April 2010, at the end of the annual national automotive industry TechBA (Technology Business Accelerator) events organised by FUMEC.

In the third week of February 2010, one government agency and one small firm were interviewed in Mexico City. These interviews provided new insights for this research and resulted in the addition of three more open-ended questions to the questionnaire used for the interviews with government agencies. These questions related to the interests behind the development of some programmes and the actors involved in the programmes or policies. Three questions were also added to the interview protocol for SMEs, based on the

[52] AERI aims at developing networks among different agents, such as universities, government and firms, in order to develop cooperative technology projects.
[53] The fieldwork in Mexico was sponsored by the automotive sector programme of the United States-Mexico Foundation for Science in Mexico (FUMEC), which promotes establishment of linkages among different agents in the system of innovation to foster growth in the automobile industry.

importance of receiving funds for acquiring machinery, sources of technology searches, and competencies. The latter provided insights into the previous accumulation of competencies. Pilot interviewees were asked to comment on the structure and content of the questions and feedback used to improve the wording of some questions. The interviews with large firms and multinational subsidiaries, universities, and chambers of commerce and industry were also piloted.

3.4.2. Focus group and results

As part of the AERI - FUMEC project, two focus groups were held in Chihuahua in March, 2010. FUMEC organised and hosted these focus groups. The focus group discussions involved 12 to 16 participants and lasted an average of six hours. The focus group members included firms, senior officers from local and central government agencies, representatives of universities and research centres, and chambers of commerce and industry. The focus group discussions aimed to uncover linkages among first- and second-tier suppliers with automakers.

The first focus group was held at Visteon, a subsidiary of a multinational auto-parts firm located in Chihuahua. There were 16 participants and discussions lasted seven hours. The participants were large firms and multi-national subsidiaries, universities, and senior officers working in local public agencies. Participants were located in different areas of Mexico. This group discussion aimed at analysing the interactions among participants in the automotive cluster, and SMEs expressed their opinion about the relationships with large firms and multi-national subsidiaries. In addition, FUMEC's representative presented an initiative to apply for a research project in CONACYT with the members of the AERI. To do so, firms exchange knowledge about areas of opportunity in which SMEs may get involved with foreign firms (members of the AERI). The findings from this group discussion supported the information gathered in the interviews on the SMEs' linkages with universities, public agencies and large firms.

The second focus group discussion was held at *Diseña* (a small first-tier supplier of embedded software) in Chihuahua. It had 12 participants and lasted six hours. It included members of small-sized firms, universities, and senior officers from public agencies, all located in Chihuahua. This meeting highlighted the importance of firms in national level policy and the importance of government support for firms. In this regard, TechBA's representatives presented information of its role and support given to firms in the car industry. This meeting also addressed the basis of research projects between small firms (members of the AERI) and universities. Here government representatives met the small firms challenges and obstacles to get involve in the car industry and their competencies in the industry. The findings from this group meeting enriched the understanding on the relations existing between government agencies and small firms as well as they contribute to shape the framework of the Mexican system of innovation.

The results of the focus groups supported and enriched the information collected in the interviews. The focus groups revealed the types and levels of interactions between SMEs and agents in the automotive industry. In these focus groups small firms referred to shortcomings related to the NLS and their efforts to foster change. Information on the linkages between those actors shaped the framework of the Mexican system of innovation and its role in the automobile industry.

3.4.3. Structure of the survey

The thirty three semi-structured interviews with actors in Mexico were conducted face to face and included open and closed questions. The open-ended questions aimed at getting qualitative data. The closed questions aimed at obtaining factual information about relationships among the actors as well as collecting quantitative data (Oppenheim, 1996, p. 112). The advantage of semi-structured interviews was that it allowed exploration of responses. I adjusted and adapted the question to enable deeper investigation of particular areas of interest. Both open and closed questions provided qualitative and quantitative data for my analysis (Creswell, 2009). The opportunity I had to do the interviews *in situ* allowed me to develop a clearer idea of the various aspects of the responses regarding the firm's technology. The interviews with SMEs provided a structure for the interviews with the other agents in the industry.

i) SMEs: The core agents in the research

The interviews for SMEs included 44 questions aimed to collect the following information:

1. General information on the firm (ownership, size of the firm, age, etc.)
2. Information on firm owner (competences, experience, etc.)
3. Supply chain (customers' nationality, type of customers – tier-level, nationality, etc.)
4. Technological capabilities (production, innovation, investment, strategic marketing and linkages)
5. External sources of information for the firm
6. Interactions with other agents in the system (large firms, universities, government agencies, and chambers of commerce).
7. Problems and obstacles related to firm growth (innovation, building technological capacity).

Section 1 and 2 of the interviews aimed to collect information related to the firm and the founders' competencies. Section 3 aimed to collect information on the relationships existing with the firms' customers (foreign firms) as well as the duration of these relationships and the activities involved in these relations. Section 4 collected information of the firm's technological capabilities and their development. This section focused on the process of the firms' technology upgrading through interactions with foreign firms. Section 5 and 6 collected information of the external sources important for the firms' technology upgrading. These sections looked at the relations between the firms with government agencies, chambers of commerce and industry as well as universities or research centres. These sections also collected information on the activities involved in these relations as well as the duration of those.

A likert scale was introduced to measure the depth and importance of relations established with government agencies, universities and chambers of commerce and industry. However, this scale was not included for the analysis of these relationships given the bias found in the firms' responses. In addition, to reduce these bias, the open-ended questions aimed to validate the answers of the close-ended questions. These were included to collect numerical information related to relations and development of technological capabilities (e.g. number of patents).

The questions and the structure of the interview were revised several times in order to ensure they addressed: i) competencies, ii) linkages capabilities, iii) technological efforts, and iv) technology upgrading

This research focuses on studying technology upgrading in small and medium sized firms (SMEs) through interactions with large firms. The interviews with large firms allowed a comprehensive picture of the influence of these firms on SMEs' technology upgrading.

ii) Large firms and their interactions in the industry

The questionnaire for the interviews with large firms and multinational subsidiaries consisted of 18 questions. However responses were explored in more detail, when necessary. The interviews with large firms included three sections: i) general information on the firm; ii) supply-chain information; and iii) interactions in the system of innovation. The first part of the interview collected information on firm's nationalities, sizes, ages, locations, etc. The second part gathered information on firms' positions in the supply chain and suppliers (SMEs). The third part collected information on the firms' linkage capabilities (technological capabilities) to transfer technology and knowledge within the supply chain. This section also focused on enquiring into establishing relationships between large firms and other actors in the system of innovation (see Graph 3.4).

iii) Central and local government agencies

Those interviews oriented toward central and local government agencies consisted of 20 and 16 questions respectively. Both interviews were divided into three sections. The first section collected information on the agency's general characteristics such as age, location, agency size, and number of employees-. The second section collected information on policy programmes oriented towards the automobile industry. It enquired about those programmes developed specifically for SMEs. The third section gathered information on the existing interactions of those agencies with other actors in the system of innovation such as universities, chambers of commerce and firms in the automobile industry. These interactions were assessed in terms of the role of government transferring technology and knowledge within the actors and developing technological capabilities in the firms of the automobile industry. Finally, the interviews addressed to central agencies collected information on external sources of information (international sources) to those agencies (see Graph 3.4).

iv) Chambers of commerce and industry

The interviews with representatives of chambers of commerce and industry were based on 15 questions in three parts. The first part related to general information such organisational size - number of employees, age, and location. The second part was related to the agency's mission in the automobile industry. It gathered information on tasks developed to accomplish its mission and the organisation's role in the transfer of technology and knowledge within the industry. The third part was related to interactions in the system of innovation and enquired about relationships with other actors, such as universities and government agencies, and how they shaped the organisation (see Graph 3.4).

v) Universities and research centres

The interviews with representatives of research centres, and public and private universities were based on 17 questions in three sections. The first section focused on general information such as age, location, and size of the university/centre. The second part was related to the involvement of academia in the automobile industry and collected information on teaching-oriented activities, programmes developed for the automobile industry, number of students participating in these programmes, etc. The third part gathered information on the role of the university in the system of innovation regarding the transfer of technology and knowledge within the automobile and auto-parts industry. Other questions related to external linkages to the university were explored. These questions were related to interactions within the automobile industry (with firms and chambers of commerce and industry) and interactions with international actors (foreign universities) (see Graph 3.4).

3.4.4. Pilot interviews

A pilot questionnaire was developed in consultation with my supervisors. Several drafts were developed to cover all the information required. A series of semi-structured interviews were developed to confirm the relationships among the different actors (such as firms, chambers of commerce and government agencies) (see Graph 3.4).

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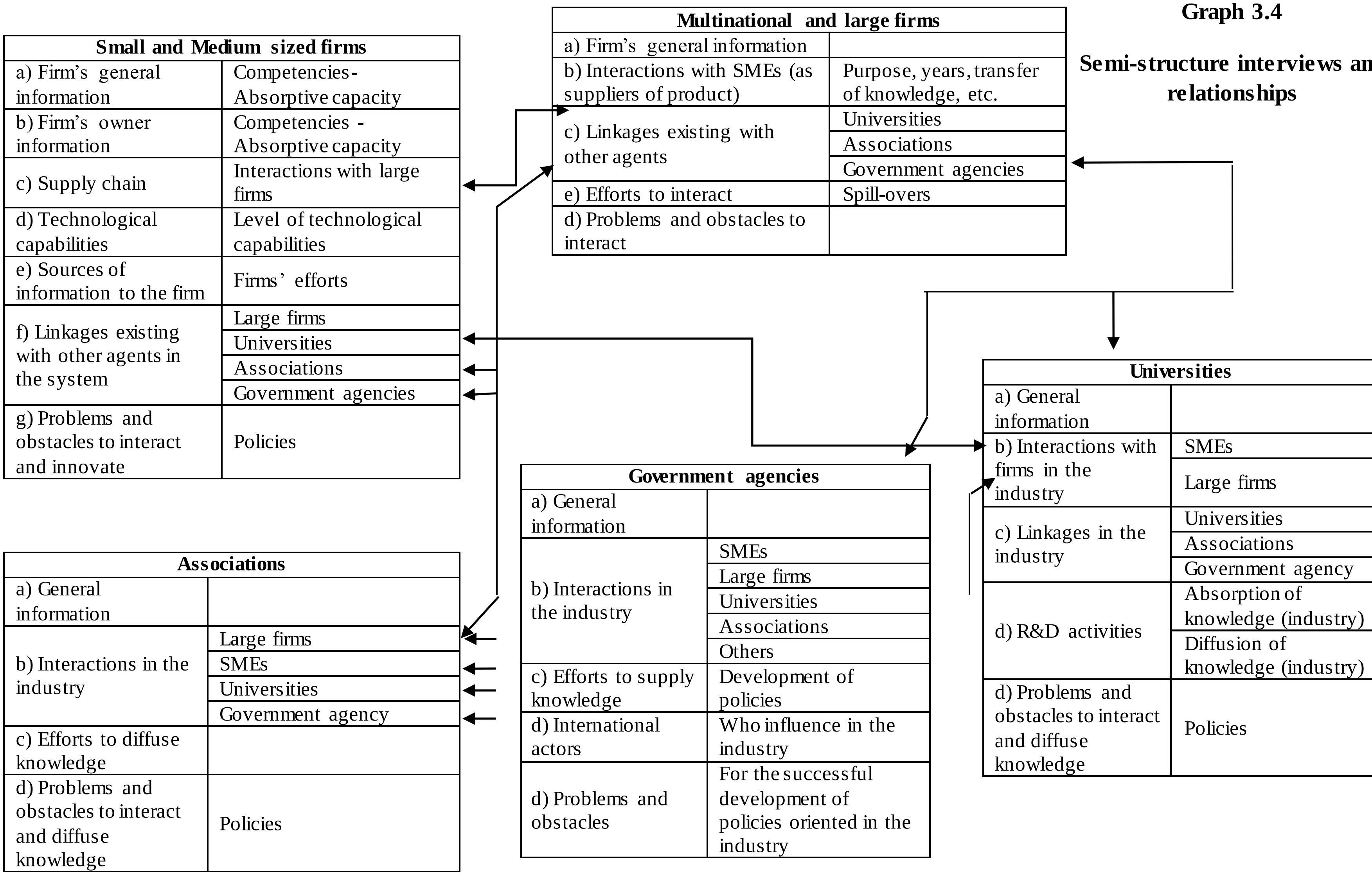
Graph 3.4

Semi-structure interviews and relationships



3.5. The sample

3.5.1. The auto-parts industry

The literature on the auto-parts sector in Mexico (Carrillo, 1997, 2001; Carrillo and Ramírez, 1997; Ochoa, 2005, Vieyra, 1999) identifies three main clusters: the northern region (i.e. Baja California Norte, Sonora, Chihuahua, Monterrey, Nuevo Leon and Tamaulipas); the north-west region (Zacatecas, San Luis Potosi, Aguascalientes, Jalisco, Guanajuato and Queretaro); and the central region (Hidalgo, Mexico DF, Tlaxcala, Morelos and Puebla).

The northern region is dominated by American auto-parts firms, including some joint ventures with automobile firms, such as Ford and Chrysler, and their spin-off corporations (such as Visteon spin-off from Ford). This cluster is characterized by the presence of maquiladoras with relations with local SMEs. The dominant automobile firms are Ford, Chrysler and General Motors, which have invested in building new plants with modern R&D laboratories (Carillo, 2001). Several scholars have argued that this cluster is highly productive and competitive by being mainly focused on exporting based on its proximity to the US (Carrillo and Ramirez, 1997; Vieyra, 1999).

There are some localised European and Japanese firms (such as Valeo, Autopartes y Arneses, Sn. Luis Coorp) in the central region. The automobile firms in this cluster are Honda, Nissan, and General Motors.

The north-west region includes a diversity of automobile firms (such as BMW, Ford, Volvo, and Daimler-Benz) and auto-parts suppliers of different nationalities (such as Japanese, German and American), as well as a high presence of local firms (mainly design houses located in Jalisco). The region is characterised by the presence of the leading automobile firms in Mexico such as Ford, Chrysler and Volkswagen. For this reason, it is argued that this ‘cluster’ is characterised by old and obsolete plants that lack investment in R&D and need complete restructuring (Carrillo, 2001; Ochoa, 2005; Vieyra, 1999).

Given the geographic spread of the auto-parts firms I searched for government institutions and other associations focused on the auto-parts sector and related to the development of technology in firm directories or other information sources. This decision was taken following a review of the empirical literature on the automotive industry in Mexico. The interest in this thesis is not in a particular region. The northern region is dominated by maquiladoras which establish few relationships with formal SMEs. The literature categorises these firms as suppliers of maquiladoras although most small suppliers operate more like workshops on the basis of informal contract arrangements. Maquiladoras (by their nature) do not establish formal linkages with domestic actors. The central region is characterised by a high presence of foreign firms and low presence of SMEs. The literature focuses mostly on the north-west region which has a high presence of domestic firms. These firms are important for this research due to their involvement in the customer supply chain. However, I was interested in exploring other possibilities because the majority of these firms are involved in the automotive industry through their capabilities in electronics; thus, they have a high presence in the electronics industry with an important cluster in Jalisco.

3.5.2. SMEs and large firms

i) Selection of SMEs before the fieldwork: Strategies

SME selection was not straightforward due to the lack of official information on these enterprises. As a first step in the selection of firms, SMEs were traced through automotive industry associations (i.e. National Institute of Auto-parts – INA). A directory of firms was used to identify core firms. INA groups multinational and large local auto-parts firms in different locations in Mexico; SMEs are categorised according to number of workers without differentiating between foreign subsidiaries and domestic firms. The firms grouped by INA are small firms based on the number of workers and are foreign subsidiaries. INA provides no information on domestic SMEs. Other industry associations were consulted but the results were no more successful.

The Ministry of the Economy was consulted, but lacked a directory of domestic SMEs. Due to the difficulty in identifying registered small and medium auto-parts firms, I sought involvement in government projects to access SMEs. FUMEC was one institution directly involved in the development of programmes for the automotive industry.

I contacted the Director of FUMEC. This institution appeared unique and heavily involved in the automotive industry. To gain access to directories of SMEs, I developed a consultancy project to establish linkages with some Mexican engineers working in the automotive industry in the UK and government institutions.[54] I identified and introduced senior engineers highly involved in government networks related to the British car industry to FUMEC representatives (e.g. a Mexican engineer working in Ricardo was contacted).[55] In exchange for this work, I received sponsorship for travel expenses involved in the development of the fieldwork in Mexico and a flight from the UK to Mexico paid by FUMEC. This strategy of involvement in a governmental project enabled access to SMEs, the core actors in this thesis research.

ii) Selection of SMEs and large firms during the fieldwork: Strategies

Given the lack of information on SMEs in the automotive industry, the sample design was based on directories of SMEs in FUMEC. To select firms with different characteristics, the following criteria were considered: i) firms that build linkages with large firms through government interventions; and ii) firms that build linkages without any type of intervention. Among large firms, two groups of firms were identified: those participating directly in FUMEC networking programmes, and those with no involvement in any government programme. The firms involved in networking programmes were identified through their involvement with FUMEC in AERI.[56] These firms were contacted and interviewed face to face. The group of firms with no government participation were identified from the directory of firms provided by the regional Ministry of Economy of Tlaxcala and are

[54] FUMEC identified a small population (40 firms in 2010) of SMEs involved in the Mexican automotive industry. Some of these firms are involved in different FUMEC programmes; others had not been contacted by FUMEC and are not involved in any government programme.

[55] A British engineering consultancy specialized in aspects of vehicle design and development of technology in engines, drivelines, intelligent transportation, vehicle systems and hybrid and electric powertrains.

[56] The AERI in the automobile industry is a networking programme based on the development of research projects involving the transfer of technological knowledge among network members. AERI is the result of search by FUMEC for members to invite to be involved in the group. In 2010, the automobile AERI of FUMEC included 3 multinational firms, 2 SMEs and 4 universities from various regions.

located in the centre region of Mexico.[57] They were contacted by email and phone; however, they were suspicious of the research, and I had to ask the help of the Ministry of Economy to contact them and arrange meetings.

The interviewees were plant general managers, controllers, engineering managers, and administrative managers. In some cases, interviews were with multiple firm members who responded based on their particular knowledge. Most of the interviews with large firms were face-to-face at the firm. Only one interview was held at a different location (Continental is located in Jalisco and the interview was conducted in Chihuahua). In a few cases, additional information on specific points was collected by phone. I recorded the contact details of all interviewees to enable follow up contact if necessary.

Most interviewees were happy to be interviewed and responded at length to all the questions posed. Around 20 percent were suspicious and their answers were very short. For these cases, I rephrased and reordered the questions in the hope of receiving more detailed comments. On the whole, large firms were more available to participate in the study than were SMEs.

To enable a richer analysis, interviewees were asked some additional questions related to their experience of working in other automobile firms. These questions were also included in the interview protocol for large firms and multinational subsidiaries. They asked about the number of years working in the present firm, previous experience in the automobile industry, and education. The findings are relevant for the analysis in this thesis and are discussed in subsequent chapters.

iii) Firms' characteristics

Ten domestic SMEs were interviewed. These firms are in different locations (see Table 3.2) and the interviewees were the firms' founders and managing directors.

[57] Tlaxcala is an important region with large firms in Volkswagen's supply chain. Volkswagen has only one assembly plant in Mexico located in the city of Puebla. Puebla is 20 miles from Tlaxcala.

Table 3.2
General characteristics of the sample

Firm	Location	Involved in
Diseña	Chihuahua	AERI
Soluciones_di	Chihuahua	
Sistemas_emb	Mexico City	AERI
Herramentales	Puebla	TechBA
Interiores	Tlaxcala	
Mec_automotriz	San Luis Potosi	TechBA
Manufactura	Aguascalientes	TechBA
Quimicos	Nuevo Leon	TechBA
Flextech	Mexico City	TechBA
Industrias MC	Mexico City	TechBA

Note: names are fictitious names to preserve the anonymity of the firms.

The large firms and multinational firms interviewed were i) Continental, ii) Visteon, iii) Condumex, iv) Haas Automotive, v) Grammer Automotive and vi) Shunk. (see Table 3.3). Three firms participated in the AERI-FUMEC programme; only one firm is in TechBA and two firms did not participate in any government programme. The interviewees were plant managers.

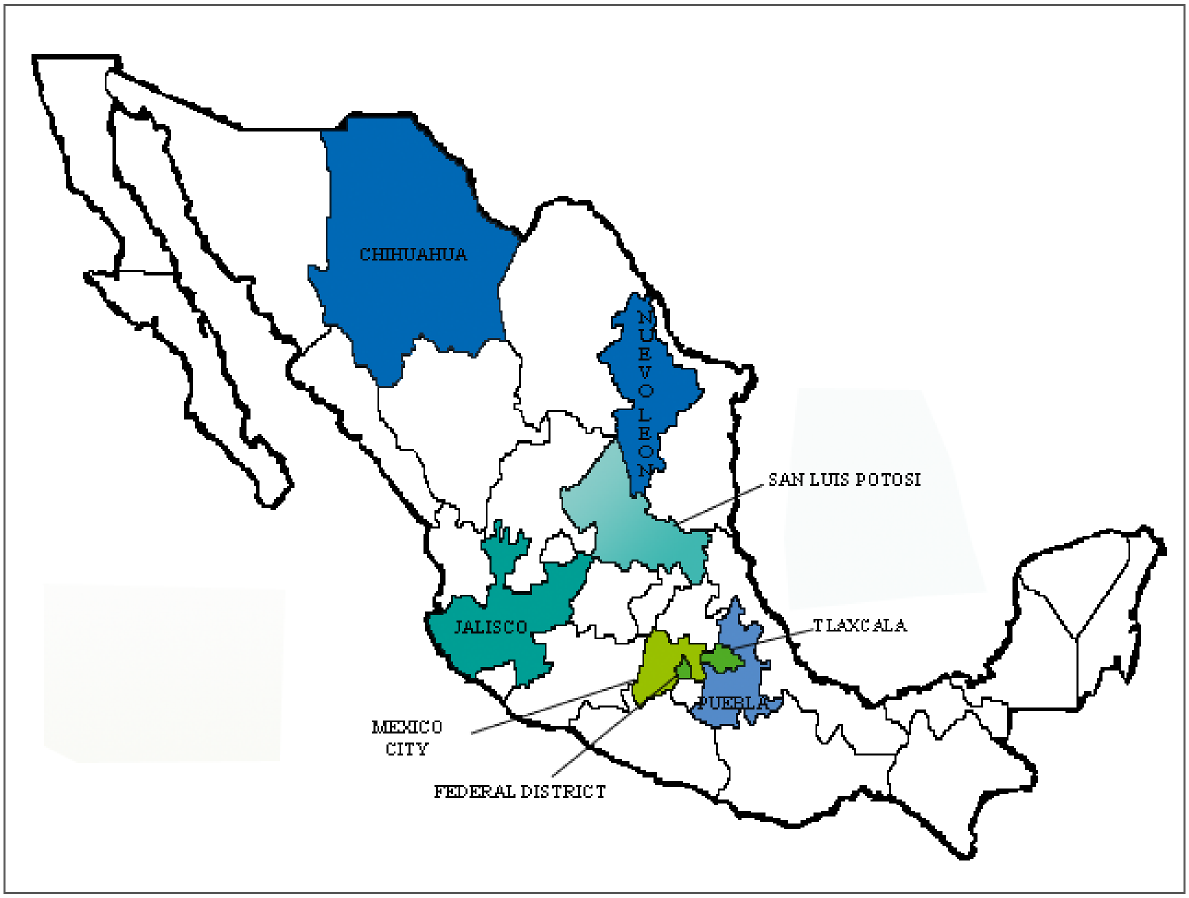
Table 3.3
Large and multinational firms interviewed

Firm	Location	Involved in
i) Continental	Jalisco	AERI.
ii) Visteon	Chihuahua	AERI
iii) Condumex	Queretaro	AERI.
iv) Haas Automotive	Tlaxcala	
v) Grammer Automotive	Tlaxcala	
vi) Shunk	Mexico City	TechBA

iv) Geographical location

The firms in this research are located in different regions. This benefited the research, which focuses on the industry rather than the region. The firms were located in the north of Mexico (Chihuahua and Nuevo Leon), the north-west region (San Luis Potosi and Jalisco), and the central region (i.e. Mexico City, Tlaxcala, and Puebla) (see Graph 3.5).

Graph 3.5
Locations of the selected firms in Mexico



v) Economic characteristics of the firms locations

In the literature on the auto-parts industry in Mexico, several authors argue that the northern region comprises new investments by existing assembly plants. The maquiladoras and the export-oriented firms in this region are equipped with modern technology and highly qualified workers. In contrast, the assembly plants in the central region are mostly old plants with out of date technology due to lack of investment in the first assembly plants established in Mexico (Brown, 1997; Moreno, 1996). In relation to GDP in the manufacturing industry, Mexico City accounts for 18.4 per cent followed by Nuevo Leon with a 9 per cent of manufacturing GDP, Jalisco with 6 per cent Puebla with 4.1 per cent, Chihuahua with 3.7 per cent San Luis Potosi with 2.1 per cent and Tlaxcala with 0.53 per cent of national manufacturing GDP (INEGI). Table 3.4 presents the locations of the surveyed firms.

Regarding the presence of multinational firms in the surveyed locations, according to Bancomext (2004) and INA (2009), Chihuahua has 48 first-tier suppliers and Nuevo Leon has 43 first-tier suppliers with two assembly lines for buses and trucks. In the north-west region, Jalisco has one assembly line with 23 first tier suppliers, and San Luis Potosi has one assembly line (buses) and 14 first tier suppliers. In the central region Mexico City has seven assembly lines of cars, buses and trucks and 30 first tier suppliers, Puebla has one assembly line and 19 first tier suppliers and Tlaxcala hosts seven first-tier suppliers but no assembly lines (see Table 3.5). [58]

[58] Tlaxcala is 20 miles northeast of Puebla and 75 miles southeast of Mexico City. Volkswagen's suppliers are located in Tlaxcala.

Table 3.4
Geographical locations of the surveyed firms: Large firms and SMEs

Region	National characteristics	Firms' locations	Economic indicators					Population (% of the national level)[59]
			Year	GDP at country level (%)	Percentage of GDP at state level			
					Primary sector	Secondary sector	Tertiary sector	
North	•Characterized by high levels of industrial development (i.e. Nuevo Leon), high concentration of maquiladoras (i.e. Chihuahua), and a high level of export orientation.[60]	Nuevo Leon	2008	7.8	0.7	36.7	62.5	4,199,292 (4.06 %)
		Chihuahua		3.3	5.8	34.8	59.3	3,241,444 (3.1 %)
Centre	• This region, specifically Mexico City, has been characterized as the leader of industrial development in Mexico since the first manufacturing plants were set up in that location. The Federal District belongs to Mexico City, the capital of Mexico, which has the largest metropolitan area in the country, and is the economic and political hub of Mexico.	Federal District	2008	27.4	0.64	21.3	78.0	22,728,411 (22 %)
		Puebla		3.5	4.4	36.7	58.7	5,383,133 (5.2%)
		Tlaxcala		0.54	4.8	31.1	64.0	1,068,207 (1 %)
North-west	-	San Luis Potosi	2008	1.8	4.5	36.8	58.6	2,410,414 (2.3%)
		Jalisco		6.6	6.9	28.8	64.1	6,752,113 (6.5%)

Source: Own elaboration based on INEGI Statistics Database on 2005, 2008.

[59] The population is according to the population census by INEGI in 2005.
[60] These maquiladoras were established in Mexico in 1965 with the ending of the Bracero programmes with US. The first two industrial parks were located in Chihuahua and Nogales. Typically, these unit plants are foreign-owned, focused on assembling imported components for export. According to some authors, the maquiladoras evolved in three stages: i) limited assembly activities and 100% controlled by parent companies; ii) plants increased manufacturing processes; and iii) plants more oriented to design and development (Buitelaar and Padilla, 1999; Cañas, 2006).

Table 3.5
Relevant population of the automobile industry:
First tier suppliers and Assembly lines

Location	Assembly lines	First tier suppliers
Chihuahua	0	Alcoa Fujikura, Alphabet de Mexico, Auma, Auto-Kabel, Avon Automotive, Bergen Cable Technologies, Breed Technologies, Capsonic Automotive, Carlisle, Cooper Industries, Croni, Cummins Diesel, Delphi, Eagle Ottawa, Electrisola, Federal Mogul, Goodyear Tyer & Rubber, Key Safety Systems, Honeywell, ITESA, ITT Automotive, Johnsons Controls, Kenwood, Lear Corporation, Leoni Cable, Letts Industries, Manesa, Moraine, Nichirin Coupler, Nypro, Pace Industries, Rapid Design Service, Robert Bosch, Saturn Elecronics, Seton, Sheldahl, Siemens, SSI Technologies, Strattec Security, Stoneridge Corporation, Sumitomo Coorporation, Superior Industries, TDK USA Corporation, T.R.W., TYCO International, Valeo, Visteon, and Yazaki North America.
Nuevo Leon	Mercedes Benz (Buses) Navistar (Trucks)	Accuride, AISIN, Allied Signal, Alcoa Fujikura, American Axle, Arnecom, Arvin Meritor, Autoclimas, Carusi, Caterpillar, Cifunsa, Delphi, Denso, Donnelly, Entrelec, Ficosa, Freightliner, Gonher, Hayes Lemmers Int., John Deere LTH, Johnson Controls, Katcon, Lear, Metalsa, Mitsubish, Mitsuba, Navistar Remsa, Nemak, Parker Hannifin, Piolax, Pioneer, Rassini, Siemens, Sisamex, Takata, Teknik, Thomas & Betts, Thomas Built Buses, Tokio Electrica, United Technologies, Visteon, Vitroflex, and Yazaki
Jalisco	Honda	Affinia, Aralmex, Asiento superior, ATR, BorgWarner Morse, Carburat, Causamex, Grupo Ferrau, Hella/Hemex, Modine, Pioneer Standard, Rockwell Automotive, Rolamex, S&Z Rolmex, Saargummi, Sachs Boge, Sanmina-SCI, Siemens VDO, Sumida, Takata, Vogt Electronics, Webb de Mexico, and Yamaver.
Aguascalientes	Nissan (engines and PC), Marcopolo (Trucks), Oymsa (Trucks)	Busscar, Calsonic, Cooper Standard, Cooplast, Forjas y Maquinas, Gestamo, Industria de asiento superior, K&S, Kantus, Morestana, Moto Diesel, Nabco, Polo Mex, Siemens, and Yorozu.
San Luis Potosi	Scania (Trucks)	Alfred Englemann, Arvin, Bosch, Continental AG, Delco Remy, Eaton, Eagle-Picture, Edscha, Fleet Guard Nelson, Industrias San Luis, Rassini, Scania, and Valeo Sylvania.
Mexico City	BMW, Chrysler, Ford, General Motors (trucks), Mercedes Benz (trucks), Volvo (2 assembly lines of trucks)	Barmes Group, Bosh, Clmex, Dana Corporation, Eaton, Federal Mogul, Firestone, FPA, Goodyear Group, Hayes Lemmerz, Henkel KGAA, Hitchiner Manufacturing, International Johnson Controls, International Hlla KG Hueck &Co Lear Corporation, Krupp, Lord Corporation, Mannesmann, Metaldyne, Michelin Corporation Magna, Parker, Perkings Industries, Sarnamotive Blue Water, Tang, TI Group Automotive Systems, Tomkins PLC, Valeo, and ZF Holding.
Puebla	Volkswagen	Benteler, Brembo Rassini, Federal Mogul, Flex N Gate, Grammer Automotive, HP Pelezer Automotive Systems, Johnson Controls, Kiekert, Kirchhoff, Kunststoff Technik, LUK, Magna International, Parke Hannifin, Siemens, SKF, Sommer Allibert, Tenneco, Textron, and TRW.
Tlaxcala	0	Arcomex, Eugen Wexler, Forjas Spicer, Haas Automotive, Johnson Control, Keiper, and Sorg Plastik.

Source: Bancomext (2004), The National Institute of Auto-parts –INA (2009), and the Automotive Cluster in Nuevo Leon – CLAUT.

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3.5.3. Agents in the National Learning System

The agents included in the research are grouped into: a) central and local government agencies, b) chambers of commerce and industry; and c) universities and research centres.

i) Central and government agencies

These agencies were chosen according to their relationship with the automobile industry. All the agencies involved in the automobile industry and those related to SMEs were included. Government agencies aimed at diffusing knowledge and development of technology were also included. Local agencies were selected according to their relationships with these central government agencies or with the automobile industry and SMEs. All were easily identified from literature and Internet searches according to their importance in the development of policies focused on this industry.

The government institutional framework is shaped by federal, state and municipal governments. The main federal offices were located in Mexico City and the identified agents in the automotive industry included:

i) The Ministry of Economy in two sub-secretariats: a) Heavy and High Technology Industries - Automotive industry unit; and b) sub-secretary of SMEs.
ii) The National Council of Science and Technology in the division of the Department of Technology and Innovation.
iii) The United States-Mexico Foundation for Science in Mexico in the automotive programme of development of networks –AERI, and the Technology Business Accelerator –TechBA. [61]

Two state government agents were identified:

i) Trade and Investment agency –PROMEXICO- located in Puebla City.
ii) The regional Ministry of Economy in the divisions of SMEs and Trade and Investment, located in Tlaxcala City (see Table 3.6).

[61] FUMEC, founded in collaboration with the United States government and Mexican governments, is aimed at promoting the development of linkages between the two countries for specific industries. These industries involve development of high-technology such as automotives, electronics and aerospace.

Table 3.6
Government agencies interviewed

Central government agencies	**Interviewee**	**Location**
i) Ministry of the Economy	i) Executive Director of the department of Automotive Industry.	Mexico City
	ii) Executive coordinator of the Department of SMEs.	Mexico City
ii) Council of Technology and Science in Mexico	iii) Executive coordinator of the Department of Technology and Innovation	Mexico City
iii) United States Mexico-Foundation for Science in Mexico	iv) Executive coordinator of the Automotive Project.	Mexico City
Local government agencies	**Interviewee**	**Location**
i) Mexican government institution to strengthen Mexican industry in international markets-PROMEXICO	i) Executive Director in Puebla	Puebla
ii) Ministry of the Economy-local agency	ii) Executive Director of the SMEs department	Tlaxcala
iii) Ministry of the Economy-local agency	iii) Executive Director of the Trade and Investment department	Tlaxcala

ii) Chambers of commerce and industry

Directors and senior officers of chambers of commerce and industry related to the automobile industry were interviewed. Note that most of these organisations were located in Mexico City. They mainly work with assembly plants and their core suppliers. They were identified according to their importance for the Mexican automobile industry. Senior officers in areas related to the aims of this research were contacted by phone and email to arrange meetings. Face-to-face interviews were done. All interviewees provided lengthy, useful responses in interviews. One Chamber of Trade and Investment official was interviewed.

The Mexican automotive industry has seven national organisations belonging to or related to the automotive industry. These are:

- Mexican Association of Automotive Suppliers (agency sales) –AMDA
- National Association of Producers of Trucks and Heavy cars - ANPACT
- Mexican Association of the Automotive Industry-AMIA
- National Chamber of the Manufacturing Industry –CANACINTRA
- National Association of Suppliers of Tires – ANDELLAC
- Confederation of Industrial Chambers of Mexico- CONCAMIN
- National Chamber of Auto-parts - INA

The interviewed organisations were: INA, AMIA and CONCAMIN. They are national organisations and are located in Mexico City. In the course of the fieldwork, another organisation was identified: The Automotive cluster in Nuevo Leon –CLAUT, which has regional scope (see Table 3.7)

Table 3.7
Chambers of commerce and industry interviewed

Chambers of commerce and industry	Interviewee	Scope	Location
i) National Institute of Auto-parts – INA	Executive in the area of economic studies	National	Mexico City
Mexican Association for the Automotive Industry – AMIA	Executive coordinator of the automotive workgroups	National	Mexico City
Confederation of Chambers of Industry - CONCAMIN	Vice president of CONCAMIN	National	Mexico City
Automotive Cluster in Nuevo Leon – CLAUT	Executive coordinator in the area of development of suppliers	Regional	Nuevo Leon

iii) Universities and research centres

The universities and research centres were selected on the basis of their involvement in the automotive industry. Core universities were identified in the focus groups. These universities work under different schemes with FUMEC and CONACYT and were identified as important agents in the system. One research centre was identified during the fieldwork based on its heavy participation in the industry. Note that some research was carried out before the development of the fieldwork in order to identify the core universities in the automotive industry in Mexico; however, the literature and data on the automotive industry were not informative about specific universities. Thus I contacted the universities identified during the fieldwork in order to reduce bias by involving universities that did not contribute to the industry. This decision stemmed from the fact that universities and research centres build linkages that are external to the SMEs involved in this industry.

The universities were contacted directly during the development of the focus groups in situ of the focus groups and were interviewed in Chihuahua. These agents are located in different regions of Mexico (see Table 3.8)

Table 3.8

Universities and research centres interviewed

Universities & Research centres	Interviewee	Location
i) Centre for Computer Research in the National Technical Institute– CIDEC-IPN	i) Researcher in the embedded systems area.	Mexico City
ii) Centre of Research Studies - CINVESTAV	ii) Director of training programmes	Jalisco
iii) Autonomous University of Queretaro - UAQ	iii) Executive coordinator of the embedded systems programme	Queretaro
iv) National Technical Institute of Tijuana -IPN	iv) Sub-director of IPN	Tijuana
v) Autonomous University of Chihuahua	v) Executive coordinator of technology parks.	Chihuahua

All the interviewed universities are funded by the public sector.

3.6.Conclusions

Chapter 3 describes the methodology applied to conduct the survey in the automobile industry in Mexico. The research design, analysis and sample were presented to explain the methodology used to answer the research questions. I set out the research questions and described the analysis and the mixed methods approach applied. The research design was discussed as the rationale for the selection of the actors and the collection of data. Section 3.5 presented the strategies developed to access the surveyed SMEs (core actors in this research) and ensure the sample's variety of the selected firms. I discussed the sample of agents in the Mexican system of innovation and provided an economic overview of the locations of the surveyed firms.

The core of this research is the study of interactions established between SMEs and large firms; this chapter described the strategies undertaken to be involved in government programmes to access auto-part SMEs in Mexico

Chapter 4 describes the empirical findings for firms. Chapter 5 describes the empirical findings for agents in the system (government, universities and chambers of industry and commerce). Chapter 6 provides the quantitative analysis and is based on use of statistical techniques to confirm the qualitative empirical findings.

CHAPTER 4:

FIRM-LEVEL SOURCES OF CAPACITY BUILDING

4.1 Introduction

This chapter and Chapter 5 present the analysis of the empirical evidence gathered in the fieldwork. This chapter provides an in-depth discussion of these interactions and SME technology upgrading resulting from such interactions. This chapter will also shed light on other relevant sources that influence SME technology upgrading, such as technological capabilities and involvement in the NLS.

The study of interactions between firms looks at the relationships established by large firms with SME suppliers and SMEs' technology upgrading as result of relationships established with large firms. This chapter offers a qualitative approach to the empirical data collected during the fieldwork. Section 4.2 presents the role of foreign and domestic large firms in the automobile industry, their type of involvement with other actors in the car industry, and large firms' interest in working with SME suppliers. This section also sheds light on the role of foreign firms in the process of technical change in developing countries.

4.2 Large firms and interactions

Data collection consisted of applying semi-structured interviews to large, first- and second-tier foreign- and Mexican-owned firms located in different parts of Mexico (see Chapter 3 Section 3.5.3). Table 4.1 presents the interviewed large firms and their characteristics:

Table 4.1
Characteristics of the interviewed large firms (foreign- and Mexican-owned firms)

Interviewee	Year of establishment in Mexico	Nationality	Product	Tier	Size (number of employees)
Shunk	1966	German	Gasoline pumps, starter systems, wash systems	1st tier	Over 500
Visteon	1986	American	Climate, interiors electronics, engine induction, lighting, and power train controls	1st tier	Over 500
Condumex	The subsidiary in Queretaro was established in 1990. The company was founded in 1954	Mexican	Cables and connectors	2nd tier	Over 500
Continental	1993	German	Body and security systems, visual display systems, control elements, radios and multimedia systems	1st tier	Over 500
Haas Automotive	1997	German	Automobile seat cover tops and hand lever covers	2nd tier	Subsidiary of 43 workers
Grammer Automotive	1998	German	Seating systems	1st tier	Over 500

The oldest firms are Shunk, set up in 1966, and Visteon, set up in 1986. The remaining four firms were set up in the early 1990s, probably as a result of the prospects for NAFTA signed in 1994; which promoted foreign investment in Mexico.

Continental (located in Jalisco) and Visteon (located in Chihuahua) mainly have relationships with customers located abroad. Customers of both firms are: Ford, Hyundai, Nissan, VMW, Honda, Renault, Tatha, and Toyota. These carmakers are mainly located in the US, with a few located in Europe. Mexico is considered a cheap labour country compared to the US, which makes establishing firms with export-oriented production more attractive. In 2007, Mexican exports of auto parts were more than $US 58 million.[62]
Grammer Automotive and Haas Automotive (both located in Tlaxcala) are mainly suppliers to Volkswagen (located in Puebla) and were set up in Mexico to supply Volkswagen. There is a strong relationship between carmakers and global mega-suppliers, which tend to follow

[62] United Nations Commodity Trade Statistics Database

their customers around the world and have closer relationships than regular first-tier suppliers.

Condumex (with a subsidiary in Queretaro) and Shunk (located in Mexico City) develop standard products. Condumex is in the telecommunications, electronics, and automotive industries. Shunk supplies Valeo (a first-tier supplier of heating and air-conditioner systems) and Mabe (electrodomestics). These firms are involved in more than one industry (see summary in Table 4.2).

Table 4.2
Category of the surveyed firms

Firms	Customers	Type of firm
Visteon	Carmakers located abroad	Export oriented firm
Continental	Carmakers located abroad	Export oriented firm
Haas Automotive	Volkswagen in Puebla	Behaviour of global mega supplier
Grammer Automotive	Volkswagen in Puebla	Behaviour of global mega supplier
Shunk	Automotive and electro in Mexico and abroad	Involved in two industries- Not specialised auto-part production
Condumex	Automotive, electronics, telecommunications in Mexico and abroad	Involved in three industries- Not specialised auto-part production

4.2.1 Large firms and interactions with SMEs

"The auto industry is often thought of as one of the most global of all industries. Its products have spread around the world, and it is dominated by a small number of companies with worldwide recognition" (Humphrey and Memedovic, 2003:2).
Globalisation in the car industry has accelerated since 1980, which is characterised by intensified global sourcing located in low-cost countries, fierce competition, and dominant worldwide companies that drive the pace of innovation and the structure of the industry (tiers). To understand the car industry and the interactions established among firms, it is important to recall the changes of the industry in terms of outsourcing. From 1980 to 1990, relationships among assemblers and suppliers changed considerably. Assemblers started

transferring in-house production (design function) levels to their leading suppliers (first tier). Leading suppliers moved toward greater customisation and production of whole modules (such as seating and air conditioning) manufactured with their own technology, rather than individual components. This high level of interaction among assemblers and leading suppliers has made leading suppliers (in other words, OEMs or first-tier suppliers) responsible for producing whole units and assuring the quality of their components. These firms are also in charge of managing second-tier suppliers. Because assemblers are more involved in the specification and quality of the production of their suppliers, they invest in long-term relationships with fewer suppliers. This pattern resulted in fewer firms with worldwide recognition involved in the car industry (Humphrey and Memedovic, 2003; see also Chapter 2). [63]

From the surveyed firms, I can infer that interactions between foreign and domestic firms and domestic SMEs in Mexico are scarce. The survey shows a few efforts devoted to establishing linkages on the part of large firms with SMEs. Those stronger relationships that large firms establish with their smallest suppliers are due to some sort of government intervention. Therefore, the large firms interacting with SMEs were identified on the basis of whether or not they had linkages with the public sector. Introducing strategies used by government to enhance the automotive industry in Mexico resulted in different programmes designed to build linkages between large firms (foreign and domestic) and SMEs (see Chapter 5 on the role of the government). Large firms interacting with SMEs participate in various government programmes. I investigated development of networks through AERI and development of a cooperative R&D programme through CONACYT. The surveyed large firms belong to the AERI programme, and the surveyed SMEs belonged either to the AERI programme or the cooperative R&D programme.

Tables 4.1 and 4.2, show that the large firms interacting with SMEs are Continental and Visteon. Interviews in those firms revealed formal linkages (formal contracts over long periods or involvement in the programme of developing suppliers) with SMEs. These firms

[63] The author of this thesis may recall the barriers to entry to the car industry (Chapter 3, section 3.2.3) to corroborate the reduced size of main players (suppliers) in the worldwide car industry.

are involved in the AERI programme, which develops inter-agent relationships with firms, universities, and government. Visteon expressed its interaction with domestic firms, emphasising that the firm "does not have to interact with that type of firm". In addition, even if Visteon would try to do so, it would be difficult due to lack of capabilities characteristic of domestic SMEs.

The nature of relationships between Continental and SMEs is rooted in the electronics cluster in Jalisco. Continental developed linkages with SMEs working on embedded systems in the region. It participated in developing some of those firms as suppliers (these firms are integrated into Continental's supply chain to learn and acquire needed methodology, tools, and technology). Half of the suppliers of Continental's embedded systems are SMEs. The firm was keen to establish linkages in the regional cluster and participates in three AERI programmes: A regional manufacturing industry programme through CANIETI (the national association of the electronic and telecommunication industry); a national AERI programme for *maquiladoras* through CANIETI; and an AERI organised by FUMEC. In the auto-parts sector, Continental worked under the AERI-FUMEC scheme for two years, focusing on developing technological research projects addressing CONACYT's search for funding. In the previous three years (to the fieldwork) Continental developed 10 SME suppliers (of embedded systems) and interacted with CINVESTAV (a well-known regional research centre in Jalisco). The firm is also affiliated with INA. Continental exemplifies strong interactions in the electronic cluster in Jalisco. [64]

Visteon is a multi-national firm involved in the AERI-FUMEC, through which it is developing one supplier (at the time of the fieldwork the SME was in the process of being developed by Visteon. See Section 4.3 case 7). Visteon's linkages are limited. It has been in Chihuahua for 24 years but only recently started developing linkages with other firms in the region. SME suppliers to Visteon represent only 5 percent of the firm's total suppliers. These small firms are design houses in embedded systems. Interactions are stronger for

[64] Continental runs seminars and workshops on different topics. These are delivered to the engineers and managers. SME suppliers learn engineering techniques to set up and run production lines and how to monitor them for product quality and cost accounting. These firms also receive training in statistical quality control, just-in-time, and industrial engineering methodologies (such as those used in the design of processes). Continental involves its own engineering staff in this training. The SMEs are trained every six to 24 months by Continental.

involvement of small suppliers in Visteon's parent company training. This training focuses on technology transfer. Visteon developed those SMEs as suppliers, including certification in quality standards. Visteon has no interactions in the industry. It interacts with INA because the firm's CEO is on the association's committee and it has been favoured in some chamber decisions. It has some knowledge linkages with regional universities (ITESM and La Salle), which have developed specific master's programmes for the firm.

The interaction between Visteon and ITESM took place over two years. The university's master's programme was adapted to the firm's needs and was compulsory for Visteon's engineers. This programme was fully adopted by the university and delivered to other large firms in the industry. La Salle contacted Visteon to update its engineering courses in quality engineering and mechanical engineering (see Table 4.3).

By comparing Continental's and Visteon's relationships with SMEs suppliers, the fact that Continental is involved in a formally structured cluster of the electronics industry in Jalisco, has made it establish stronger interactions with SMEs in the electronics and car industry. The importance of this cluster at the national level has also made possible stronger involvement of all their members in several governmental programmes. In contrast, Visteon is an export-oriented firm located in northern Mexico, with mainly operations in the US. The firm established fewer relationships with SMEs, and the type of knowledge spill-overs were those that result from developing specific teaching programmes by local universities. Continental and Visteon are in the process of developing further SMEs suppliers due to the fact that both firms are involved in the AERI of the automotive industry. In this regard, the government intervention for establishing relationships between foreign firms and Mexican-owned SMEs is important for the development of relations of foreign firms with other firms in the Mexican car industry. Table 4.3 summarises these findings, and Table 4.4 presents Continental's and Visteon's interactions with other actors in the car industry.

The importance of spill-overs for developing countries lies in FDI's contributions to increasing productivity and competitiveness of the domestic industry.[65] However, the positive externalities of spill-overs in developing countries have been questioned, in terms of this picture being more optimistic for industrialised countries where possibly stronger R&D interactions occur (see Section 1.2). Table 4.4 groups together the different interactions established at the national and industry level by the surveyed firms. Although these results may not allow us to generalise our conclusions because they refer to some specific firms, I may predict that firms such as Continental may have higher positive externalities, given their presence and interactions in the car industry.

[65] There is still no evidence of positive externalities generated by foreign firms in developing countries (Rodrik, 1999). See Chapter 1, Section 1.2.3.

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Table 4.3
Inter-firm interactions: The surveyed large firms

Firm	Type of firm	Year of establishment	Interactions in the industry	Interactions with SMEs	Development of suppliers	Interactions with the NLS
Continental (Jalisco)	1st tier – Export oriented activities	After NAFTA	Continental has strong interactions with different agents in the industry. The firm has been involved in the AERI programme for 3 continued years.	The firm showed a great interest in developing small and domestic firms as its suppliers. So far the firms' SMEs suppliers account 50% of its total suppliers.	Yes, Continental has assisted SMEs through trainings, visits, workshops and transfer of processes.	The firm is involved with regional chambers of commerce and industry such as CANIETI and CINVESTAV as well as with other regional universities.
Visteon (Chihuahua)	1st tier – Export oriented activities	Before NAFTA	The firm has been sporadically involved with local universities and it is currently participating in the AERI programme. The firm joined to this programme in 2009.	Visteon declared a poor interest from the corporative side to develop SMEs as suppliers. The firm has only 5% of SMEs suppliers belonging to the electronics industry. Currently, the firm is involved in a government programme to develop SMEs suppliers.	Visteon is currently developing one small firm to get it involved in the car industry. Both firms – Visteon and the small firm- are involved in the AERI programme.	The firm has a great interest in being considered in the development of policies of the Mexican car industry to defend its interests and get more benefited, e.g. tax benefits. To do so the firm's CEO is in the Board committee of INA. In the region, the firm showed fewer interactions with universities and the nature of these interactions are merely based on the development of specific teaching programmes for Visteon.

Table 4.4
Inter- and intra-industry relationships: Sources of knowledge

Firm	Age	Location	Regional characteristi cs	Regional industry involvement	National industry involvement	Interactions with SME	Nature of interactions with SME-	Types of interactions from these firms	Government role in connection with SMEs
Continental	17	Jalisco	Cluster of electronics industry	The firm is highly involved in the region with universities, and domestic firms	The firm is highly involved with chambers and associations of industry and commerce at national level and government institutions	The SMEs supplier counts 50% of Continental and these are design houses of embedded systems.	Rooted in the cluster of electronics in Jalisco	•Cross-border interactions: among regional and national entities (Badinger et al, 2008) •Industry interactions: inter-firm relationships - foreign and SMEs; universities relationships; and relationships with chambers. •Intra-industry interactions: electronics and auto parts.	Through the AERI-FUMEC programme.
Visteon	24	Chihuah ua	Dominated by export-oriented foreign firms	The firm has been involved with some regional universities	Visteon has few linkages with some chambers of industry and commerce and it is recently involved in government programmes	The SMEs supplier counts 5% of Visteon and these are design houses of embedded systems.		• Industry interactions: Visteon has established some interactions with private universities and it is involved in INA.	Through the AERI-FUMEC programme.

4.2.2 Large firms with scarce interactions

This thesis presents two types of large firms in the surveyed sample: Global mega-suppliers (Grammer Automotive and Haas Automotive) that only supply Volkswagen; and first- and second-tier firms that supply more than one assembler. Global mega-suppliers do not interact with other firms. These firms are located in Tlaxcala, and their suppliers are first-tier firms (large firms) located in Mexico or abroad. These firms also declared a lack of interest in interacting with other agents in the region due to the low level of these agents' resources. This included universities, industry associations, and government at both the regional and national levels.

The first-tier suppliers (Shunk and Condumex) were also not interested in interacting with domestic SMEs. Their perception was that these firms lacked the capabilities to interact directly with them. However, unlike the global mega-suppliers, these firms were more interested in interacting with government and universities. Shunk and Condumex are involved in government programmes to enhance relationships. Shunk is involved in TechBA to meet potential customers located in the US. Condumex is involved in AERI to develop linkages with other firms involved in its programmes. Condumex, like Visteon, has some links with regional universities to develop specific master's programmes. Shunk and Condumex do interact with domestic SMEs through these programmes.

The role of large firms in technology upgrading of the Mexican automobile industry is rather limited. The following section focuses on the same issues from the point of view of selected SMEs. Table 4.5 presents the most important characteristics of the surveyed large firms, as well as the type of influence in the car industry through labour mobility (personal hiring) and internships.

Table 4.5
Inter-intra industry relationships: Sources of knowledge

Firm	Age in 2010[66]	Type of firm	Location	Interactions with SMEs	Relationships in the NLS	Type of spill-overs from these firms	Involvement in government programmes
Grammer automotive	12	Global mega supplier behaviour	Tlaxcala	No	No	Labour mobility and internships	No
Haas Automotive	13		Tlaxcala	No	No	Labour mobility and internships	No
Shunk	44	1st tier	Mexico City	No	Few	Labour mobility and internships	Shunk joined to TechBA to increase its presence in the US market.
Condumex	20	2nd tier	Queretaro	No	Few	Labour mobility, internships and industry relationships through universities	Condumex joined to AERI-FUMEC to acquire funding for development of technology and develops inter-agent networks

[66] Age refers to when the firm was established.

4.3 Small- and medium-sized firms in the Mexican auto-parts industry

This section presents the surveyed SMEs in the Mexican automobile industry. It describes the technology upgrading process in terms of competencies and absorptive capacities focused on acquiring technological capabilities through learning. This section also illustrates the type of relationships that SMEs establish with foreign firms and other actors in the car industry.

The surveyed SMEs include: Mexican-owned software firms that provide customised products; Mexican-owned firms that mass-produce products following customer specifications; and foreign-owned firms that mass-produce products based on customer specifications. The third group of SMEs was included to compare the technology upgrading process between domestic and foreign small firms in Mexico. The case studies presented in this section are further analysed in the principal component analysis in Chapter 5.

1) The case of Diseña (software firm)

Diseña was founded in 1985 and produces embedded systems for automatic test equipment and lighting controls for first-tier firms in the car industry, both in Mexico and abroad. The firm has four patents and two trademarks. The firm is located in Chihuahua and has 23 employees, of which 20 are white-collar workers (engineers) and three are blue-collar workers. Diseña has five stakeholders, all of whom hold an engineering degree in electronics, industrial engineering, and programming. The founder/CEO of the firm studied industrial engineering and holds several technical degrees from the University of Texas, the University of Chihuahua, and the Technological University of Chihuahua. These technical courses are in areas such as magnetism, mathematics, and technology design. He worked for five years in the design and programming of embedded systems in American firms located in Chihuahua. The other shareholders also worked in multi-national firms in Chihuahua before establishing their firm. The knowledge acquired during these years was related to software development, mechanical design, manufacturing, computer-aided design, and materials management. The firm's shareholders are highly interested in acquiring and upgrading knowledge in the firm's field. For this reason, they hold more than one MsC

degree and several certificates of different science and technology modules from the University of Chihuahua and the Technological University of Chihuahua.
The acquisition of knowledge regarding programming and software is based on intensive research and training. The firm established strong linkages with the University of Chihuahua and the Technological University of Chihuahua for training personnel and developing research projects. This relationship has continued for seven years. The firm also invested in original software and high-tech robots. Diseña's founders regularly attend fairs and technology expositions in the United States and Shanghai to be informed about the latest trends in technology related to embedded systems.

Diseña is involved in regional efforts to develop a cluster of embedded systems in Chihuahua. This project is led by seven software firms working to upgrade skills and knowledge on software for secondary and high-school students. The firms deliver workshops and seminars on mathematics and algorithms, as well as courses on programming. The project also aims to form entrepreneurs. The founders' joint efforts come from the lack of prepared professionals in the area of embedded systems.

For the past 10 years, the firm has participated in government schemes for acquiring machinery and developing research projects. Diseña applied to programmes on science and technology sponsored by CONACYT and FONCICYT. These programmes are finance-based and enhance the establishment of linkages between firms and universities.

2) The case of Quimicos (chemical company)

Quimicos was founded in 1990 and produces chemicals and oils for first- and second-tier firms in the car industry in Mexico and abroad. The firm is located in Nuevo Leon and has 20 employees, of whom 15 are white-collar workers and five are blue-collar workers. Quimicos has only one founder, who has a degree in electronic engineering and a second degree in arts. He also has a MsC degree in management and business and worked for one year in a multi-national company of the car industry located in Mexico, where he learned about industrial norms and control systems.

The firm acquires knowledge about the firm's products through intensive investment in research. In addition, the company hires personnel with a PhD and has three laboratories. Customers are also an important source of information regarding product trends in the market and provided training for product management systems and strategies, such as just-in-time, bottleneck management and control, Kanban, and other similar methods. The firm has also visited customers' plants to learn from the sort of technology that customers use.

Quimicos is strongly involved in the automotive cluster of Nuevo Leon City. This is a government initiative to develop and strengthen relationships between local firms and multi-national companies located in Nuevo Leon City. In this cluster, multi-national companies provide training and workshops in product management systems and other methods to local firms. Through this association, Quimicos has gotten workshops.

The firm applied to several private and government financing schemes to acquire equipment and machines. The firm was mainly built through external financing and was also involved in TechBa to expand its market in the US. The firm has a trademark and several patents.

3) The case of Industrias_MC (mass-production manufacturing firm)

Industrias_MC was founded in 1964 and started producing transmission supports, radiator hoses, and rubber parts. Currently, the firm's core products are motor supports, brake diaphragms, radiator hoses, engine motor mounts, and rubber suspensions. The firm's customers are car assemblers, and first- and second-tier companies in Mexico and the US. It also supplies the spare-parts market in Mexico, the US, Venezuela, Brazil, Honduras, Guatemala, and El Salvador. Industrias_MC is located in Mexico City and has 250 employees, of which 30 are white-collar and 220 are blue-collar. It has one founder who has a secondary-school education and acquired the knowledge related to auto parts through his own auto-parts store. In 1961, the founder opened a small workshop to produce only rubber auto parts. In 1964, he opened Industrias_MC to produce other parts. The firm started exporting in 1970 to the US and opened two sister companies in the 1990s.

Industrias_MC searches for technology to acquire from American firms, international technology fairs, machinery suppliers, technology magazines, and Internet searches. Since the 1960s, the firm has evolved through different stages of technology acquisition. Early on, Industrias_MC built its own manufacturing equipment and acquired second-hand machinery that was modified and adapted to the firm's manufacturing requirements. In the second stage, machinery acquisition consisted of more sophisticated second-hand machinery from abroad to which the firm made minor improvements. The third stage was acquiring new, sophisticated machinery and equipment that the firm adapts in minor ways, and hiring external staff to deal with major technology changes. The firm also invests in R&D and has three laboratories: Rubber process development, metrology, and product testing. There is one blue-collar worker per facility.

Regarding establishing relationships with multi-national companies, the firm had different types of assistance from its customers over the years. In the 1960s, multi-national companies provided stronger assistance to Industrias_MC. Since few auto-parts firms were in Mexico, car assemblers developed their own suppliers and transferred knowledge on organisational and managerial systems such as inventory management and logistical systems. Car assemblers also provided access to several business intelligence tools such as ERP and logistics management. The information Industrias_MC received from its suppliers consisted of technology information about products, technical parameters, and technical specifications.

Industrias_MC also had access to its customer's technical intelligence, including information on their products, parameters, and specifications. Moreover, customers provided customised workshops and trainings to revise, provide guidance on accomplishing, and monitor progress on implementing actions to solve problems or gaps identified by suppliers. In the 1980s and 1990s, customers were strongly involved in training for acquiring ISO standards. These trainings included kaizen, just-in-time, kanban, and lean systems workshops, among others. These workshops aimed to improve quality and efficiency in production processes and reduce inventory costs. At this time, car assemblers and first-tier companies certified their suppliers in ISO standards and other production-improvement practices. From 2000 onwards, relationships that multi-national companies built with their suppliers were weaker. Multi-national companies participated less in developing and training suppliers. In this regard, auto-parts firms must develop their own understanding to move up the scale of knowledge regarding developing and managing production-process techniques. Moreover, external consultancy firms audit and certify the implementation of ISO standards in the auto-parts suppliers.

For Industrias_MC, the support from its customers in the first stages was relevant for its growth. Since 2000, Industrias_MC developed relationships with government institutions such as CONACYT, the Ministry of Economy, and Bancomext.[67] The firm has since applied for 11 CONACYT funding programmes and was awarded eight. These funding programmes, based on technology development, were used to develop products and technology in production assembly lines. These programmes involved cooperating and developing with university research. Funding was used to develop a research centre in Industrias_MC. This research centre is still in development and aims to group the development of research projects for Industrias_MC and its sister companies. In 2001, Industrias_MC received technical assistance through Bancomext for acquiring ISO 14000. Industrias_MC was also involved in TechBA since 2006. Through TechBA, the firm assisted in negotiations with potential US customers. The fact that TechBA is located in Detroit eased communications with existing customers in Detroit, as well as the search for new customers. Industrias_MC also received financing from TechBA to develop technology. In this regard, the firm applied this financing for testing products and developing robots and machinery for testing of new products. Industrias_MC is developing third-generation hydraulic supports (also called intelligent supports). The financing from TechBA has been important for this project. TechBA also supports the firm with financing for developing a cell production to maximise the manufacturing production.

The firm has been involved in the car industry for 50 years and experienced different types of relationships with customers and different stages of technology development.

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[67] Bancomext is a government institution that supports SMEs in trading in global markets through financing, training and technical assistance. It was created in 1937 and was replaced by PROMEXICO from 2006–2011. In 2012, Bancomext was reopened due to poor results with PROMEXICO.

4) The case of Manufactura (mass-production manufacturing firm)

Manufactura was founded in 2006 and produces stamped parts, and tube bending and forming. The firm is located in Aguascalientes and has 40 employees, of which 36 are blue-collar workers and four are white-collar workers (engineers). There are two Manufactura shareholders: The founder and the partner. The founder/CEO of the firm has an engineering degree in robotics and worked in the car industry for six years before setting up his firm. He provided services to multi-national companies as a contractor. This service consisted of selling tools and spare parts, and a few small machining projects to adapt and integrate machines in the multi-national companies' assembly lines. During this, he acquired experience related to machines, tools, and knowledge of the latest technology trends in the car industry. The founder stated that his sales skills (developed during his years as a contractor) were quite important in establishing relationships with customers for Manufactura. In fact, Manufactura's opening resulted from a project to produce samples of tools for a Nissan filial. The founder was awarded this project and asked for a bank loan to set up Manufactura and start mass production of these tools. The partner, who is the founder's brother, has an engineering degree in control and automation. His first experience working in the car industry was with establishing Manufactura. Nissan is the firm's only customer, but it is developing relationships with another car-assembly firm.

Regarding the acquisition of machinery, the firm acquires second-hand machines from American companies and new robots for testing. The purchases of this machinery are in situ, and the firm adapted several machines for its needs. In fact, some of these machines are no longer available in the market, but Manufactura still uses them because it knows how to fix and upgrade them. The firm is concerned with acquiring knowledge of the latest trends in machinery and equipment. The founders regularly attend international technology fairs. The founder has attended technology fairs in the United States since 2007. In 2009, the firm's shareholders attended a technology fair in China. The firm obtained some government funding for purchasing machinery. In 2009, the firm received funding for the technical failure resulting from the economic crisis of 2008–2009. This funding was provided by the department of the Automotive Industry of the Ministry of Economy, which provided finances to pay salaries, and reduce or avoid unemployment in the automotive industry.

Regarding establishing relationships with its customer, Manufactura was developed by Nissan as a supplier of the automotive industry. Nissan's assistance involved trainings to acquire the methodology based on the principles of Toyota Production System. This methodology consisted of providing engineering assistance, and quality and productivity techniques (such as 5s, kaisen, kaban, and just-in-time). Manufactura also received knowledge of the customer's product specifications and designs to meet Nissan's products requirements.

The firm was established through a bank loan. In this regard, the firm applied for funding from government programmes for acquiring certifications, machinery, and research. The firm was certified in ISO and TS standards by the automotive department of regional agencies of the Ministry of Economy. [68] This certification consisted of training and workshops to learn and adapt the norms of quality control. In addition, the firm received some funding for acquiring machinery. In contrast to chambers of commerce, the firm received more support from the chambers of the automotive industry in Aguascalientes. These chamber organisations develop industrial clusters in Aguascalientes and provide training focused on automotive firms' needs. Through regional government agencies, the firm attended national technology and automotive fairs. The firm is involved in TechBA (since January 2010) to export to the United States. Through TechBA, the firm attended workshops on negotiations and network development.

5) The case of Herramentales (mass-production manufacturing firm)

Herramentales was founded in 2000 and produces dimensional control devices for first-, second- and third-tier firms in the car industry. The firm is located in Puebla City and has 40 employees, of which 36 are blue-collar workers and four are white-collar workers (engineers). There are five Herramentales' shareholders. They hold engineering degrees in

[68] TS standards are applicable to any organisation involved in the automotive supply chain that manufactures, or adds value, to, parts for supplying the automotive industry.

industrial engineering, mechatronics, electronics, and similar areas. The founder/CEO of the firm studied industrial engineering and worked for four years in the car industry before establishing his firm. He worked in a German subsidiary in Mexico, and the knowledge he acquired was related to designing and manufacturing systems. He is concerned about acquiring knowledge in his field. He completed a MsC degree in manufacturing systems and management of materials in 2009 at the University of Warrick in England. The founder expressed interest in developing skills. For this reason, the four engineers are regularly trained in different areas of design and automation.

The firm's knowledge about machinery comes from its suppliers, who advise it about the latest machinery and equipment trends in the market. The firm applied for bank loans and government funds to acquire machinery and equipment. In this regard, the founder perceives there is a lack of financing by Mexican banks for enhancing the growth of technological firms. The government funds were not crucial for expanding the manufacturing capacity (such as machinery). Herramentales learned through its experience of working with assemblers in the car industry, and strong interactions with customers were important for the firm's acquisition of knowledge. Transfer of know-how was observed in the information received by assemblers regarding the product's specifications, product performance feedback, and firm audits. Developing manufacturing techniques such as 5s, lean system, and quality measures were adopted through external consultants. The firm was certified by Chrysler to be a qualified supplier in the car industry. This certification included visits from Chrysler's personnel to the firm to check for specific ISO standards, lean system, 5s, and others manufacturing techniques. Some customers also cooperated with the firm. These customers enabled Herramentales' development as a supplier in the car industry and regularly provided projects. These cooperative customers mainly provided regular feedback about the product's design. Through the experience Herramentales acquired, it learned from its customers' requirements and developed its own manufacturing processes for designing its customers' products.

The firm's main problem in acquiring machinery was lack of finances. The firm applied for government funds and received some financing for machinery that was not relevant in terms of novelty for the firm. These funds permitted it to acquire low-technology, low-cost machinery which has been useful in accelerating daily production processes. For Herramentales, suppliers that helped the firm with financing are the main source of machinery. It has been difficult for the firm to assure government funds, which are scarce. The firm developed some equipment that is in the process of being patented. Regarding government influence for the firm, Herramentales applied for TechBa and got assistance in negotiating with customers in the United States. The firm increased its presence in the US market as result of being involved in TechBA.

6) The case of Mec_automotriz (mass-production manufacturing firm)

Mec_automotriz was founded in 1993 and designs and manufactures dies for the white industry. The firm is applying for ISO standards and developing manufacturing techniques to be certified as a supplier in the car industry. Ten percent of its customers belong to the automobile industry. The firm is located in San Luis Potosi and has 240 employees, of which 20 are white-collar workers and 220 are blue-collar workers. There are two Mec_automotriz's shareholders: The founder and a partner. The founder/CEO only has secondary-school education. He worked for 17 years in a small workshop designing locks and keys and later founded a small firm to design and manufacture dies. In 1993, the founder opened Mec_automotriz. He is the main source of knowledge related to designing new processes and products. The partner joined in 2000 and collaborated with knowledge related to the automobile industry such as ISO standards and manufacturing techniques (JIT, lean system, and 5s), work cells, and human resources. The partner worked for 15 years in two car assemblers.

Regarding acquiring machinery, the firm acquires second-hand machines and equipment that are adapted to its needs. These machines, developed in Germany and Japan, belong to firms located in the US in the electronics, automobile, and aerospace industries. The firm also purchases new, low-cost machinery from Taiwan. In 2006, it received a government fund for purchasing a low-tech machine. The firm's main problem is the lack of finances, which is the main reason it is forced to adapt and manipulate its machinery.

Mec_automotriz accumulated vast knowledge related to die design and manufacturing. The firm has 17 years in the white industry, and the founder acquired more than 20 years of experience before establishing his firm. The experience acquired was related to die design and production. To work in the automobile industry, the firm is being developed as supplier by KYB, a Japanese firm located in Spain. This relationship was developed through the Ministry of Economy in San Luis Potosi. KYB cooperated with Mec_automotriz in terms of transferring know-how and know-why to replicate and master a specific production process. Mec_automotriz was concerned with acquiring government support and approached the Ministry of Economy in 2005 to receive training on mastering Japanese technology and lean manufacturing. It also received advice on finances. This training and advice were delivered by consulting firms in Mexico. The firm is applying for CONACYT schemes to develop technology. The firm is involved in TechBA to promote and acquire customers in the US. TechBA helped it negotiate with American firms.

7) The case of Sistemas_emb (software firm)

Sistemas_emb was founded in 1995, and designs and produces embedded systems, software circuits, and circuit boards. The firm is located in Mexico City and is being developed by Visteon as a supplier in the automobile industry. The firm has 28 employees, of which 13 are white-collar workers and 15 blue-collar workers. The firm's founder has a degree in electronic engineering and communications, and a MsC and a PhD in electrical engineering from the CIDE (Coorporacion Internacional para el Desarrollo Educativo). He was awarded a scholarship to study MsC in France in 1975. In 1976, he set up a firm to design and produce embedded systems. This firm went bankrupt in 1994, and he set up Sistemas_emb in 1995. The experience acquired in these 30 years contributed to his mastering software design and programming.

Acquiring knowledge related to programming and software was mainly based on research, as the firm spent several hours to master programmes. In this regard, customers did not significantly influence the firm's acquisition of knowledge. Sistemas_emb is an authorised supplier of Freescale and Texas Instruments (both are American semiconductor manufacturers), and received training, hardware tools, software tools, and samples from

Freescale. Access to software licences through Freescale was very important for Sistemas_emb's learning, as it lacks finances to buy the software. Sistemas_emb attended conferences organised by Freescale in the United States and are currently involved in the AERI to be developed by Visteon as a supplier of embedded systems in the automobile industry. This includes upgrading ISO standards. The firm is acquiring SPICE and CMMI (software quality standards for semiconductors), and Visteon is providing it the norms to develop software. These norms are involved with developing new processes, and the firm is learning to programme according to them. It also forced the firm to increase its design team from six to nine engineers. The firm also hired external consultants to manage the software.

Sistemas_emb applied for CONACYT funds to acquire technology (robots), but has not obtained any funding. The firm has basic technology in terms of hardware and advanced technology in terms of software.

8) The case of Soluciones_di (software firm)

Soluciones_di was founded in 2006, and designs and produces/programs electronic circuit stimulators, printed circuit boards (PCBs), programmable logic controllers (PLCs), and embedded systems. The firm is located in Chihuahua, and its customers are *maquiladoras* and first-tier companies of the car industry. The firm has 20 workers, all of whom are blue-collar. There are four founders of the firm, and they hold engineering degrees in electronics (two founders), mechatronics, and industrial engineering. One of the founders completed a MsC in electronics. Another founder is completing a PhD in programming and design in the UK. The firm acquired knowledge related to its products was acquired through the founders' experience working in *maquiladoras* and mostly in American car firms in Chihuahua. The founders spent more than 15 years working in those firms, where they acquired knowledge on software development, and mechanical and electronic design. The founders also acquired knowledge related to implementing ISO and software standards, as well as six sigma and other processes and production techniques.

Regarding acquiring new knowledge, the founders are the only engineers in the firm and lead product design and development. They spend several hours reading and mastering new programming codes. New software development is based on extensive research and self-learning from books, Internet, catalogues, and programmes. The firm's main barrier to growth is the lack of finance to acquire licensing software. Soluciones_di accesses these software programmes through pirated copies. The firm acquired new projects thanks to its high-quality products. However, the firm lack of any quality standards and certifications.

The firm received know-how transfer in the form of product design specifications, product samples, and operations specifications from its customers. Because the firm's founders are still working in multi-national companies, they use the laboratories of these firms to test their product prototypes. Soluciones_di has very limited machinery. The founders purchased the minimum equipment and machines necessary for production. In contrast to other firms in the region (Chihuahua), the firm is behind in its technology levels. Acquiring new contracts and customers is based on its high six-sigma score achieved in product prototypes.[69] A product with a high six-sigma score indicates a good use of engineering practices and methods throughout all manufacturing processes. Despite this, the firm has not formally implemented any production practice (such as 5s or lean system) and also lacks certifications of quality standards.

Soluciones_di has not established linkages with universities, chambers of commerce, or government agencies.

The cases of 9) Flextech and 10) Interiores (foreign SME mass-production firms)

Flextech and Interiores are German-owned small firms located in Mexico. These firms were considered to illustrate the case of not only Mexican-owned firms, but also the differences or similarities with foreign auto-parts suppliers.

Flextech is a German subsidiary firm located in Mexico City that designs and manufactures flexible air ducts, polyurethane hoses, high-temperature hoses, and insulation hoses. The firm's customers are first-tier companies. The firm was founded in 1999 and receives all technology from its parent company in Germany. The firm set-up, and machinery and

[69] A six-sigma score of 99.99966% indicates that the product is statistically free of defects.

equipment installation was carried out by German engineers and the firm's managers are German. The company was located in Mexico to supply a specific customer that the parent company was supplying in Germany. Because it is a German subsidiary, establishing relationships with global assemblers in Mexico was easy. Similar to other auto-parts suppliers, the firm implemented ISO standards and other manufacturing practices.

Regarding acquiring knowledge, the firm received all its know-how from its parent company, which updates the firm in terms of technology. Flextech has been involved with TechBA to acquire customers in the United States and obtain training on sales, decision-making, and management. Flextech is also establishing linkages with CONACYT to acquire funding for research. The firm established linkages with INA and CANACINTRA, and strong linkages with CAMEXA due to this. CAMEXA is a German chamber of commerce located in Mexico and eases Flextech's communications with its parent company. Flextech also established linkages with German universities to develop research. As a small company, Flextech expressed that there are many barriers in Mexico to the growth of firms. Access to financing is difficult and expensive, and there is a lack of prepared human capital. Blue-collar workers lack the skills to understand technology, and it is expensive for Flextech to train them.

Interiores was the second German company I interviewed. The firm is located in Tlaxcala City and was set up to supply Volkswagen. Currently, the firm supplies Volkswagen, General Motors, Seat, Johnson Controls, and Lear. The firm received all the technology content from its parent company and, similar to Flextech, German engineers established the firm in Mexico. The firm was founded in 1992 and produces plastic pieces for automotive interiors. The firm was sold to American investors in 2004. Since then, the firm has established linkages with government agencies to apply and obtain funding for acquiring new machines and equipment. Similarly, the firm applied for research funding and is currently developing a robot with a local university.

For acquiring new technology, the firm attended technology fairs. Its suppliers were an important source of knowledge regarding machinery and equipment technology trends in the car industry. In this regard, suppliers trained the firm to ease the implementation of new technology.

The firm received know-how from its customers in terms of product specifications and design. General Motors provided access to an extensive database of different product specifications, norms, and regulations.

4.4 Absorptive capacity, technological capabilities, and technology upgrading in SMEs

The technology upgrading for SMEs occurred in different stages and varied from the type of firm (mass-production manufacturing or software). At the initial stage, nine of 10 firm founders acquired skills and knowledge related to their firms and products by previously working in the automobile industry. The skills and knowledge acquired before establishing the firm was crucial for the development of products and growth of the firm. The founders' competences played an important role for the future learning. At the growth stage, the type of learning differed between software and mass-production firms. For software firms, acquiring competences was crucial for enhancing the firms' absorptive capacity. The dominant type of learning was through research and advances in science and technology. For mass-production firms, the dominant type of learning fell into the categories of learning by interacting. These firms are more dependent on their customers (foreign firms).

Government programmes and public funding were also important for the technology upgrading process in the surveyed firms. The technology upgrading differed between foreign-owned firms and Mexican-owned firms. The former firms received technology content from their parent companies and had access to the latest technology trends through their parent companies. These firms established fewer linkages than domestic firms with universities and other actors in the industry. Despite their size, these firms showed a pattern of global mega-suppliers. They were established in Mexico to supply specific firms.

Similarly, there were differences in the influence of large firms on SMEs. For mass-production firms, the interactions with large firms were important for their development as suppliers in the car industry. Large firms trained and certified SMEs and provided assistance in engineering and acquiring production techniques. In addition, the mass-production firms learned from the different projects they developed for their large-firm customers. In this regard, the SMEs receive product technical information, design, and samples. In addition, the mass-production firms received advice on product design. One firm was taught a specific manufacturing process to acquire and master it.

In contrast, software firms were less influenced by large firms. They were not certified to be suppliers in the car industry. However, they received information on product design, technical specifications, and samples from large firms. The most important influence for software firms came from universities and research centres. The founders of software firms expressed: "Large firms do not provide anything to us. Everything I know is because I have learnt through our experience and our hard work". For software firms, acquiring competences were crucial for their growth. Their founders studied several technical courses and MsCs. In this regard, these firms had more than 50 percent white-collar workers.

Table 4.6 summarises the type of interactions existing between large firms and SMEs, as well as the sources of knowledge for these firms. Table 4.7 summarises the different types of learning in SMEs.

Table 4.6
Technology upgrading at firm level through interactions in the NLS

Firm	Type	Age	Number of employees	Industries involved	Founder's education	Certified as supplier by large firms	Supply chain relations with large firms	Type of knowledge received from customers	External sources of technology (knowledge)	Internal sources of technology (knowledge)	Interactions in the NLS
Soluciones_di	Software firm	3	20	Automotive	PhD on Software design (1 founder) and MsC on software design (1 founder)	No	Technical	Product design and product specifications	The founders' employers (large firms in the car industry)	Intensive study of software codes	No
Manufactura	Mass-production	4	40	Automotive	Robotics engineering	Yes (Nissan)	Technical and managerial	Engineering assistance and techniques on quality and productivity. Product design and product specifications	Customers	Own training, knowledge accumulated through customers' projects and R&D project with university	Yes
Herramentales	Mass-production	9	40	Automotive	Mechanical engineering	Yes (Chrysler)	Technical, managerial	Regularly feedback about the product's design. Engineering assistance and techniques on quality and certifications. Product design and product specifications.	Customers	Own training and knowledge accumulated through customers' projects	Yes
Flextech	Mass-production	10	120	Automotive	Industrial engineering	Yes (parent company in Germany)	Establishment, locational, informational, financial, raw material, and managerial,	Rich know-how and know-why content from its parent company	Parent company	Own training and knowledge accumulated through customers' projects	Yes
Interiores	Mass-production	14	146	Automotive	Finance and Business	Yes (parent company in Germany)	Establishment, locational, informational, financial, raw material, and managerial,	Rich know-how and know-why content from its parent company	Parent company	Own training and knowledge accumulated through customers' projects	Yes

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Firm	Type	Age	Number of employees	Industries involved	Founder's education	Certified as supplier by large firms	Supply chain relations with large firms	Type of knowledge received from customers	External sources of technology (knowledge)	Internal sources of technology (knowledge)	Interactions in the NLS
Sistemas_embebidos	Software firm	15	28	Electronics	Electronic engineering	Yes (Visteon)	Managerial	Engineering assistance and techniques on quality and certifications	Texas instruments and Freescale	Own training, knowledge accumulated through customers' projects and R&D project with university	Yes
Mec_Automotriz	Mass-production	17	240	White appliances and automotive	-	Yes (Kayaba)	Technical and managerial	Engineering assistance and techniques on quality and productivity. Product design and product specifications	Customers	Own training and knowledge accumulated through customers' projects	Yes
Quimicos	Software firm	20	20	Chemical and automotive	Electronic engineering	No	Technical	Feedback about the product's performance	Universities	Intensive R&D projects, universities, own training and experience accumulated through customers' projects	Yes
Diseña	Software firm	25	23	Electronics and automotive	Industrial engineering and two MsC on software design	No	Technical	Product design and product specifications	Universities	Intensive R&D projects, universities, own training and experience accumulated through customers' projects	Yes
Industrias_MC	Mass-production	50	250	Automotive	-	Yes (first customer)	Technical and managerial	Product design and product specifications	Customers	Own training and experience accumulated through customers' projects	Yes

Table 4.7
Types of learning in the surveyed firms

Software firms					
Firm	**Types of learning observed**				
Diseña	Learning by spill-overs: The founders worked in the car industry before setting up their firm. The knowledge acquired was on development of software, mechanical design, manufacturing, computer aided design and management of materials	Learning by using & doing through repetitive experiences: the founders stressed that the knowledge acquired through the customers' project during these years have helped them to be competitive in the industry.	Learning from advances in science and technology and learning by searching through strong interactions with research centres. Diseña has established continued relations with the University of Chihuahua for the development of research projects. The firm and the university awarded a prize in 2010 for their collaborative work and achievements. In addition the firm awarded a prize from the National Council of Science and Technology for its development of technology in the industry.	Learning by interacting in market trends through interaction with customers. The firm receives know-how related to the product's specifications and product's technical information from its customers. Diseña stressed that this knowledge has not been significant for the growth of the firm.	Learning by searching through continual R&D efforts and exhaustive training. The firm has exerted intensive efforts focused on research and the founders have been intensively trained in different technical fields. Similarly, the firm has 87% of white collar workers.
Quimicos	Learning by using and doing through repetitive experiences. Quimicos has acquired experience through the years working in the car industry and the use	Learning from advances in science and technology and learning by searching. Quimicos hires PhD staff and specialised staff for the development of internal research projects. The firm also has established linkages with research centres for the development of research projects.			

Types of learning in the surveyed firms (cont.)

Software firms				
Firm	**Types of learning observed**			
Sistemas_emb	Learning by using & doing through repetitive experiences in the previous founder's firm. The founder had a firm of embedded systems for 19 years before the establishment of Sistemas_emb.	Learning by interacting. Freescale has provided intensive support to Sistemas_emb which has helped it to acquire software and knowledge related to software design.		
Soluciones_di	Learning from spill-overs (acquisition of industry gained through previous experience). The founders of the firm are still working in multinational companies of the car industry. Through these employers they have knowledge of the last trends of software design and they also have access to some software.	Learning by using and doing through accumulation of experiences. The knowledge acquired through the few customers has helped to Soluciones_di to increase its knowledge related to embedded systems.	Learning by searching through many hours of literature research by the founders of the firm. Because the firm lack of finance to acquire software, they learn from pirated software and spend several hours in understanding and learning new programming codes.	Learning by interacting. Soluciones_di has also learnt from the customers' projects requirements. The firm receives samples and products' specification as well as technical information.

Types of learning in the surveyed firms (cont.)

Mass-production firms					
Firm	**Types of learning observed**				
Industrias_MC	Learning by doing through tacit knowledge acquired from previous work experience and technological activities. The founder acquired knowledge of the industry through the establishment of a previous workshop to produce only rubber auto-parts.	Learning by using through construction and acquisition of second-hand machinery. In the early years of establishment of the firm, Industrias_MC built its own manufacturing equipment and acquired second-hand machinery which was modified and adjusted to the firm's needs.	Learning from inter-industry spill-overs through market trends in the industry. For the founder, the market trends are important to address the growth of the firm in terms of development of products and export.	Learning by interacting through different level of interactions with foreign firms from rich engineering content to poor engineering content	Learning by searching through continual R&D efforts on diversification of products. So far the firm has awarded 8 funding with CONACYT either for the acquisition of machinery or development of R&D collaborative projects.
Manufactura	Learning by doing through tacit knowledge acquired from previous work experience and technological activities. The founder worked as freelancer in the car industry and during these years he acquired experience of the trends of technology in the industry. This knowledge is important for the acquisition of machinery for the firm.	Learning by using through construction and acquisition of imported technology. The firm lacks of finance to purchase up-to-date machinery and it acquires second-hand machines and old version robots which are adapted and adjusted to the firm's needs.	Learning by interacting, the firm was developed as supplier by Nissan subsidiary. The training received from Nissan consisted in the acquisition of the Toyota Production system and techniques on quality and productivity.	Learning by searching through strong efforts in acquisition of foreign high-tech equipment and machineries and high investment for R&D activities (innovation). The firm's founder has attended to technology exhibitions in Unites States and Mexico. For 2010, he attended to technology fair in China.	

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Types of learning in the surveyed firms (cont.)

Mass-production manufacturing firms					
Firm	**Types of learning observed**				
Herramentales	Learning by spill-overs through the founder's acquisition of knowledge previous work experience. Before the establishment of Herramentales, the founder worked in the car industry where he learnt about design and manufacturing of systems.	Learning by doing and using through repeated experience. The founder expressed that the customers' projects are important for the learning of the firm in which the firm master and applied its knowledge or acquire new knowledge.	Learning from inter-spill-overs through visits to customers' plants (acquisition of knowledge on the latest trends of technology). In this regard, observation of the customers' machines	Learning by interacting, the firm was developed as supplier by Chrysler subsidiary and the firm has been assisted in design by its customers. Similarly, customers have procured the development of Herramentales through providing it projects regularly.	Learning by searching through continual R&D activities. Herramentales has applied to some R&D projects through CONACYT. In addition the firm has developed some patents,
Mec_automotriz	Learning by doing through tacit knowledge acquired by the previous founder's firm and technological activities. The founder acquired knowledge related to the product design during the establishment of a previous small workshop	Learning by using through acquisition of second-hand machinery from American firms. Because of lack of finance, the firm has acquired second-hand machinery from abroad and adapt it and adjust it to the firm's needs.	Learning from inter-spill-overs through visits to customers' plants (acquisition of knowledge on the latest trends in technology).For the shareholders of the firm, the visits to the customers' plants are very important to be informed of the use and the latest trends of technology in the industry.	Learning by interacting, the firm has been supported by foreign firms through assistance in detailed engineering product content and fewer requirements for becoming a supplier. The firm was developed as supplier by KYB. The assistance from KYB consisted on the learning of production processes to replicate them and master them.	

Table 4.7 shows that learning from spill-overs from large firms played an important role for the surveyed firms. The establishment of the SMEs originated from spill-over (labour mobility) of the foreign firms in the Mexican car industry. In addition, learning by interacting between firms was enriched by using and doing in the SMEs. Similarly, learning by searching may unveil the intensity of efforts SMEs use for acquiring new knowledge (this is further discussed in Chapter 6). In this regard, Table 4.6 suggests that firms with linkages in the NLS are more exposed to a higher number of sources for acquiring machinery. Factors such as age and intensity of efforts influenced a greater number of linkages established in the industry. For instance, Soluciones_di has been in the industry for three years and acquired machinery by self-funding from the firm's founders. It has not applied for any government funding or collaborative project. All of this firm's efforts are addressed to learning and mastering new programming codes. In contrast, Manufactura has been in the industry for four years. It applied to one programme of funding, one programme of collaborative R&D projects, and one programme to expand its market. By 2010, Manufactura was developing a patent. Its efforts were addressed to developing technological capabilities through learning from advanced technology (old versions of robots) and adapting it to the firm's needs. By comparing these two firms, I may also hypothesise that competences are not as significant as the intensity of efforts because Soluciones_di's founders worked in the car industry for at least 10 years and one founder holds a PhD and another holds MsC studies on software design. However, the lack of efforts in establishing linkages in the industry may explain why this firm is behind in the regional level of technology. Soluciones_di relies on few customers, and some are also its employers. On the other hand, development of technological capabilities and technology upgrading are based on multiple factors. The fact that Soluciones_di is a software firm may influence its technology growth. To confirm or reject the previous hypotheses, Chapter 6 provides a quantitative analysis, and the following section introduces the main characteristics of the surveyed firms in more detail.

4.5 The surveyed SMEs: Important characteristics

This section presents the important features of the surveyed SMEs in terms of competences, product type, and number and type of linkages established in the automobile industry. This information is further analysed through principal component analysis in Chapter 7. The firm characteristics can be grouped into:

- Location
- Age and type of products
- Type of linkages established in the NLS
- Founders' competences
- Labour skills
- Technology level

4.5.1 Location of the surveyed SMEs

Chapter 3 discussed the sample of firms located in seven different cities: Chihuahua, Nuevo Leon, San Luis Potosi, Aguascalientes, Mexico City, and Puebla (see Graph 3.6 in Chapter 3). These cities are in the northern, central, and north-west regions. The northern region (along the US border) generally has a high level of *maquiladoras* and an export-oriented economy (Chihuahua). The central region has a high level of industrialisation (Mexico City) and important institutions in Mexico City. Aguascalientes and San Luis Potosi are in the north-west region, which is notable for the high number of clusters in Jalisco related to different industries (such as electronics and beverages). The characteristics of the northern and central regions may explain the existence of domestic auto-part SMEs. In 2004, Chihuahua and Nuevo Leon had 91 first-tier suppliers, and two truck assemblers. Mexico City and Puebla had 49 first-tier suppliers, three car assemblers, and four truck assemblers (Bancomext, 2004; INA, 2009). Aguascalientes and San Luis Potosi, in the north-west region, had three truck assemblers and 29 first-tier suppliers. The interviewed firms are located in the regional capitals, which are the most urbanised areas (see Table 4.8).

Table 4.8
Location of interviewed firms

Firm	Region	Location
Diseña	North region with 2 truck assemblers and 91 first tier firms	Chihuahua
Soluciones_di		Chihuahua
Quimicos		Nuevo Leon
Mec_automotriz	North-west region with 3 truck assemblers and 29 first tier suppliers	San Luis Potosi
Manufactura		Aguascalientes
Flextech	Centre region with 3 car assembler, 4 truck assemblers and 49 first tier firms	Mexico City
Industrias_MC		Mexico City
Sistemas_emb		Mexico City
Herramentales		Puebla
Interauto		Tlaxcala

4.5.2 Age of the firm and type of product

As mentioned in Chapter 1, some of the factors that influence the development of technological capabilities in SMEs in developing countries are: firm age (experience), workers' technical education, channels for searching for information, and training. I first consider the firm's structural characteristics (age, industry, and type of product[s]). I focus on factors related to enhancing absorptive capacity and competences, such as technical education, training, and number of information channels.

The surveyed firms fall into three main age groups. Group 1 includes firms established for less than 10 years. Group 2 includes firms between 10 and 20 years of age. Group 3 includes firms established for 20 years or longer (Table 4.9).

Table 4.9
Age of surveyed firms

0-5	6-10	11-15	16-20	21-25	26-49	50
•Soluciones_di (3) •Manufactura (4)	•Herramentales (9) •Flextech (10)	•Interiores (14) •Sistemas_emb (15)	•Mec_automotriz (17) •Quimicos (20)	•Diseña (25)		•Industrias_MC (50)
Group 1		Group 2		Group 3		

Older firms (more than 15 years old) are commonly involved in two industries. Three of the four firms producing software and hardware are involved in two industries (automobile and electronics), and one of six firms (just jess than 15 years old) producing processes and tools is also involved in two industries (white goods and automobiles) (see Table 4.10).

Table 4.10
Surveyed firms: Type of industries

Firm	Age	Industries	Product
Diseña	25	Electronics (50%) and automotive (50%)	•Automatic test equipment •Automatic lighting control system •Building automation
Soluciones_di	3	Automotive	•Panels: PLC[70] •Mechanical parts •Electronic design
Quimicos	20	Chemical (20%) and automotive (80%)	•Car oils
Mec_automotriz	17	White appliances (90%) and automotive (10%)	• Dies
Manufactura	4	Automotive	•Stamped parts (interiors) •Tube bending and forming
Flextech	10	Automotive	•Duplex coatings •Hexavalent chromium-free galvanic finishings •Organic coatings •MKS-coatings of rack parts
Industrias MC	50	Automotive	•Motor support •Brake diaphragm •Radiator hose •Engine motor mounts •Rubber suspension
Sistemas_emb	15	Electronic (100%) and automotive (in the process)	•Embedded systems •Software circuits •Circuit boards
Herramentales	9	Automotive	•Dimensional control devices
Interiores	14	Automotive	•Automotive panels •Purr foam (seats) •Gear shift covers •Plastic parts: plastic retainers and others

4.5.3 Establishment of linkages in the NLS

I examined establishment of interactions with the NLS in relation to: Searching for technological information (industry and commercial associations); developing R&D projects (universities); and building technical capacity (based on government financing to acquire machinery and technology).

[70] A programmable logic controller (PLC) is a digital device used for machinery automation and electromechanical processes in assembly lines or fixtures.

The firms established formal relationships with industry associations and chambers of commerce for legal advice on finance and production-practices training, such as lean manufacturing, machine-safety management, and quality-certification processes. Table 4.11 shows that nine of the 10 firms surveyed were affiliated to chambers of commerce and industry associations for approximately 3 years. *Industrias_MC*, which was established for more than 50 years in the industry, was affiliated with CANACINTRA for 40 years. The surveyed firms felt these interactions were not significant for their process of technology upgrading. The interactions were seen as more useful for providing information on the industry. Quimicos was the only firm that evaluated interactions with chambers of commerce and industry organisations as significant for increasing its technology upgrading. Quimicos is involved with a regional organisation in Nuevo Leon (CLAUT), which focuses on developing regional clusters for the auto-parts region in Nuevo Leon. Through CLAUT, Quimicos received training in production practices (5s, just in time) and is involved in networking programmes (with other first-tier suppliers) to exchange information on production practices. The firm has improved its basic routines through involvement in CLAUT programmes.

The firms have formal relationships with local universities under government cooperative R&D schemes. These programmes are aimed at obtaining funding for developing new products based on intensive research. They include AERI and CONACYT programmes. Firms conducting intensive in-house research (Diseña and Quimicos) established further formal linkages with universities. Diseña collaborated with universities to give advice on engineering department curricula and develop workshops and seminars for engineering students. The firm is involved in efforts by regional institutions to develop a cluster for embedded systems. It contributes to the final year of students' high-school education by helping to update the curricula for mathematics and computer programming courses. It is involved also in enhancing students' entrepreneurial skills. Quimicos interacts on an ongoing basis with local universities and research centres by developing intensive research involving PhD students and laboratory facilities.

The surveyed firms developed formal relationships with government agencies to: Build technology capacity through funding (CONACYT programmes and the Ministry of Economy); develop R&D cooperative projects (CONACYT and AERI programmes); and expand the firm's market by acquiring new customers (TechBA)

Table 4.11
Interactions in the NLS: SMEs

Linkages established	Surveyed Firms									
	Herramentales	**Manufactura**	**Mec_automotriz**	**Industrias MC**	**Quimicos**	**Interiores**	**Flextech**	**Diseña**	**Sistemas_emb**	**Soluciones_di**
Associations	CANACINTRA	The firm was affiliated to CANACINTRA for three years.	CANACINTRA	The firm was affiliated to CANACINTRA for 40 years.	•CANACINTRA •CLAUT •COPARMEX • CANACO	None	•INA, •CANACINTRA• CAMEZA •FEMIA	None	CANACINTRA	None
Universities	Internships	Cooperative R&D	Internships	Cooperative R&D	Cooperative R&D and Hired of staff and university's facilities	Cooperative R&D	None	Cooperative R&D and Enhancement of human capital competencies	None	None
Government agencies	•TechBA (1 year), •CONACYT (1 programme of acquisition of machinery)	•TechBA (2 years), •CONACYT (1 cooperative R&D programme), •Regional Ministry of Economy (acquisition of machinery)	•TechBA (4 years), •CONACYT (1 programme of acquisition of machinery)	•TechBA (3 years), •CONACYT (1 cooperative R&D programme) • CONACYT (acquisition of machinery)	•TechBA (2 years), •CONACYT (1 programme of R&D investment) •Several government funding schemes.	None	•TechBA (2 years)	•CONACYT (1 cooperative R&D programme) • AERI (development of networks based on R&D projects) • Regional institutions of clusters (7 years) •CONACYT (acquisition of machinery)	•AERI (development of networks based on R&D projects)	None

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To understand more in detail the surveyed firms' interest in exerting efforts to establish linkages in the industry, Table 4.12 presents the number of linkages the firms established and the category to which these linkages belong. In this regard, older firms have a greater number of linkages. This also helps us understand that government funding programmes helped the firms grow. By contrast, firms that were originally founded by foreign investors were only recently establishing industry linkages that focus on R&D collaborative projects. Soluciones_di is the only firm that lacks linkages in the industry. Perhaps the firm's age would help us understand this, given that the firm has only been established for three years.

Table 4.12
Firms' interests in building linkages in the NLS

Firm	Age	Expanding market	Investment in R&D through interactions in the NLS	Build technical capacity
Soluciones_di	3	No	No	No
Manufactura	4	Yes (2 years)	Yes (1 programme)	Yes (1 funding)
Herramentales	9	Yes (1 year)	No	Yes (1 funding)
Flextech	10	Yes (2 years)	No	No
Interiores	14	No	Yes	No
Sistemas_emb	15	No	Yes	Yes (1 funding)
Mec_automotriz	17	Yes (4 years)	No	Yes (1 funding)
Quimicos	20	Yes (2 years)	Yes (1 programme)	Yes (several)
Diseña	25	Yes (7 years)	Yes (1 programme)	Yes (many)
Industrias_MC	50	Yes (3 years)	Yes	Yes

4.5.4 Competencies

The process of technology upgrading requires technological capabilities. Forming technological capabilities requires competencies (see Chapter 2 for a review). This section presents the surveyed firms' competencies.

i) Founders' education

The surveyed managers had engineering training or no engineering training, or very basic education. Trained engineers worked at seven firms: Diseña, Flextech, Herramentales, Manufactura, Qumicos, Sistemas_emb, and Soluciones_di. The manager of Interiores had no engineering training, and the managers of Mec_automotriz and Industrias_MC had only basic education. The firms managed by individuals with further education in engineering are: Herramentales, Sistemas_emb and Soluciones_di. The managers of Quimicos and Interiores had master's degrees in non-engineering fields (Table 4.13).

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Table 4.13
Education of the surveyed firms' founders

Group	Manager's firm	Type of studies	Further studies
Engineering education	Diseña	Industrial Engineering	-
	Flextech	Industrial Engineering	-
	Herrramentales	Mechanical engineering	•Master's degree in manufacturing systems (University of Warwick)
	Manufactura	Robotics engineering	
	Qumicos	Electronic engineering	•Master's degree in business and finance
	Sistemas_emb	Electronic engineering	•Master's degree in electronic engineering (IPN-Mexico) •PhD degree in electronic engineering (IPN-Mexico and France)
	Soluciones_di	Electronic engineering	•PhD degree in electronic engineering (University of Sussex)
Non-engineering education	Interiores	Finance and Business	•Master's degree in finance
Lack of education	Mec_automotriz	-	-
	Industrias_MC	-	-

ii) Firms' labour skills

Firms are grouped into two categories in relation to competencies of the firm's workers. They are either mass-production manufacturing or software firms. The mass-production manufacturing firms are: Herramentales, Manufactura, Industrias_MC, Mec_automotriz, Interiores, Flextech, and Soluciones_di. They all have a higher percentage of blue-collar workers (Table 4.14). In contrast, some software firms are ahead in terms of the technology level (machinery and equipment) compared to other domestic firms in the same region (Table 4.15).

Table 4.14
Firms' labour skills

Type of firm	Firm	Total	Type of labour skills			
			White collar		Blue collar	
				%		%
Mass-production manufacturing	Herramentales	40	4	10	36	90
	Manufactura	40	4	**10**	36	90
	Industrias_MC	250	30	**12**	220	88
	Mec_automotriz	240	20	8.3	220	91.7
	Interiores	146	6	4.2	140	95.8
	Flextech	120	4	3.3	116	96.7
	Soluciones_di	20	0	0	20	100
Software house	Diseña	23	20	**87**	3	13
	Quimicos	20	15	**75**	5	25
	Sistemas_emb	28	13	46.4	15	53.6

iii) Firms' level of technology

Firms were asked about their type of technology (machinery and equipment). Firms that import technology were leaders with respect to similar firms in the region. Firms without up-to-date machinery and equipment were at an average level of technology compared to similar firms in the region. Firms with little machinery or equipment were behind other similar firms in the industry (Table 4.15).

Table 4.15
Surveyed firms' level of technology

Level of technology	Firm
Ahead	Diseña
	Quimicos
	Herramentales
	Manufactura
	Industrias_MC
	Flextech
Average	Mec_automotriz
	Interiores
	Sistemas_emb
Behind	Soluciones_di

This section differentiated between: Founders' education; workers' education; and technology level. The findings may reveal differences in forming capabilities. Von Tunzelmann (2009) stresses that competences and capabilities are distinctive elements. Competences assist in the process of production or transformation. The surveyed firms' competences might indicate differences in existing advantages (better-educated labour) or disadvantages (basic equipment and machinery) in the development of technological capabilities. Chapter 6 further analyses the firms' competences.

4.6 Conclusions

This chapter introduced the characteristics of the surveyed large firms and SMEs. In addition, this chapter provided some insights to the interactions between large firms and Mexican-owned SMEs in the car industry. To do so, the chapter introduced case studies for each of the surveyed SMEs and presented some hypotheses and other arguments that Chapter 6 analyses further analysed.

Chapter 4 examines why the large firms established stronger interactions in the automotive industry and why SMEs established different levels of interactions in the industry. Large firms fall into groups that either interact in the industry or don't interact very much or at all. SMEs are grouped into either mass-production manufacturing or software firms. This chapter provided insights into different types of firm learning in relation to level of competences, established linkages in the NLS, and development of technological capabilities.

This chapter draws some conclusions about the role of large firms in the Mexican car industry and that the large firms' labour spill-overs have been significant for acquiring knowledge that leads to establishment of Mexican-owned SMEs. Similarly, large firms were important in training SMEs and involving them as certified suppliers in the car industry. However, large firms did not play the same role for software firms, which exerted higher efforts in acquiring knowledge from scientific and technological advances. For these firms, the most influential sources of knowledge are universities and research centres. Diseña expressed its concern about the lack of knowledge based on technology in Mexico. Diseña and other regional firms are working with universities to improve and update teaching curricula in mathematics and software programming for secondary and tertiary education. However, large firms were also an important source through labour spill-overs for the founders of the software firms.

The findings in this chapter also note that intensity of efforts and competencies were not important factors for all the surveyed firms. However, intensity of efforts was more influential than the founders' competencies for acquiring knowledge related to the firms' products. The intensity of efforts was measured through the nature of linkages the surveyed firms established in the NLS.

Chapter 6 further analyses the previous findings, and Chapter 5 shows the role of the surveyed central and regional government agencies in the car industry, as well comparing the NLS in Mexico with Brazil, Japan, and South Korea.

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CHAPTER 5:
EXTERNAL CAPACITY BUILDING

5.1 Introduction

Chapter 4 analysed the role of large firms in the car industry and how they influenced technology upgrading of auto-parts SMEs. This chapter also presented the SMEs' efforts to acquire technology and the linkages they established in the industry. This chapter consists of two sections. The first section analyses Mexico's efforts to upgrade technology in terms of competencies and absorptive capacity, which are important for development of technological capabilities at the industry level. It also compares these efforts with systems of innovation (Japan), active NLS (South Korea), and passive NLS (Brazil) to position Mexico's efforts in the literature of systems of innovation. The second section presents the findings from the fieldwork based on the government's interest in addressing the process of technology upgrading in the automobile industry. This section presents the findings from the surveyed central and regional government agencies, universities, and chambers of commerce and industry.

5.2 NIS versus NLS

To study the position of Mexico in the system of innovation, this section conducts a comparative cross-country analysis (macro-indicators to compare the system of innovation versus systems of diffusion, or active versus passive systems). Three main categories of macro-indicators are used: Competences at the national level (labour education and technology acquisition); absorptive capacity, measured by efforts related to learning (R&D); and national efforts measured by technology acquisition (Table 5.1).

Table 5.1
Technological indicators at the country level

Technological indicators at country level	Macro indicators
Competencies: education and training of the labour force	Adult illiteracy
	Percentage of age group in secondary education
	Performance of secondary students in 2002
	Percentage of age group in tertiary education
	Number of tertiary students per 100,000 inhabitants
	Percentage of first university degrees in engineering
	Percentage of population at working age enrolled
Absorptive capacity: development or resources to technological learning	Expenditure on R&D as percentage of GNP
	Expenditure on R&D by source of funds (%) • Government • Productive enterprise Other
	Government preferential financing of the industry's R&D
	Scientist and engineers engaged in R&D (per million inhabitants)
	Researchers in: • Government institutions • Universities Private sector
National efforts: technology acquisition and patents	Imports of capital goods as ratio of the GDI
	Foreign direct investment up to
	Direct purchase of technology
	Imports of US industrial processes
	Imports of foreign technology (Japan, Germany)
	National patents: National patents granted by the national bureau Patents granted by the national bureau to resident
	US patents: • US patents granted to residents in each country Percentage of US patents granted to non-residents
	Trade in high-tech products with the US: Exports of advanced technology products
	Diffusion of new productive technologies:[71] • Robots per million in employment • CAD per million in employment NCMT per million in employment

Source: Viotti (2002)

[71] In this thesis, diffusion of new productive technologies is not included because of lack of information on those indicators for Japan, South Korea, Mexico, and Brazil.

5.2.1 National efforts: NSI versus NLS

In the National Systems of Innovation (NSI) literature, Japan is well-known for its intense efforts to stimulate growth in the manufacturing system (Freeman, 1987). South Korea was studied in relation to processes of catching up in industrialised countries. Due to its efforts, South Korea is an active system in NLS literature (Kim, 1997, 1999). In contrast, Brazil is a late industrialising Latin American country that made fewer efforts to catch up. Because of this, it is a passive system in NLS literature (Viotti, 2002). To provide a better glance for the different countries for the following indicators, Table 5.2 introduces the total population in 2003 and 2009.

Table 5.2
Country populations: A quick glance

	Japan	**South Korea**	**Brazil**	**Mexico**
Population total (2003)	127,718,000	47,859,000	181,633,074	103,902,569
Population total (2009)	127,557,958	48,747,000	193,246,610	112,033,369
Growth (%)	-0.12	1.86	6.39	7.82

Source: World Bank

i) Competencies: Education and training of the labour force

The pattern of technological learning in Korea is similar to the pattern in Japan. In 2009, Korea resolved the problem of widespread adult illiteracy. Adult literacy in Mexico was higher than in Brazil, but significantly lower than in Korea and Japan. In Mexico, 8.3 per cent of the labour force was unable (not sufficiently educationally prepared) to undertake meaningful technological learning (Table 5.3). Seventy percent of the Mexican population is enrolled in secondary education, with mean mathematics and science scores below average for OECD countries. Japan and Korea score significantly higher than the OECD-country average. From 2000 to 2010, Mexico doubled its number of graduates in engineering, manufacturing, and construction (44,606 to 89,964), which is evidence of recent efforts to increase technological learning. However, the number of Mexican workers with tertiary education in 1999 was only 24 per cent. In 2007, this dropped to 17 per cent, which contrasts with the pattern in South Korea, in which 24 per cent of the labour force had a tertiary education in 1999. By 2007, this increased to 35 per cent. Mexico increased technological learning (in 2007, there was an increase from 14 per cent to 16 per cent for tertiary education in engineering), which was hindered by a significant reduction on the side of the labour force with tertiary education. In Brazil, the part of the labour force with tertiary education slightly increased from 7 per cent (1999) to 9 per cent (2006). The number of people with engineering training in the labour force remained static (Table 5.4). In relation to GDP expenditure on education, Brazil has the highest share with 5.4 per cent. Mexico and South Korea have 4.9 and 4.8 per cent, respectively, and Japan has the lowest share, at 3.9 per cent.

Table 5.3
Macro-indicators of education and training of the labour force in countries

Technological indicators	Macro indicators	Years	Japan	South Korea	Brazil	Mexico
Public education and training of the labour force	Adult illiteracy	2009	-	-	13,899,196.63	5,561,065.644
	Enrolment in secondary education	2005	7,710,439	3,786,224	24,863,112	10,654,404
		2009	7,299,966	3,986,079	23,616,942	11,474,483
	% school enrolment secondary education	2009	99	96	-	70
	Secondary students repeaters (% of total enrolment)	2005	0	0	21	2
	Performance in mathematics and science for 15 years old students-PISA assessment	2009	534 significantly above the OECD average	542 significantly above the OECD average	395.5 significantly below the OECD average	417.5 significantly below the OECD average
	Enrolment in science. Tertiary education (%)	2009	3	9	8	12
	Enrolment in engineering, manufacturing and construction. Tertiary education (%)	2009	15	27	9	20
	Number of graduates in engineering	2009	-	164,166	71,594	106133
	% of graduates in engineering	2009	-	41.5	8.22	25.02
	Labour force with secondary education (% total)	1999	48	44	20	29
	Labour force with tertiary education (% total)	1999	33	24	7	24
	Current expenditure on education as % of GDP	2008	3.9	4.8	5.4	4.9

Source: OECD and World Bank

Table 5.4
Labour force with tertiary and engineering education

Indicator	Year	Japan	South Korea	Brazil	Mexico
Labour force with tertiary education (% total)	1999	33	24	7	24
	2007	40	35	9*	17
% of tertiary graduates in engineering	1999	19	35	6	14
	2007	18	26	6	16

**In 2006. Source: OECD*

The picture for education and training can be summarised as follows:

- NIS and NLS (active) have steady growth in the labour force, with tertiary education.
- Mexico has a slight increase in graduates in engineering at a time when the numbers in other developed and catching-up countries have decreased. However, this growth in technological learning has been offset by a significant decrease in the tertiary-educated labour force.
- The absorptive capacity of Mexico, which is shaped by its level of understanding of technological learning (measured by performance in science and mathematics) is lower than average for OECD countries. Japan and South Korea have higher levels for this indicator. Although expenditures on education (% of GDP) in Mexico are higher than in Japan and South Korea, performance is hindered by the low level of education required to enhance technological learning.
- Although efforts to improve the performance of technology in Mexico (increasing the number of engineers) have increased, the tertiary-educated labour force has fallen. In contrast, Brazil has steady growth in both factors (increased number of engineers and stable numbers of tertiary-educated labour force) (Table 5.3)

ii) Absorptive capacity: Development of resources for technological learning

For development of resources to enhance absorptive capacity at a country level, Japan and Korea spent more on R&D (% of GDP) in 2007. In the developing countries, Brazil spent more than Mexico, whose R&D investment was very small (Table 5.5). In 1995 and 1996, the automotive industry shows the highest investment in total R&D expenditures of all industries. In South Korea, the automobile sector used 26.8 per cent of expenditures on R&D from the business area, compared to other industries. In 1995, Mexico spent 9.4 per cent of GDP on R&D. This was significantly less than in previous years (Table 5.6).

Table 5.5
Macro-indicators of development or resources for technological learning by country

Technological indicators	Macro indicators	Years[72]	Japan	South Korea	Brazil	Mexico
Development or resources to technological learning	Expenditure on R&D as percentage of GDP	2007	3.44	3.21	1.07	0.37
	Expenditure on R&D by source of funds (%)- Automotive industry*	1996 (Japan and Korea), 1995 (Mexico)				
	Business		14.15	26.81	-	9.39
	Government		0.04	0.39	-	0
	Other national		-	-	-	-
	Funds from abroad		0.01	0	-	0.45
	Expenditure on R&D (%) in industrial production and technology*	2003				
	Business enterprise		-	55.67		23.95
	Government		2.70	4.05		3.90
	Higher education		-	2.46		6.60
	Private non profit		0.48	0.91		0.06
	Total researchers (%) in:	2003	830,474	198,171		44577
	Business		59.92	62.59		23.98
	Government		4.37	6.38		16.19
	Higher education		34.24	30.15		54.24
	Research and development expenditure (% of GDP)	2003	3	2	1	0
	Researchers in R&D (per million people)	2003	5,307	3,207	437	325
	Technicians in R&D (per million people)	2003	530	571	-	148

Source: OECD, World Bank

[72] The years considered are dictated by the availability of data for all indicators for the different countries. More recent years have more missing data.
* The data presented is that available in the OECD database. These numbers do not add to 100 per cent.

Table 5.6
Business enterprise R&D expenditure by source of funds: Mexico
(Millions of current US dollars)

Motor vehicle sector	1993	1994	1995
Business enterprises	42.99	32.061	25.062
Government and other national	0	0	0
Funds from abroad	0	0	1.219

Source: Own elaboration of OECD data.

In comparing the gross domestic expenditure on R&D by socioeconomic objectives and sources (Table 5.7), South Korea had the greatest share of expenditure on R&D for industrial production and technology by the business area by 2003.[73] In the same category of expenditure on R&D for industrial production and technology, Mexico had a greater share from higher education than government (6.6 per cent from higher education and 3.9 per cent from government). In Mexico, the highest share of R&D expenditures in 2003 was on healthcare, with 20.47 per cent by government and 29.14 per cent by higher education (Table 5.7). In Japan, the highest percentage of researchers is in higher education (Table 5.5). In South Korea the highest percentage of researchers is employed in business firms (Table 5.5). The number of researchers and technicians per million people are highest in Japan and South Korea. Brazil and Mexico have smaller percentages of researchers per million people, with 437 million and 325 million, respectively (Table 5.5).

[73] According to the OECD, socioeconomic objectives are: Exploration and exploitation of the earth; environment; exploration and exploitation of space; transport and telecommunications; energy; industrial production and technology; healthcare; agriculture; education; culture and mass media; political and social systems; general advancement of knowledge; and defence.

Table 5.7
Gross domestic expenditure on R&D by socioeconomic objectives and sources

Socioeconomic objectives	**South Korea**				**Mexico**			
2003	Business	Government	Higher education	Non-profit	Business	Government	Higher education	Non-profit
Exploration and exploitation of the Earth	9.031	38.946	29.556	0	1.012	60.263	115.581	1.511
Environment	278.741	177.383	102.46	6.257	42.787	136.666	160.07	5.238
Exploration and exploitation of space	24.523	199.282	25.438	0	..	..	..	..
Transport & telecommunication	228.063	56.318	81.338	0	40.102	6.324	81.436	0.367
Energy	563.16	252.493	116.37	2.649	26.118	35.553	93.527	0.176
Industrial production and technology	13365.88	972.627	590.28	219.305	1051.76	171.383	289.81	2.788
Health	512.828	150.562	322.788	17.669	127.716	235.27	485.419	11.298
Agriculture	142.736	402.1	147.118	0	24.871	228.198	94.657	1.893
Education	..	..	..	..	..	..	..	..
Culture and mass media	..	..	..	..	..	..	..	..
Political and social systems	..	..	..	..	..	..	..	..
General advancement of knowledge	410.217	297.742	511.228	23.772	..	..	..	..
Defence	365.773	371.262	18.278	1.59	..	..	..	..
Total (Million US dollars-current prices)	18267.64	3022.919	2433.22	283.657	1519.02 1	1149.275	1665.848	57.768

Source: Own elaboration of OECD data

Development or resources for technological learning in industrialising and late-industrialising countries shows the following features:

- In South Korea and Mexico, the highest R&D expenditures for building industrial capacity and technology come from the business sector. In Mexico, government R&D expenditures were oriented toward healthcare, followed by agriculture.
- Japan and South Korea show higher levels of R&D in the business area (for innovation), and the highest percentage of researchers in that area. In Mexico, the highest percentage of researchers are in education, followed by almost equal shares in business and government, which points to the lack of industrial capacity in Mexico.
- Mexico shows low figures for development of R&D as a percentage of GDP. In 2003 and 2007, expenditures in Mexico were below the level in Brazil.

iii) National efforts: Technology acquisition

National patterns of technological acquisition (Table 5.8) show capital goods imports in 2005 for Mexico, which implies that imports are an important source of foreign technology (technology embodied in manufactured imports). Similarly, Mexico's FDI (greater than Japan's) confirms foreign firms' investment in Mexico's technology capacity. In 2005, Japan led in technology purchases, followed by South Korea. Japan and South Korea showed steady growth up to 2005, while Mexico's technology purchases were just US$1.8 billion (Table 5.9). In 2009, Korea almost matched Japan for technology purchases. In 2005, Mexico's imports of goods and services by the automotive industry were at a higher level than in Japan and South Korea, but in contrast to Japan and South Korea it did not outsource services on R&D. In all the studied countries, automotive-industry imports increased between 2000 and 2005 (Table 5.10). In 2005, Mexico's automotive-industry imports represented 17 per cent of total imports, which was the second highest level after the computer industry (21.82 per cent of total imports).

Table 5.8
Macro-indicators of technology acquisition in countries

Technological indicators	Macro indicators	Years	Japan	South Korea	Brazil	Mexico
Technology acquisition	Manufactured imports (% of GDP)	2005	54	61	72	83
	FDI millions of US dollars:	2000-2010	173,776.151	61,992.905	-	252,175.737
	Imports of foreign technology-% of total good imports (ICT)[74]	2005	13	15	12	17
	Purchase of technology (current US dollars millions)	2005	6,384.68	4,525.10	-	1847.97
	Imports of intermediate goods and services (thousands of current USD) by industry:	2005				
	Motor vehicles industry		13,098,841	7,967,664	5,983,753	27,193,650
	R&D (all industries)		1,410,254	565,107	0	0

Source: OECD, World Bank

[74] ICT category includes technology equipment, communications equipment, and software (OECD)

Table 5.9
Purchases of technology (current US dollars millions): Mexico

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
225.11	386.65	419.89	471.71	502.12	592.57	484.16	360.03	501.36	453.48	554.16	406.74

Source: OECD

Purchases of technology (current US dollars millions): Japan, South Korea, and Mexico

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Japan	4512.33	4320.29	4862.84	5246.58	6384.68	6065.30	6033.85	5805.44	5716.58
South Korea	2642.67	2721.50	3236.50	4147.50	4525.50	4837.60	5103.50	5669.90	8438.10
Mexico	418.52	689.00	671.61	1354.69	1847.97	1632.14	1388.61	891.76	2038.18

Source: OECD

Table 5.10
Imports of intermediate goods and services: Motor vehicle industry and R&D
Thousands of current USD dollars

	Motor vehicle industry		Growth	R&D		Growth
	2000	2005	%	2000	2005	%
Japan	6,435,262	13,098,841	103.55	891,488	1,410,254	58.19
South Korea	3,809,258	7,967,664	109.17	240,223	565,107	135.24
Brazil	2,320,588	5,983,753	157.86	0	0	0
Mexico	21,632,248	27,193,650	25.71	0	0	0

Source: OECD

The cross-country comparisons for technology acquisition show that:

- Purchase of technology for Mexico is significantly lower than for Japan and South Korea.
- Japan and South Korea showed steady growth for purchase of technology in 2001–2009 (Table 5.9). Mexico saw a significant increase after 2004. In 2008, South Korea achieved outstanding catch-up for technology acquisition and almost matched Japan (Table 5.9).
- An important source of industrial supplies and material for the Japanese and South Korean automotive industry is from abroad, which confirms the high level of globalisation of this type of industry.
- In Japan and South Korea, industries imported foreign supplies for R&D, as compared to no imported foreign supplies for R&D in Mexico and Brazil.
- The automotive industry in Mexico is the second-largest importer of intermediate supplies after the computer industry. This may be due to the absence of suppliers in Mexico and/or the importance of intermediate goods for technology upgrading.

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iv) National technological efforts: Patents

The evidence gathered for Japan, South Korea, Brazil, and Mexico confirms the findings for development of knowledge and innovation. In 2008, Japan produced the largest number of technology patent applications to the European Patent Office (EPO) with 18,865, followed by South Korea with 3,883, Brazil with 280, and Mexico with 70 (Table 5.11). In Mexico, the most frequent cooperation partner is the US, confirming the close relationships between these two countries. Brazil's most frequent partners are European countries, followed by the US. In 2008, Japan, South Korea, and Brazil had higher numbers of patent applications to the EPO than to the US Patent and Trademark Office (USPTO). From 2004–2008, all countries had higher numbers of patents awarded by the EPO than by the USPTO (Table 5.12). For patents related to the motor vehicle industry, Brazil and Mexico show few applications to both the EPO and USPTO (Tables 5.13 and 5.14). Brazil showed small growth in patent applications to the USPTO. Mexico had no patents for the motor vehicle industry.

Table 5.11
Macro-indicators of national efforts: Total number of patents by country

Technological indicators	Macro indicators	Years	Japan	South Korea	Brazil	Mexico
National efforts	Foreign ownership of domestic patents (total patents)	2009	28 284	8 456	573	183
	Total patent cooperation abroad with Japan (number of total patents)		-	24	2	0
	Total patent cooperation abroad with US		373	112	43	45
	Total patent cooperation with European Union		347	56	66	18
	% of patents owned by foreign residents* (total cooperation with abroad)		3.0	2.6	22.2	38.8
	Number of patents by technology granted at the EPO (all domains of technology)	2008	18865	3884	280	71
	Number of patents by technology granted at the USPTO (all domains of technology)	2008	9109	2744	61	39
	Number of patents related to motor vehicle sector granted at the EPO	2008	586	20	3	0
	Number of patents related to motor vehicle sector granted at the USPTO	2008	185	14	0	0

***** Share of patents owned by foreign residents in total patents invented by resident(s) of country x (inventor) (OECD)

Table 5.12
Total patents awarded by country

Total patents by technology (%) applied to the EPO*					
	2004	**2005**	**2006**	**2007**	**2008**
Japan	17.73	16.30	16.24	16.25	15.44
South Korea	3.43	3.83	3.88	3.53	3.18
Brazil	0.14	0.15	0.17	0.21	0.23
Mexico	0.04	0.06	0.06	0.06	0.06
Total number of patents (world)	130,104	133,656	132,199	128,181	122,186

*Total patents include all types of technologies: ICT, biotechnology, nanotechnology, and environmental technologies
Source: Own elaboration of OECD data

Total patents by technology (%) applied to the USPTO*					
	2004	**2005**	**2006**	**2007**	**2008**
Japan	21.00	21.00	20.00	18.00	14.00
South Korea	5.10	5.70	5.50	5.00	4.20
Brazil	0.10	0.10	0.10	0.10	0.10
Mexico	0.00	0.10	0.00	0.10	0.10
Total number of patents (world)	183,521	167,005	143,377	108,932	65,982

*Total patents include all types of technologies: ICT, biotechnology, nanotechnology, and environmental technologies
Source: Own elaboration of OECD data

Table 5.13
Total patents awarded by country: Motor-vehicle sector

Total patents by technology related to motor vehicles (%) applied to the EPO										
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Japan	26	28	31	31	35	38	36	37	37	32
South Korea	0.5	0.3	0.3	0.2	0.5	0.3	0.7	0.5	0.8	1.2
Brazil	0	0.1	0.1	0	0	0	0.1	0.1	0.1	0.2
Mexico	0	0	0	0	0	0	0	0	0.1	0
Total (world) number of patents	2,176	2,425	2,439	2,439	2,421	2,392	2,230	2,371	2437	2112

Table 5.14
Total patents awarded by country: Motor-vehicle sector

Total patents by technology related to motor vehicles (%) applied to the USPTO										
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Japan	35	33	37	37	41	41	39	38	33	23
South Korea	1.6	0.8	0.9	1.0	2.1	1.0	1.9	1.8	2.2	1.7
Brazil	0	0	0	0	0.2	0.1	0.1	0.1	0.2	0
Mexico	0	0	0.1	0.1	0	0	0	0.1	0	0
Total (world) number of patents	2,916	3,346	3,293	3,425	3,280	2,797	2,005	1,767	1454	817

Source: Own elaboration of OECD data

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Compared to Japan and South Korea, Mexico shows passive development of innovation. Brazil's development of innovation is slightly better, although still far from the levels in Japan and South Korea.

v) Mexico: NLS

Compared to the industry, Mexico shows passive behaviour and performance for upgrading technology. R&D socioeconomic objectives (see Table 5.10) present the main aims of the different agents (government, business, and higher education). Mexico's growth in industrial capacity has historically been based on foreign firms, whose participation in the automobile industry is limited to a few interactions of knowledge transfer with other Mexican-owned firms. Mexico's absorptive capacity is hindered by the low numbers of its labour force with tertiary education and poor performance in science and technology. Mexico, similar to Brazil, demonstrates passive behaviour toward technology upgrading.

5.3 The automotive industry in the Mexican NLS: Role of their agents

5.3.1 Structure of the automobile industry in Mexico

The above section provides a framework for the NLS in Mexico from a macro-perspective to understand the development of efforts for technology upgrading by the main agents in the automobile industry. The present section provides a qualitative analysis of the surveyed agents in the automotive industry. These agents were identified by their interactions in the industry. They are governments, associations, and universities (see Chapter 3). These agents were selected on the basis of their influence on the growth of the industry and engagement in developing national technological efforts.

The findings from the fieldwork confirm a lack of policies oriented to support auto-parts SMEs (Mexican-owned firms). Government efforts are oriented to foreign firms, which have sufficient technology capacity to support the country's technical change. Domestic firms (SMEs) face high levels of competition and have limited indigenous skills that are generally developed through their own efforts. Mexican agents' efforts in the automotive industry generally take the form of training and promotion of firms.

In general, efforts toward technology upgrading of the automotive industry are quite recent. Most of the government programmes to enhance technology transfer in the car industry started in 2000, but some were hindered by the economic crisis (2008–2009) that ended AERI-FUMEC, PRODIAT, and Ministry of Economy initiatives (Table 5.15).

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Table 5.15
Interviewed government agents: General characteristics
Year: 2010

Interviewee	Age (year of establishment)	Size of the department (number of employees)	Focus and scope
Central government agencies			
Department of the automotive industry	1980	15 senior officers in the automotive industry and 500 employees.	Policy oriented at the national level
Department of SMEs	2002	3	Programmes oriented at the national level
Department of technology and innovation-AVANCE programme	2003	8	Policies and programmes oriented at the national level
FUMEC's automotive project	In 2003 FUMEC set up the automotive department; the AERI started in 2008.	100 approx.	Programmes oriented at the national level
FUMEC & Ministry of Economy – TechBA	2004	100	Programmes oriented at the national level
Local government agencies			
Trade and investment-PROMEXICO in Puebla	2007	1	Programmes oriented at the national level
Department of SMEs	2005	6	Programmes oriented at the national level
Trade and investment- Ministry of the Economy	2005	6	Programmes oriented at the national level

5.3.2 Efforts for the automotive industry: Surveyed agents

The automotive industry in Mexico is led by foreign car assemblers, on whom growth of the car industry depends. Therefore, the government focused on diffusing technological learning, rather than innovating. Chambers of industry and commerce are intermediaries between government and firms. These associations in the automobile industry involve only foreign and large firms, with little or no involvement of auto-parts SMEs.

i) The Ministry of Economy and the automotive industry

The automotive-industry department in the Ministry of Economy was founded in 1980, mainly for car assemblers in Mexico. The auto-parts sector is represented by chambers of commerce and industry associations.[75] The institutional framework of the sub-secretariat of the automotive industry is part of the Secretariat of Heavy Industry and High Technology. The Secretariat is responsible for the electronics, metallurgical, aviation, and automotive sectors. Government policy interventions in these industries are aimed at attracting FDI and creating employment. The sub-secretariat of the automotive industry is responsible for developing automotive decrees, policy intervention in environmental norms, alignment of FDI objectives for high-technology firms, imports, exports, tariffs, and taxes.

The most recent programme launched by the automotive secretariat was the Programme for the Development of High Tech Industries (PRODIAT) (2007–2008), based on finding market failures in an industry. The main failure detected in the automotive sector was poor performance of blue-collar workers in firms. The programme was aimed mainly at providing funds for training, technical assistance (process development, and machinery and equipment acquisition), and information. The programme received small funds ($USD 3.7 million for high-tech firms) and ended as a result of the economic crisis.[76] The department of the automotive industry suffers from lack of federal funding and poor scope of developed programmes.

ii) FUMEC and the automotive industry

[75] In the late 1970s, the Mexican automotive industry lacked an auto-parts sector. At that time, the automotive-industry department was founded in the Ministry of Economy. Previously, automotive components were acquired from the same car assemblers' subsidiaries (which produced their own parts) or from multi-national firms (abroad) that met necessary technological standards for the export-oriented production of car assemblers in Mexico (Bennet and Sharpe, 1979).
[76] The programme received $50 million Mexican pesos.

FUMEC is a joint Mexican-US government agency founded in 1993. The Mexican part is managed by the Ministry of Economy and the National Science and Technology Council (CONACYT), and promotes collaboration with the US in specific industries. The collaboration includes various programmes such as: Attraction of new customers for Mexican firms; and development of strategic alliances and innovation networks (AERIs). The automotive-industry programmes were launched in 2003–2004 (see Table 5.16).

Table 5.16
Programmes addressed to the automotive industry: FUMEC

Programme	Purpose	Scope
AERI	Development of work interactions among members of small groups that include large firms, universities, and small firms.	The members (universities and firms) are identified through the local agencies of national councils of science and technology and universities that have developed research projects with firms (large firms and SMEs)
TechBA	It is a department rather than a programme, that is focused on the promotion of firms abroad (US and Spain), and entrepreneurial training for SMEs	This programme is focused more on SMEs (Mexican owned and foreign owned) who contact the agency directly.
SATE	It is a department rather than a programme that is focused on advice to firms on how to apply for government funding, and entrepreneurial training.	The programme is addressed mainly to SMEs who contact the agency directly.

Agency efforts are limited by scope of programmes and low levels of funding. In 2008, the first AERI was established with six firms (three multi-nationals and three SMEs), but the programme ended in 2009 due to the economic crisis. In 2010, AERI restarted. Efforts are oriented toward mature firms and strong networks (such as the electronics cluster in Jalisco). The firms involved in the AERI programme did not necessarily apply to it. The SMEs were selected on the basis of their roles in the industry. These firms have either a high presence in the sector of embedded systems or are collaborating in advanced R&D programmes with universities. These firms are contacted through the universities or directly by FUMEC's representatives at AERI. Similarly, large firms were selected on the basis of leading the growth of the car industry in Mexico. These firms were identified through their strong involvement in central government agencies, car-industry associations, and research centres. To build linkages among participants (Large firms and SMEs) in the AERI, there are annual meetings in which firms are invited to participate for collaborative R&D projects with financial support from CONACYT. Representatives of universities, and regional and central government agencies, as well as CEOs of large firms and SME founders attend. These meetings are also an opportunity for FUMEC to let firms know about the programmes it is developing in the car industry.

In contrast to the AERI process of firm selection, TechBA launches public calls to which all firms can apply. The requisites for being a candidate are: Use of advanced technology (R&D laboratories, machinery); a strong, established managerial team; a mature product in the market; and a meaningful proposal in terms of market expansion abroad. Firms' applications are evaluated, and those that fulfil these requisites are selected for the TechBA business accelerator. They receive support, training, and promotion for establishing negotiations with firms in United States (see Chapter 4).

For 2010, the AERI gathered SMEs on embedded systems and worked with CINVESTAV and Carnegie Mellon University to design and develop training in software standards such as Capability Mature Model Integration (CMMI) and Software Process Improvement and Capability Determination (SPICE).[77]

iii) CONACYT

CONACYT was founded in 1970 to support Mexico's technical change by providing fiscal stimuli such as funding for acquiring technology, R&D investments, technological advice, development of networks among universities and firms, development of researchers, and information. CONACYT also promotes the development of networks for technology firms and institutions. Table 5.17 presents a summary of the most important programmes for firms. Table 5.18 presents the outcomes of CONACYT's efforts, described below:

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[77] This model consists of best practice in system and software development and maintenance. It was developed by the Software Engineering Institute of Carnegie Mellon University. SPICE is a set of technical standards for software development.

- In 2003 to 2007, CONACYT's total expenditure decreased by around 2.22 per cent. The category mainly affected was R&D where expenditure decreased by around 2.57 per cent. In 2003 to 2004, CONACYT's spending decreased by 10.2 per cent (Table 5.18).
- In 2001 to 2009, total federal expenditure on science and technology increased by around 80 per cent (Table 5.19).

Table 5.17

Programmes for development of entrepreneurial innovation

Programme	Description	Incentives	Target group
Programmes for innovation	It promotes the R&D investment at national level.	It provides funds for development of R&D projects, processes or products at firm level.	Firms registered in the "National Registry of Scientific and Technology firms and institutions"[78]
Funding for technology and innovation	It is a trust fund developed with the Ministry of Economy and it aims to support micro and small technology firms.	It provides fund to technology projects at firm level.	Large firms that include the involvement of 10 micro or small technology firms
AVANCE Programme	It aims to identify technology opportunities and development of firms on science and technology	It provides funds and access to networks of science and technology.	Firms, universities, researchers, research centres, scientist registered in the "National Registry of Scientific and Technology firms and institutions"

Programmes for Innovation is mainly focused on providing finances for acquiring machinery, developing new products, or developing research projects such as laboratories or in-house research. Funding for Technology and Innovation includes micro-/small firms in large firms' supply chains. In this programme, large firms commit to develop 10 micro-

[78] The National Registry of Scientific and Technology firms (RENIECyT) and institutions is a database of firms, universities, research centres, and nonprofit institutions focused on development of science and technology. To register in RENIECyT, the firms provide evidence of patents, collaborative R&D research with universities or research centres, development of industrial projects, development of products, or technological training to human resources. The universities interested in applying provide evidence of research projects, publications, national/international awards, and human resources training.

/small firms through the transfer of knowledge on international production practices and processes. This programme provides finances and other stimuli to participants. The AVANCE programme is jointly run by CONACYT and FUMEC. The firms involved in AERI mainly work together in a research project funded by CONACYT through the AVANCE programme. AVANCE also includes other programmes oriented toward developing firms based on science and technology, and commercialisation of research.

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Table 5.18
CONACYT's expenditures in different categories
(% from total federal funding by state government on science and technology)
(Millions of Mexican Pesos-Current pesos)

Expenditure	2001			2002			2003			2004			2005			2006			2007			2009		
	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)	Total federal funding	Assigned to CONACYT	% (CONACYT)
Expenditure on R&D	14,307.10	2,065.80	8.14	15,163	2,487	9.97	17,406.30	3,079.90	10.58	17,251.50	2,658	9.31	18,525.80	2,354.10	7.51	20,178	2,735	8.17	21,314	2,444	6.74	28,136	4,878	10.65
Expenditure on education and training	6,280.60	1389.7	5.48	5,357	1673	6.7	6,308.00	2,073.10	7.12	6787.8	1,901.10	6.66	6,842.80	2,193	7	7,835	2,270	6.78	9,164	2,634	7.27	12,185	3,731	8.14
Expenditure on science and technology services	4,785.30	300.5	1.18	4435	361.7	1.45	5,396.00	448	1.54	4,518.80	470.2	1.65	5,970.40	485.7	1.55	5,455	506	1.51	5,778	503	1.39	5,502	530	1.16
Total	25,373	3765	14.84	24,955	4521.8	18.12	29,110.30	5,601	19.24	28,558.10	5,029.40	17.61	31,339.00	5,032.80	16.06	33,468	5,511	16.47	36,256	5,581	15.39	45,822	9,139	19.94

Source: CONACYT and INEGI

Table 5.19
Total federal expenditures in science and technology
(Millions of Mexican Pesos)

Total expenditure	2001	2002	2003	2004	2005	2006	2007	2009
Expenditure on R&D	14,307.1	15,163	17,406.3	17,251.5	18,525.8	20,178	21,314	28,136
Expenditure on education and training	6,280.6	5,357	6,308	6787.8	6,842.8	7,835	9,164	12,185
Expenditure on science and technology services	4,785.3	4,435	5,396	4,518.8	5,970.4	5,455	5,778	5,502
Total	25,373	24,955	29,100.30	28,558.1	31,339	33,468	36,256	45,822

Source: CONACYT

International agents that support industrialisation in Mexico through CONACYT include the World Bank and the International Monetary Fund (IMF). For instance, the development of CONACYT's AERI and AVANCE programmes are part of a World Bank scheme.

Table 5.20 summarises the main agents' efforts to improve industrialisation in the NLS and automotive industry

Table 5.20
Efforts by the surveyed government agencies: Aims and scope

Agency	Purpose	Scope
Automotive industry-Ministry of Economy	Mainly based on funding	Car assemblers and auto-parts firms
FUMEC	Entrepreneurial trainings and developing relations between firms and universities	The SMEs
CONACYT	Funding and developing relations between firms and universities, development of researchers	All types of technological entities (firms, universities) and human sources.

Mexico has not been active in catching up with industrialised countries. Market failures were responsible for the lack of deliberate efforts among government agencies. Mexico's efforts to build technological capacity lack continuity and intensity.

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iv) Efforts by the surveyed government agencies: National and regional

Similar to the central agents' efforts focused on the automotive industry and development of technology, the remaining surveyed agencies (Secretariat of SMEs, PROMEXICO, and Trade and Investment Secretariat) mainly focus on providing funds, training, and promotion of firms. These efforts are not oriented toward any specific industry. Any firms that fulfil certain requirements can apply to those programmes (Table 5.21). In contrast to central agencies, the regional agencies are aligned to the national pattern of growth of the central agencies.

Table 5.21
Efforts by the surveyed central and local agencies

Agency	Purpose	Scope	Outcomes
Department of SMEs	Managerial training and consultancy through funding	SMEs of all industries (National level)	•In 2009, the central agency delivered funds of MNX$84,476,309 to support 5,000 small firms. •This agency developed its own consultants who were trained by the Japan International Agency-JIA
Trade and investment-PROMEXICO in Puebla	Mainly based on promotion of industries	All type of industries and export-oriented firms (Regional level)	•In 2009, 15 multinational firms were supported by the agency.
Trade and investment-Ministry of the Economy	Promotion of firms and local industries	All firms and multinational firms (Regional level)	•In 2007-2010, the multinational firms located in the region (8 first-tier firms) were supported through trade agreements, taxes and INCOTERMS.[79] •In 2007-2010, funds were delivered for 3 international fairs. 2 firms were supported to attend the Expo-show in Frankfurt (2008).

[79] International Commercial Terms are international rules for the sale of goods related to costs and risks involved in the delivery of goods from sellers to buyers. The rules are published by the International Chamber of Commerce.

v) Chambers of commerce, industry organisations and universities

Organisations related to the automotive industry are aimed at car assemblers and first-tier firms (multi-national and Mexican-owned large firms) (Table 5.22).

Table 5.22
Interviewed chambers of commerce and industry associations

Chambers of commerce and industry	Interviewee	Age	Size (Number of employees)
i) National Institute of Auto-parts – INA	i) Executive in the area of economic studies.	1961	10
ii) Automotive cluster in Nuevo Leon - CLAUT	ii) Executive coordinator in the area of development of suppliers	2007	9
iii) Mexican association for the automotive industry – AMIA	iii) Executive coordinator of the automotive workgroups	1951	11
iv) Confederation of chambers of industry - CONCAMIN	iv) Vice president of CONCAMIN	1918	11

The main activities of the chambers are providing legal advice, market information, training in ISO standards and certification processes, and promotion of firms (Table 5.23).

Table 5.23
Chambers' activities and outcomes

Chamber	Purpose	Scope	Outcomes
INA	Represent the affiliates' interests for the government (reduction of taxes), provide legal advice, market information, training in ISO certification and promotion of firms	National	•In 2010, the agency had 200 affiliate firms, 80% foreign firms and 20% Mexican owned large firms. •No interactions with universities. •Strong interactions with the secretariat of the automotive industry in the Ministry of Economy.
AMIA	Represent the affiliates' interests and concerns to different government agencies.	National	•The affiliates are car assemblers. •Strong interactions with government agencies. •Poor or no interactions with universities. •In 2010, the chamber achieved the development of a car commissioned by the Chamber of Deputies.
CONCAMI N	Represent the chambers' interests for the government agencies	National	•This organisation groups 64 chambers of commerce and 56 associations. •It has developed 3 programmes oriented to SMEs (Fondo PYME in the Ministry of Economy), Innovation (Fondo de Innovación in CONACYT) and the Software industry (PROSOFT). •It works with universities under the AERI programmes.
CLAUT	Develop a cluster for the auto-parts industry in the region through developing interactions among universities, firms and government agencies.	Regional	•Organisation was founded in 2007 and in 2009 had 40 affiliates. •Affiliates are truck assemblers, car assemblers, and 1st-tier firms. In 2010, it launched a new group for 2nd-tier firms (medium sized firms). •Strong interactions with regional universities.

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The central chambers of commerce and industry are oriented more toward providing information and diffusing existing techniques. They serve the interests of multi-national firms. The chambers have few or no interactions with universities and SMEs in the automobile industry.

The regional CLAUT has made efforts to build a regional auto-parts cluster and is oriented towards diffusing techniques and best practices in mature firms to standardise the performance of second-tier firms in the region. It was established in 2007 and had 40 members in 2009: 15 tier-one firms (multi-national suppliers), two car subsidiaries, two government agencies, three universities, and 18 second-tier firms (medium-sized firms). In 2010, it also had a group of small firms (fewer than 250 employees). It contacted 30 firms in the region about membership. Firms must fulfil some requirements and show an important impact in the industry. They also pay a membership fee. The chamber has seven groups on: Logistics; human development; supplier development; innovation; energy; investment; and second tier.

vi) Universities

The interviewed universities are aligned to the automotive industry through involvement in AERI-FUMEC (Table 5.24).

Table 5.24
Surveyed universities

University	Age	Size (number of employees)
Centre for computer research in the National Technical Institute– CIDEC-IPN	2009	7
Centre of research studies - CINVESTAV	In 1988, the research centre was set up and in 1997, the university was founded.	8 academic staff involved in automotive projects with 30 trainers.
Autonomous University of Queretaro - UAQ	In 1951 the university was founded and since 2009 has been involved in automotive projects.	100
National Technical Institute of Tijuana -IPN	The research centre was founded in 1990 and in 2009 developed linkages with automotive projects.	5
Autonomous University of Chihuahua	University founded in 1835 and in 2007 developed an industrial park focused on IT and embedded systems.	5

The interviewed universities diffuse knowledge by developing specific programmes to address multi-nationals' concerns (Table 5.25). Only CINVESTAV has developed efforts to enhance technical change in the regional automobile industry.

CINVESTAV belongs to the electronics cluster in Jalisco. This cluster was established in the early 1960s with the establishment of the first electronics plants (multi-national firms) in Mexico. This cluster was reinforced by strong interactions between multi-national firms and research centres. For example, the Technology Centre of Semiconductors in Guadalajara was founded in 1988 as a CINVESTAV-IBM project. In 2002, this centre began to offer training based on accumulated know-how. INTEL and CONTINENTAL developed joint training on embedded systems for the automobile and telecommunications industries. They offer their courses to firms and recent engineering graduates. In 1995, CINVESTAV developed master's and PhD programmes on automatic control, electronic design, electronic systems, telecommunications and computer sciences, based on accumulated knowledge,. By 2010, CINVESTAV was involved with CONTINENTAL in developing a mobile phone device for cars.

Table 5.25
Interviewed universities: Technology diffusion activities

University	Involvement in the industry	Outcomes
CIDEC-IPN	AERI	•In 2009, the university developed a research centre on micro and nano-technology. •It is in the process of developing linkages with large firms in AERI
UAQ		•In 2007, the university developed and carried out a Master's programme for VITRO (Mexican large firm) •The university offer an online training programme on software standards delivered by Carnegie Mellon University •Before the university's involvement in the AERI, UAQ had poor interactions with firms and government agencies
National Institute of Tijuana-IPN		•It is in the process of developing interactions with the members of AERI; previously, the university had no interactions with firms or with the automotive industry. •The purpose of this involvement is delivery of training in quality standards.
Autonomous university of Chihuahua		•In 2007, the university together with the state government, developed an industrial park to group firms on embedded systems. •In 2010, this park hosted 4 firms.
CINVESTAV		•The research centre has strong interactions with CONTINENTAL in Jalisco[80] •In 2003, 1 training programme had been developed for Intel. In 2007, 3 training programmes were developed for CONTINENTAL. •In 2009 2 full time, 5 month training programmes on design of appliances were developed for CONTINENTAL. •CONTINENTAL, Intel and Freescale have transferred equipment and machinery to CINVESTAV for academic purposes.

[80] Multi-national firms played an important role in building the electronics cluster in Jalisco. The sources of technological learning were enriched by strong participation in the regional system. In 1988, IBM and CINVESTAV developed the semiconductor technology centre. Since 2007, CINVESTAV has developed training programmes for CONTINENTAL. The strong participation of multi-national firms (CONTINENTAL, Intel, Freescale) with CINVESTAV is based on funding for training programmes.

The qualitative evidence presented above shows that central and regional government agencies recently developed technological efforts focused on SMEs in the automobile industry. The surveyed chambers of commerce and industry organisations have few or no interactions with Mexican-owned firms in the industry. Similarly, the surveyed universities develop interactions in the industry under government schemes focused on transferring knowledge. The surveyed agents with the strongest involvement in the NLS are engaged in regional efforts to grow industry clusters.

5.4 Conclusions

Chapter 5 provided insights into how agents in the system influence the development of interactions between SMEs and large firms. In Mexico, as in other developing countries in Latin America (Brazil), the development of only a few efforts (small number of firms benefit) and lack of purpose have hindered SMEs' technology upgrading. However, the findings also show that the interactions between large firms and small firms through government interventions are successful for the SMEs' technology upgrading.

Chapter 5 positions Mexico within the literature on NLS. Chapter 1 referred to the distinction between active and passive systems as mainly depending on the chosen national technological strategy. A country becomes part of a passive system when its technological efforts are minimal and based on absorbing existing innovation. In contrast, active systems show deliberate efforts to enhance innovation (Viotti, 2002). In this regard, Viotti (2002) emphasises that the dominant firm strategy (passive or active) can exist alongside the country's strategy (passive or active). This means that the behaviour of leading firms, such as those that set the standards for competition, may prevail over the country's strategy.

The surveyed agents, who lead technological growth in the automobile industry by implementing policies, made recent efforts to enhance knowledge. Combined with the passive behaviour (few interactions developed in the NLS) of the leading firms in Mexico (see Chapter 4), this is evidence that intervention in the development of interactions between SMEs and large firms is necessary for successful knowledge transfer.

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The qualitative evidence presented in this chapter provides insights into how agents influence the development of interactions between SMEs and large firms. Government efforts were addressed to establish linkages among the different agents in the industry. Large firms are involved with SMEs under network (cluster) schemes and specific technological projects involving SMEs and universities (AERI). SMEs are involved with large firms through government schemes of promoting industries abroad (TechBA). Universities are involved with firms mainly through government R&D programmes (CONACYT). However, there is still a lack of policies addressing involvement of SMEs in the automobile industry.

In Mexico, the national pattern of industrialisation is focused on foreign firms, with little concern for other types of firms. Large firms interact with SMEs under government knowledge-transfer schemes. The government plays an important role in leading the development of interactions in the NLS. However, these recent efforts in the car industry (since 2009) are hindered by failures in the system (such as a lack of absorptive capacity to enhance technological learning), poor federal funding to support government schemes for enhancing technological knowledge, and poor scope of policies oriented toward technological fields. It remains an open question of to what extent agents' interventions affect technological interaction between SMEs and large firms. Chapter 6 provides a quantitative analysis to address this question and provide further insights.

CHAPTER 6:

DEVELOPMENT OF TECHNOLOGICAL CAPABILITIES IN SMEs OF THE AUTOMOBILE INDUSTRY IN MEXICO: A STATISTICAL ANALYSIS

6.1 Introduction

This chapter presents a quantitative method that summarises the patterns of the data gathered from the surveyed firms. This quantitative approach focuses on: Important competences and absorptive capacity of SMEs for their technology upgrading; and established interactions with large firms and other agents in the NLS that influence SMEs' technology upgrading.

Chapter 4 presented the qualitative findings for the surveyed firms. This showed the level of involvement of large firms in the automobile industry.[81] The type of learning dominant in the surveyed SMEs and intensity of efforts in search of knowledge were presented, together with the history of technology upgrading at the firm level. Chapter 5 presented empirical findings for the surveyed agents in the automobile industry and showed Mexico's position regarding its technology upgrading efforts. This chapter summarises the empirical findings from Chapters 4 and 5 through a quantitative approach that will be extended in future research.

The first section of the chapter introduces principal component analysis (PCA) as the main quantitative approach in this research and briefly recalls the theoretical concepts in Chapter 1 and the empirical review in Chapter 2 to address the thesis research questions. It describes the variables used in the analysis. The second section presents the quantitative findings from the analysis.

6.2.Absorptive capacity in SMEs in developing countries: Quantitative analysis using PCA

PCA was chosen 'to analyse the interrelationships among a large number of variables and to explain these variables [...] into a smaller set of factors with a minimal loss of

[81] Chapter 5 refers to the level of involvement of large firms in the automobile industry, analysed in relation to establishing interactions with domestic firms (SMEs) and core agents in the automobile industry.

information' (Hair et al., 2006, p. 17). The aims of the analysis are twofold: Find quantitative support for the qualitative findings in Chapters 4 and 5 regarding firm-level technology upgrading in developing countries; and establish the nature of the relationships between absorptive capacity and the influence of large firms and agents in the industry in upgrading technological knowledge and capabilities. PCA uncovers the contributions of the interactions in the industry to the upgrade of technological capabilities in the surveyed SMEs and their absorptive capacity. Because of the large number of variables and high levels of correlation among the observed variables, PCA uses a composite indicator for these variables.

The dataset consists of 45 variables (Table 6.1), grouped according to three theoretical bodies (see Chapter 2): Technological capabilities and absorptive capacity; interactions with large firms in terms of received knowledge; and interactions with other agents in the industry in terms of received knowledge and support. These bodies also refer to the following concepts: Competences; technology upgrading; and intensity of efforts. These are introduced to present the proxy variables.

The sample is 10 firms in different regions in Mexico (see Chapters 3 and 4). The analysis is developed on the basis of the variables operationalised in the above theories (Table 6.1).

Table 6.1 Description of the considered variables considered: Part I

	Main concept	Operational concept	Variable		Description	Type of variable	Measurement of variable
1	Competencies	Manager's competences	Education	Engi_degree	Firm's founders with engineering degree	Ordinal – Dichotomous	Yes = 1, No = 0
2				Master_eng	Firm's founders with a Master's degree in Engineering	Ordinal – Dichotomous	Yes = 1, No = 0
3				PhD_eng	Firm's founders with PhD degree	Ordinal – Dichotomous	Yes = 1, No = 0
4				Finance	Firm's founders with studies in Finance (Master's and 1st degree)	Ordinal – Dichotomous	Yes = 1, No = 0
5				Not_educ	Firm's founders without tertiary education	Ordinal – Dichotomous	Yes = 1, No = 0
6		Firm's competences	Background	Age	Number of years since firm was founded	Ratio	From 0 to 99
7				Size	Number of total employees	Ratio	From 0 to 250
8				Product_man	Nature of product: manufactured parts (mass-production based product)	Ordinal – Dichotomous	Yes = 1, No = 0
9				Product_des	Nature of product: embedded system/electronic design (software based product)	Ordinal – Dichotomous	Yes = 1, No = 0
10				Ahead_tech	Firm with advanced technology (ahead to other domestic firms)	Ordinal – Dichotomous	Yes = 1, No = 0
11				Average_tech	Firm with intermediate technology (average technology)	Ordinal – Dichotomous	Yes = 1, No = 0
12			Level of tier	Car_assembler	Firm whose customer are car assemblers	Ordinal – Dichotomous	Yes = 1, No = 0
13				Foreign assemblers	Firms whose customer are foreign firms (1st tier)	Ordinal – Dichotomous	Yes = 1, No = 0
14			Work labour force	White_collar	Percentage of engineers from the firm's total employees	Ratio	From 0 to 99
15				Blue_collar	Percentage of blue collar workers from the firm's total employees	Ratio	From 0 to 99
16				Managers	Number of founders (absolute value)	Ratio	From 0 to 99

Table 6.1 Description of the considered variables considered: Part II

	Main concept	Operational concept	Variable		Description	Type of variable	Measurement of variable
17	Accumulated technological knowledge	Manager's knowledge	Type of experience prior to the establishment of the firm	Years_mult	Number of years of experience of founder from working in multinational firms	Ratio	From 0 to 99
18				Years_firm	Number of years of experience of founder from working in a previous own firm	Ratio	From 0 to 99
19			Acquisition of knowledge previous to the establishment of the firm	Know_prev_design	Founders' previous knowledge on design	Ordinal – Dichotomous	Yes = 1, No = 0
20				Know_prev_process	Founders' previous knowledge on production processes	Ordinal – Dichotomous	Yes = 1, No = 0
21				Know_prev_market	Founders' previous knowledge on markets trends	Ordinal – Dichotomous	Yes = 1, No = 0
22	Technological capabilities	Firm's capabilities	Technological capabilities existing in the surveyed firms	Qua_control	Firm with qualitative, production and inventory control systems	Ordinal – Dichotomous	Yes = 1, No = 0
23				Search_abroad	Search for technology abroad	Ordinal – Dichotomous	Yes = 1, No = 0
24				Major_modif	Major technology modifications	Ordinal – Dichotomous	Yes = 1, No = 0
25				Number_lab	Number of laboratories	Ratio	From 0 to 99
26				Endogenous_plant erection	Equipment erections and establishment of plant	Ordinal – Dichotomous	Yes = 1, No = 0
27				Patents	Development of patents and trademarks	Ordinal – Dichotomous	Yes = 1, No = 0
28				Innovation	Development of products	Ordinal – Dichotomous	Yes = 1, No = 0
29	Technological efforts	Firm's efforts through interactions in the system	Level of efforts in establishing interactions	High_interactions	High number of interactions in the industry	Ordinal – Dichotomous	Yes = 1, No = 0
30				Med_interactions	Medium number of interactions in the industry.	Ordinal – Dichotomous	Yes = 1, No = 0
31				Low_interactions	Low number or no interactions in the industry	Ordinal – Dichotomous	Yes = 1, No = 0

Table 6.1 Description of the considered variables considered: Part III

	Theories associated	Operational concept	Variable		Description	Type of variable	Measurement of variable
32	Absorptive capacity (sources)	Efforts to learn	Acquisition of knowledge	Man_trainings	Manager's continuous training	Ordinal – Dichotomous	Yes = 1, No = 0
33	Technology upgrading	Firm's technical change	Upgrade of technological capabilities through Interactions with large firms	Dev_suppliers	Developed as supplier by current customers	Ordinal – Dichotomous	Yes = 1, No = 0
34				Assistance_ISO	Training in ISO and lean manufacturing	Ordinal – Dichotomous	Yes = 1, No = 0
35				Assistance_product	Information on product specifications	Ordinal – Dichotomous	Yes = 1, No = 0
36				Strong_inter	Strong interactions with large firms perceived by the founders	Ordinal – Dichotomous	Yes = 1, No = 0
37			Upgrade of technological capabilities through absorptive capacity	Know_design_after	Knowledge acquired in design after interactions with large firms	Ordinal – Dichotomous	Yes = 1, No = 0
38				Know_process_after	Knowledge acquired in processes after interactions with large firms	Ordinal – Dichotomous	Yes = 1, No = 0
39				Know_market_after	Knowledge acquired in market after interactions with large firms	Ordinal – Dichotomous	Yes = 1, No = 0
40			Technology upgrading influence through interactions in the system	Gov_links	Number of linkages with government	Ratio	From 0 to 99
41				Years_gov	Number of years working in government schemes	Ratio	From 0 to 99
42				Gov_machinery	Acquisition of machinery through government schemes	Ratio	From 0 to 99
43				Gov_exp_market	Training received by government to increase managerial skills and expand market	Ordinal – Dichotomous	Yes = 1, No = 0
44				Gov_networks	Involvement in networks for cooperative research	Ratio	From 0 to 99
45				Cham_links	Establishment of strong linkages with chambers	Ordinal – Dichotomous	Yes = 1, No = 0

6.3. Principal Component Analysis

6.3.1. Selection of factors

PCA was selected to explain the relationships between highly correlated variables and study their common essential correlations. An initial component extraction was run to obtain the factors, and nine components were identified. The higher eigenvalues were for the first five components (Figure 6.1).[82] This was confirmed by the scree plot of each eigenvalue, in which the point of inflexion changed from factor 6 to factor 7. Factors 1 to 5 were extracted to develop the analysis. The variables in the dataset (Table 6.2) were standardised (range 0 to 1) to reduce biases in the scales of the original variables. The PCA is less arbitrary with the use of new variables with variance equal to their corresponding eigenvalues (Jolliffe, 2002, p. 22).[83,84]

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[82] Different techniques for selecting eigenvalues suggest selecting values greater than 1. For this study, the eigenvalues were selected on the basis of the power of each constructed factor (eigenvalues greater than 1) (Kaiser, 1960) and relative importance considering the cut-off point of the scree plot (Catell, 1966).

[83] With large differences in the units of measurement of the variables, the variables with the greatest variances will tend to dominate the first principal components (Jolliffe, 2002, p. 22).

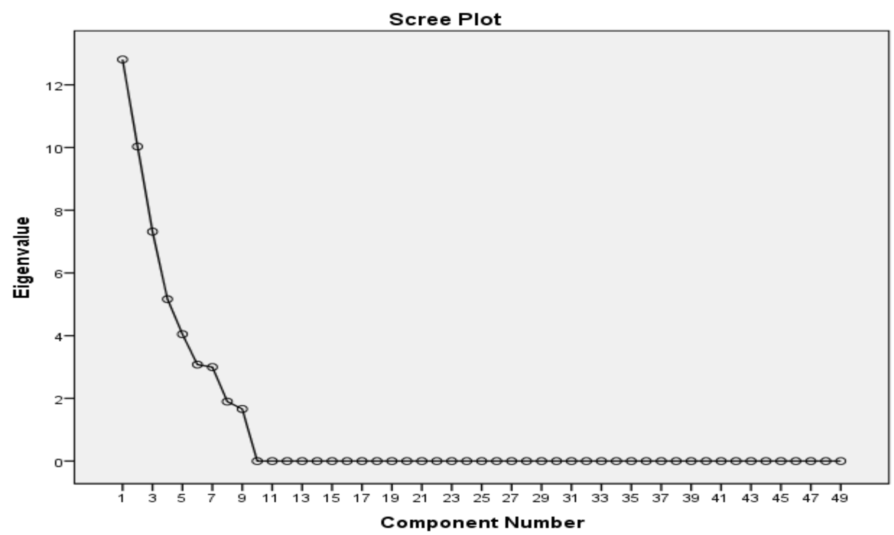
[84] The dataset includes variables coding into 0 and 1, together with variables coding into different units of scale greater than 1.

Figure 6.1
Extraction of components: Total variance explained and scree plot

Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.807	26.138	26.138	12.807	26.138	26.138	10.660	21.755	21.755
2	10.030	20.470	46.608	10.030	20.470	46.608	6.616	13.502	35.256
3	7.317	14.934	61.541	7.317	14.934	61.541	6.428	13.119	48.376
4	5.164	10.539	72.080	5.164	10.539	72.080	5.882	12.003	60.379
5	4.047	8.259	80.339	4.047	8.259	80.339	4.998	10.199	70.578
6	3.079	6.283	86.622	3.079	6.283	86.622	4.615	9.419	79.998
7	2.998	6.118	92.740	2.998	6.118	92.740	3.814	7.783	87.781
8	1.897	3.872	96.612	1.897	3.872	96.612	3.020	6.164	93.944
9	1.660	3.388	100.000	1.660	3.388	100.000	2.967	6.056	100.000

Extraction Method: Principal Component Analysis.



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6.3.2. Component analysis

i) Innovation capabilities (firm competencies and interactions in the industry)

At a theoretical level of interpretation for each component, I considered the variables with loadings greater than 0.50. The first component involves variables that are highly correlated to firm competencies and capabilities. These are *percentage of white-collar workers*, *software development in the firm*, *existence of intensive R&D*, *strong linkages with universities*, and *number of patents* (see Table 6.2). All these variables have loadings greater than 0.90. Other variables with lower loadings, but still highly correlated, are *managers with strong training*, *embedded systems products*, *number of managers in the firm*, and *strong chamber linkages*. These variables have loadings of 0.50 to 0.70. At first glance, the first group of variables indicates the existence of capabilities in the firm and competences that evolve into capabilities (such as founder's competences). All these variables refer to firms with learning from advances in science and technology that may expend greater efforts on developing advanced technological capabilities due the nature of the product (science-based). The efforts are embedded in the number of engineers employed by the firms, the number of managers, founders' continuous training, and strong linkages with research centres, universities, or other organisations. Capabilities and competences are highly correlated for the first factor, which indicates evolution from competences to capabilities (von Tunzelmann, 2009) and the high importance of founders' competences for specific types of firms (research-based product). Competences and capabilities that are highly correlated refer to the concept of absorptive capacity and Cohen et al.'s (1990) reference to absorptive capacity as a function of prior knowledge (competences) and diverse backgrounds (experiences) for assimilating and developing new knowledge (such as skills). Absorptive capacity at the firm level is developed by enhancing the culture of learning (Garvin, 1993; Kim, 1997, 1998). The existence of a large number of engineers reinforces the culture of learning in the surveyed firms. Several works point to the influence of other agents in the system as crucial for diffusing knowledge and fostering organisational learning (Kim, 1999; Edquist, 1997). This is consistent with our findings that those variables that indicate strong relationships with universities and other organisations are highly correlated with the previous variables.

Following Field (2009), factors loadings greater than 0.4 are reliable. Two variables with lower loadings were observed for the first factor. The variables *high number of interactions in the industry* (0.499) and *networks for cooperative research* (0.469) (see Table 6.2) have loadings greater than 0.4, which supports the previous findings. *High number of interactions in the industry* groups firms with high numbers of linkages with different agents in the system (chambers of commerce, industry associations, universities, government, and institutions). This variable is important, since the number of linkages can measure the efforts focused on developing capabilities. The variable is also correlated with the previous variables for firm capabilities and competences. The variable measures the number of linkages related to the scope of sources of information to enhance the absorptive capacity at the firm level. The variable *networks for cooperative research* measures the efforts firms in investing and developing R&D (see previous variables) and indicates the influence of government efforts to diffuse knowledge in the system through linkages between foreign firms (multi-national companies) and domestic firms (Mexican-owned SMEs).[85]

ii) Production capabilities (government influence)

The second component includes fewer variables than the first. These variables are highly correlated: *Quality control system, routine maintenance systems and inventory-control systems, manufactured parts, number of linkages with government, knowledge acquired of production processes previous to the firm*, and *training received from the government* (Table 6.2). These variables seem to be strongly related to production capabilities and refer to manufacturing firms. The second component represents higher production capabilities. The main difference between the first and second components is in the type of technological capabilities developed and the types of linkages that might influence developing these technological capabilities. For instance, the first component shows that firms producing research-based products are related to R&D capabilities: Innovation and highly competent firm founders, strong interactions with universities and chambers of commerce, and high number of linkages with different agents in the system. The second component is related to mass-production manufacturing firms, higher production

[85] Table 6.3 shows that *networks for cooperative research* involves firms that participate in government programmes to develop networks of SMEs and large firms for research projects.

capabilities, and strong linkages with government agencies. The second component may indicate two important outcomes:

a) The type of product influences the firm's technological capabilities.

It affects the efforts devoted to developing innovation capabilities or production capabilities. This recalls Bell and Pavitt's (1993a) claims that technological capabilities are the outcome of knowledge related to production capacity (see Chapter 1). Technological learning is based on knowledge specialisation and capabilities for generating and managing technical change (Bell and Pavitt, 1993a). This is an important finding for reviewing the government's influence on the accumulation of production capacity in developing countries.

b) The type of technological capabilities at the firm level is strongly related to agent linkages in the industry.

Firms with higher innovation capabilities establish linkages with several different agents (universities, chambers of commerce and industry, government), whereas firms with higher production capabilities only establish linkages with government agencies. This is an important finding in line with discussion of the role of NIS in accumulating technological capabilities at the firm level. Government agencies are highly correlated with production capabilities, which may confirm the existence of NLS in developing countries, in which policies are concentrated on diffusion, rather than innovation. This outcome is in line with studies of developing countries (Bell and Pavitt, 1995; Viotti, 2002) that find policies might adopt a technological dynamic position to develop, adopt, and use technology (Bell and Pavitt, 1993a; 1995).

For this component, founders' competences are not significant. This is corroborated by the variable for *higher studies by the founders*, which is negatively correlated (-0.947) (see Table 6.2). Accumulated knowledge related to technological processes appears significant. *Knowledge acquired in production processes previous to establishing the firm* indicates that founders' previous experience acquired in multi-national firms promotes further development of production capabilities by the firm. This confirms the importance of tacit knowledge and highlights the role of learning by doing (see Chapter 4) for developing production capabilities (Bell and Pavitt, 1993a). The variable *ahead in technology* has a lower loading (0.443) (see Table 6.2), which is still reliable (Field, 2009). This variable supports previous findings on efforts to develop production capabilities based on acquiring high-tech equipment and machinery. This component indicates that managers' competences are not significant (not important) for mass-production manufacturing firms, which rely on establishing linkages with government agencies. For this component, government influence is higher than for the first component, and absorptive capacity is embedded in founders' experiences acquired before establishing the firm.

iii) Technology upgrading (government influence)

This factor groups the variables *training received in ISO and lean manufacturing,* and *years working in previous own firm* with factor loadings from 0.5 to 0.60 (see Table 6.2). Lower loadings, between 0.4 and 0.5, apply to *number of linkages with government, training received by government to increase managerial skills, acquisition of machinery through government schemes,* and *medium number of linkages in the industry.* These variables refer to government influence through various programmes. The two highest correlated variables may indicate internal sources of technology upgrading through training and experience acquired before the firm was established. These internal sources may refer to absorptive capacity at a firm level. Government involvement seems to promote technology upgrading in the surveyed firms. Interestingly, the variables for the influence of large firms are highly negatively correlated for this component. These variables are *knowledge acquired in design after firms, information received in product specifications, strong interactions perceived, years working in multinational firms*, and *low interactions in the industry.* This might be explained by reviewing large firms' involvement or government influence. The negative variables for large firms are explained by the lack of interactions in the automobile industry. In Chapter 5, these firms were observed for their interactions with SMEs in government schemes. Large firms that are not involved in any government programme have no interactions with SMEs. In relation to government, the negative variables are explained by reviewing the effectiveness of government programmes in transferring knowledge from large firms to SMEs. These negative variables may indicate that establishing relationships through government schemes is based more on training large firms provide to SMEs in manufacturing techniques (quality standards, just in time, lean manufacturing) than on transfer of technological knowledge.

iv) Technology upgrading (knowledge accumulation)

The variables with high factor loadings for component 3 are *age*, *number of laboratories*, *number of years working under government schemes*, *lack of tertiary studies*, and *size* (see Table 6.2). These variables have loadings greater than 0.60, which may be related to the absorptive capacity of the firm, based on tacit knowledge (learning by doing). This component may also explain technology upgrading in the firm through learning (such as longer-established firms having more laboratories). This component also includes government influence based on number of years working in government programmes. Therefore, technology upgrading is related to the number of years involved in government programmes. There are different government programmes related to acquiring machinery or investing in R&D. Government programmes are an external source of capacity-building for the surveyed firms. *Lack of tertiary studies* is not very informative for this component. This variable in this component indicates that a firm's physical capacity is independent of founders' competences or lack of them.

v) Technology upgrading (firm's efforts)

The variables grouped in this component show less variance compared to other factors, which may confirm that the next factor (sixth factor) is the point of inflexion (as referenced in the criteria for selection factors). Meaningful factors have greater variance (Field, 2009, p. 641). The variables grouped in this component are related to founder and firm competences needed for developing investment capabilities. The highly correlated variables, such as *ahead in technology, search for technology abroad, knowledge acquired in market previous to the establishment of the firm*, and *development of products* (see Table 6.2), refer to investment and marketing skills. Other variables that are highly correlated with lower factor loadings (0.4–0.5) are *engineering degree, training received by the government to increase managerial skills*, and *high number of interactions in the industry*. This may indicate that existing investment capabilities are related to founders' competences (engineering degree) and previous marketing experience, which promote searching to upgrade skills. In this context, the government supplies training to develop marketing skills.

From the above, I conclude that components 3, 4, and 5 of technology upgrading present different factors related to developing technological capabilities in the surveyed firms. Component 3 of technology upgrading through government influence implies that acquiring manufacturing techniques needed in the automobile industry occurs via large firms involved in government schemes. This component may reflect the success of government schemes in involving SMEs in the automobile industry to supply large firms. This component groups highly negatively correlated variables related to acquiring knowledge through interaction with large firms. This refers to the type of NLS in Mexico discussed in Chapter 5. Mexico appears to be a passive NLS in terms of development of efforts on technology upgrading. The lack of 'deliberate efforts and the lack of investment in technology' (Viotti, 2002, p. 662) reflects failure in technological knowledge transfer among firms. The variables for acquiring knowledge through interactions with large firms are negatively correlated with variables for government influence in establishing these interactions.

Component 4 of *technology upgrading through knowledge accumulation* reflects the firm's absorptive capacity. For instance, *age* can be explained as a 'function of accumulated experience or learning-by-doing' (Arrow, 1962 cited in Romijn, 1999, p. 199). Older firms are highly correlated with greater firm capabilities (more laboratories). In this component, the higher numbers of *years of involvement in government schemes* reflect government involvement in the growth of the firm's physical capacity based on government funding. Component 5 of *technology upgrading through the firms' efforts* shows that firms with accumulated knowledge of the industry are likely to acquire advanced technology and develop products, confirming that investing in physical capital influences the development of technological capabilities (Bell and Pavitt, 1995).

Table 6.2 Component matrix and component-rotated matrix

Component matrix and component rotated matrix	Component Matrix[a]						Rotated Component Matrix[d]				
	Components						Components				
	1	2	3	4	5		1	2	3	4	5
Percentage of white collar workers	0.869						**0.961**				
Percentage of blue collar workers	0.84	-0.47					-0.96				
Development of software	0.84	-0.47					**0.956**				
Intensive in house R&D	0.84	-0.47					**0.956**				
Strong university linkages	0.84	-0.47					**0.956**				
Development of patents and trademarks	0.797						**0.956**				
Manager's continuous training	0.784			0.48			**0.772**				
Mass-production based product	0.767	-0.51					-0.69	**0.688**			
Software based product	-0.77	0.514					**0.692**	-0.69			
Quality control systems	0.767				0.48			**0.947**			
PhD in engineering	0.727				0.575			-0.95			
Routine maintenance systems and inventory control systems	0.638		-0.55					**0.947**			
Number of linkages with government	0.61							**0.639**	**0.424**		
Knowledge on production processes from previous experience	-0.58		-0.46					**0.583**			
Training received by government to increase managerial skills and expand market		0.891						**0.554**	**0.468**		0.446
Masters in engineering		-0.89						-0.5			
Knowledge acquired in design after interactions		0.766							-0.92		
Information received in product specifications		-0.76					-0.43		-0.84		
Strong interactions perceived		-0.75							-0.84		
Years working in multinational firms		0.714							-0.79		
Low number of interactions in the industry	0.4	0.666		0.473					-0.74		

a. Extraction Method: PCA. Nine components extracted.
d. Extraction Method: PCA.
Rotation Method: Varimax with Kaiser Normalisation. Rotation converged in 11 iterations.

Table 6.2 Component matrix and component-rotated matrix

Component matrix and component rotated matrix	**Component Matrix[a]** Components					**Rotated Component Matrix[d]** Components				
	1	2	3	4	5	1	2	3	4	5
Number of managers in the firm	0.526	0.616				**0.577**		-0.69		
Training received in ISO and lean manufacturing	0.526	0.616						**0.589**		
Age of the firm	-0.53	-0.62							**0.94**	
Number of laboratories		0.598		0.52					**0.849**	
Numbers of years working in government schemes		-0.58		-0.5	0.477				**0.765**	
Lack of tertiary studies	0.456	0.563							**0.757**	
Size of the firm	-0.48		-0.77			-0.44			**0.743**	
Engineering degree			0.764						-0.7	0.472
Average in technology (domestic firms)			0.754							-0.95
Ahead in technology (domestic firms)	0.546		0.722				**0.443**			**0.798**
Search of technology abroad			0.708		-0.52					**0.693**
Years working in the previous own firm		0.5	0.696					**0.643**		-0.65
Knowledge of market trends based on previous experience			-0.67		-0.47				0.483	**0.637**
Development of innovation: products	-0.56		-0.63							**0.513**
Equipment erection and establishment of the plant			0.599							
Knowledge acquired in market after interactions			0.504	-0.44	0.417					
Customers are 1st tier firms				0.765						
Acquisition of machinery through government schemes				0.752				**0.45**		
Supplier to car assemblers				0.665						
Studies in Finance	0.525			0.622						
Strong chamber linkages		-0.42	0.559	0.573		**0.502**				

a. Extraction Method: PCA. Nine components extracted.
d. Extraction Method: PCA.
Rotation Method: Varimax with Kaiser Normalisation. Rotation converged in 11 iterations.

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Table 6.2 – Component matrix and component rotated matrix

Component matrix and component rotated matrix	**Component Matrix**[a]					**Rotated Component Matrix**[d]				
	Components					Components				
	1	2	3	4	5	1	2	3	4	5
Knowledge in design acquired through previous experience	-0.48				-0.76				-0.57	
Knowledge acquired in processes after interactions	0.51	-0.44								
Developed as suppliers by their current customer				-0.53						
Major modifications to technology	0.496									
Medium number of interactions in the system	0.544							**0.461**		
High number of interactions in the industry	-0.42		0.444			**0.499**				0.433
Networks for cooperative research				-0.45	0.431	**0.469**				

a. Extraction Method: PCA. 9 components extracted.
d. Extraction Method: PCA.
Rotation Method: Varimax with Kaiser Normalisation. Rotation converged in 11 iterations

Component Transformation Matrix

Component	1	2	3	4	5	6	7	8	9
1	.733	.307	.204	.274	.410	.093	-.150	.136	.185
2	-.573	.585	.315	.434	.074	-.122	-.075	.095	.079
3	-.059	-.293	.595	.048	-.089	.542	.362	.346	-.046
4	-.092	-.129	-.594	.610	.039	.490	-.017	.064	-.063
5	-.219	.207	-.270	-.426	.651	.174	.397	.159	.132
6	.216	.287	-.187	.115	-.472	-.154	.675	.045	.345
7	-.139	-.426	-.048	.081	.070	-.278	-.198	.439	.690
8	.034	.384	-.179	-.372	-.393	.301	-.395	.529	-.014
9	-.083	.083	.099	-.151	-.102	.470	-.179	-.591	.584

Extraction Method: PCA.
Rotation Method: Varimax with Kaiser Normalisation

6.4.Qualitative and quantitative outcomes

This section used the qualitative outcomes from Chapters 4 and 5 to complete analysis of SMEs' development of technological capabilities. Five factors were extracted from the PCA. The quantitative outcomes are reviewed below as an extension of the qualitative outcomes.

6.4.1. Absorptive capacity and development of technological capabilities in the surveyed SMEs

i) Founders' competences, firms' types of learning, and types of technological capabilities

The surveyed firms showed different sources of absorptive capacity (see Chapter 4). The qualitative findings in this chapter show that software are engaged in different types of learning (learning by searching through exhaustive R&D investment), compared to mass-production manufacturing firms, which are more related to learning by doing and using (repeat experience) (Chapter 4). The quantitative findings confirm that firms producing embedded systems and chemicals have high innovation capabilities, while the rest of the firms are highly correlated with production capabilities. Absorptive capacity, defined by Cohen et al. (1990) as the process of absorbing information that develops into knowledge, is influenced by different types of learning at a firm level (see also Malerba, 1992). Different types of learning are encountered in developing different types of technological capabilities (production/innovation). I found high levels of competence in founders of the surveyed firms producing embedded systems. In the component for *innovation capabilities* (see Section 6.4.2), founders' competences are highly correlated with firms' innovative capabilities and strong interactions with universities and percentage of white collar workers in the firm. Founders' competences influence the culture of learning in science-based firms.

The component of *production capabilities* indicates that the development of production capabilities is not strongly influenced by founders' competencies but is strongly related to tacit knowledge and learning by doing and using. The qualitative analysis shows that manufacturing firms are more likely to learn from repeat experience (tacit knowledge).

6.4.2. Technological capabilities and linkages in the automobile industry

i) Type of technological capabilities and agents interacting with the firms

In the surveyed SMEs, the quantitative outcomes show that firms with higher innovation capabilities have greater numbers of linkages with different agents in the system (such as government, universities, and chambers of commerce) (see component for *innovation capabilities*). In contrast, firms with high production capabilities only interact with government agencies (see component for *production capabilities*). The large number of linkages established by design firms may be explained by the great effort to engage in more channels of information, which enhances the firm's absorptive capacity to innovate. The qualitative findings show that agents (one industry association and one research centre) which made deliberate efforts to involve Mexican-owned firms have stronger interactions with SMEs (see Chapter 5). This confirms and reflects that agents with higher levels of performance in deliberate technological efforts may influence the firm's technical change.

These findings help explain that design firms make greater efforts to interact in the system to extend their absorptive capacity. Government influence is more related with establishing linkages for technological projects between foreign and science-based firms. For manufacturing firms, government influence is more related to training and funding.

6.4.3. Agents' impact on the development of technological capabilities

The qualitative analysis in Chapter 5 showed that Mexico lacks deliberate technological efforts. Policies are focused on diffusion, rather than innovation. The interviews with different agents show that they are more concerned with growth and development of the industry through foreign assemblers. Very few agents make deliberate technological efforts. These agents are involved in regional automobile clusters.

In the quantitative analysis, the *government influence* component for *production capabilities* is correlated with the presence of government and accumulation of physical capacity in the surveyed SMEs. This component also indicates that the government focuses on enhancing manufacturing techniques in SMEs without transferring technological knowledge from large firms.

6.4.4. A closer look at the interactions between large firms and domestic SMEs

The interactions between large firms and domestic SMEs are crucial for the development of technological capabilities. The qualitative findings show weak linkages with foreign firms in the industry. The quantitative findings provide no evidence on influence of large firms on SMEs.

The interactions between large firms and SMEs are reviewed only in relation to the qualitative findings in Chapter 4. The large firms do not interact in the Mexican automobile industry. The linkages established by these firms are limited to other foreign firms and exclude diffusing knowledge to other types of firms (such as domestic firms). Among SMEs, the qualitative analysis shows that firm founders acquired their knowledge from experience working in multi-national firms before setting up their firm. The quantitative analysis shows that stronger interactions between multi-national firms and SMEs are mediated by the interaction of agents in the system, rather than being developed further. Chambers of commerce, industry associations, and government are intermediaries in setting up linkages among foreign firms and SMEs.

6.5.Technological capabilities of the surveyed firms

Chapter 6 also sets out to identify the level of technological capabilities in the surveyed firms. The semi-structured interviews gathered information on these capabilities (Chapter 3), which was broadly confirmed by the qualitative analysis and partially confirmed by the quantitative findings (production capabilities, innovation capabilities, and investment capabilities). To identify the level of technological capabilities in the surveyed firms, I adopt a taxonomy of capabilities adapted to the automobile industry (Tables 6.4 and 6.5). They categorise firms based on the information gathered in the semi-structured interviews.

Table 6.4
Taxonomies of technological capabilities by function: Automotive industry

Taxonomy of capability	Concept	Description
Production capabilities	Capabilities needed to carry out activities in manufacturing	• Quality control • Production scheduling • Trouble shooting • Preventive maintenance • Minor adaptations to local conditions • Testing of final products • Inventory control
Investment capabilities	Capabilities needed to acquire new equipment or machinery	• Development of feasibility studies • Search for suppliers of technology: › Acquisition of machinery, equipment or software • Bargaining with suppliers • Drawing up contracts • Procurement of hardware • Plant erection • Process engineering
Innovation capabilities	Capabilities needed for creating new technological possibilities	• Adaptations to product or process • In-house R&D • Cooperative R&D • Adaptations to product or process (innovation) • Development of hand-operated equipment
Strategic marketing capabilities	Capabilities needed to be involved in new markets	• Involvement in new markets • Development of new distributions channels • Provision of customer services • Continuous improvement of the firm competitive advantages
Linkages capabilities	Capabilities needed to transfer technological knowledge and diffusion of knowledge	• Competence to organise knowledge and transfer technology to other networks within the firm • Competence to organise knowledge and transfer technology to other firms

Source: Adapted from Lall (1992), Romijn (1997), Kim (1999), Ernst et al. (1998), Malerba (1992), Revilla et al. (2003), and Padilla (2006)

Table 6.5
Firm-level technological capabilities

Level	Production	Investment	Strategic marketing	Firms
Basic	•Basic maintenance of facilities •Routine operations •Replication of fixed specifications and design •Assimilation of product design •Assimilation of processes technology •Qualitative control preventive •Inventory control •Minor adaptations to product to fit market needs	•Preparation of initial project outline •Site selection •Simple plant erection •Scheduling of investment •Feasibility studies •Outline planning •Equipment erection	•Continuous development of competitive advantage	Soluciones_di Sistemas_emb
Intermediate	•Processes improvement and cost saving •Licensing new technology •Assimilating new imported product technology •Product quality improvement •Monitoring productivity •Improved coordination •Automation of processes •Processes adaptation •Introducing organisational changes	•Technology choice •Overall project management •Search for technology choice •Negotiation of contracts •Equipment procurement •Training and recruitment of skilled personnel	•Development of new distribution channels •Provision of customer services	Mec_automotriz Herramentales Flextech Interiores Manufactura
Level	**Innovation**	**Linkages**	**Strategic Marketing**	**Firms**
Advanced	•Develop new processes specifications •Basic research •In-house processes innovation •In-house product innovation •R&D collaboration •Developing new production systems and components •Equipment design	•Collaboration in technology development •Licensing out of own technology •Turnkey capability •Cooperative R&D	•Involvement in other industries and international markets	Diseña Quimicos Industrias_MC

Source: Adapted from Lall (1992), Bell and Pavitt (1995) and Ariffin and Figuereido (2004)

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Different levels of technological capabilities were observed. For instance, firms with strong basic production capabilities were improving to an intermediate level of technological capability. Table 6.5 develops a new category of technological capabilities.

Table 6.6
Evolving scope of technological capabilities for the surveyed firms

<table>
<tr><th colspan="6">Technological capabilities</th></tr>
<tr><th colspan="2">Basic</th><th colspan="2">Intermediate</th><th colspan="2">Advanced</th></tr>
<tr><th>1*</th><th>2*</th><th>1</th><th>2</th><th>1</th><th>2</th></tr>
<tr><td>Soluciones_di
Sistemas_emb</td><td colspan="2">Herramentales
Mec_automotriz
Flextech
Interiores</td><td>Manufactura</td><td>Industrias_MC</td><td>Diseña
Quimicos</td></tr>
</table>

*Level 1 refers to a basic level of technological capability (within the category) and Level 2 refers to those firms that are evolving the scope of their capabilities.

Soluciones_di and Sistemas_emb have basic technological capabilities due to the lack of capabilities needed for the automotive industry. These firms lack production capabilities such as quality-control standards, inventory control, and 5's. Both firms are lagging in technology compared to other firms in the region and developed few efforts to increase their technological capacity.

Herramentales, Mec_automotriz, Flextech, and Interiores are evolving to intermediate capabilities. They have modern production processes in place, such as just-in-time and quality-standards certification, which are needed for the automotive industry. However, they are weak in other categories such as investment and strategic marketing capabilities.

Manufactura plays an important role in capabilities upgrading. The firm was established for four years and involved in innovating, and developed several linkages in the industry. This indicates efforts to increase the number of channels of information. The firm made huge efforts to acquire high-tech equipment and machinery from abroad, confirming its strong production capabilities. Manufactura developed new products with government funding for innovation. It is evolving from intermediate to advanced capabilities.

Quimicos, Diseña, and Industrias_MC have advanced technological capabilities. Quimicos and Diseña have good innovation capabilities, as seen by their production of patents and their own products. These firms have the highest percentages of white-collar workers, confirming the culture of learning in the firms. Industrias_MC is the oldest interviewed firm (50 years) and has strong physical capacity (three laboratories). The firm developed some of its own products but is less innovative than Quimicos and Diseña. It is categorised as having advanced technological capabilities but behind Quimicos and Diseña.

6.6.Conclusions

Chapter 6 presented PCA to validate and extend the findings of the qualitative analysis in Chapters 4 and 5. The PCA analysis in this chapter provides a method for analysing the development of firm-level capabilities. The analysis confirms the qualitative outcomes and extends them to a discussion of the factors underlying the development of capabilities.

The use of PCA enriched the findings on *founders' competencies, firm's absorptive capacity, development of innovation and production capabilities in SMEs, firms' technology upgrading based on knowledge accumulation*, *government influence*, and *development of efforts*. The results for the different components provide important information on the development of technological capabilities in the surveyed SMEs, as well as their process of technology upgrading. The results of this chapter support the qualitative findings of a lack of interest from the surveyed firms in interacting in the industry and developing technological capabilities in SMEs. In the PCA, the surveyed large firms show no significance for any of the components. Large firms interact with SMEs mainly through government schemes and other agents in the industry. To provide a framework for the development of technological capabilities in the surveyed SMEs, this chapter ends with a classification based on the qualitative and quantitative outcomes of the surveyed firms, grouping them according to their level of technological capabilities. This chapter builds on the literature on technological capabilities to present an adapted taxonomy for the automobile industry in Mexico.

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The main findings from the quantitative analysis are in line with the theories of absorptive capacity, technological capabilities, and NLS. The different types of firms (design and manufacturing) stress differences in the application of those theories. The findings from this chapter, and Chapters 4 and 5, are used in Chapter 7 to respond to the research questions.

CHAPTER 7: CONCLUSIONS

7.1. Introduction

The notion of technology upgrading has not been well developed in the literature, which has instead focused on technical change, thereby missing the process of technology upgrading for late industrialising economies. Similarly, in late industrialising countries, the literature has paid more attention to large and foreign firms as the main contributors for innovation. For this reason, the present thesis has focused on technology upgrading in small and medium-sized firms in developing countries such as Mexico. In this chapter, I present a summary of the findings and the conclusions from this research, recalling the theoretical literature and the empirical results obtained from the fieldwork to respond to the research questions. The study aimed to understand the process of technology upgrading of SMEs in the car industry by looking at the internal and external sources of technology for these firms.

This concluding chapter has five sections. Section 7.2 summarises the analytical framework of this research, before Section 7.3 presents and responds the research questions. Section 7.4 summarises the main findings of the research. Section 7.5 provides some policy implications related to the automotive industry and some policy recommendations in section 7.6, and also discusses some of the limitations of this research and identifies some avenues for future research.

7.2. Analytical framework

The analytical framework was designed for a firm-level analysis in order to integrate the findings of the surveyed firms (SMEs and foreign firms) with the findings of the surveyed NLS actors (governments, universities, chambers of commerce and industry). The findings of the surveyed firms consisted of: i) the role of foreign firms in the car industry (on diffusing technology); ii) the SMEs characteristics in terms of competencies, absorptive capacity and technological capabilities; and iii) the interactions between firms (case of study). The findings of the surveyed actors consisted of: i) the position of Mexico in the literature of NLS (active or passive country for technology upgrading); and ii) the role of the surveyed agents in the car industry.

Figure 7.1 summarises the framework and different bodies of the thesis. Chapter 1 presented the research questions and the literature reviewed in this research, Chapter 2 introduced empirical cases of the car industry and technology upgrading, and Chapter 3 presented the methodology and research design. Chapters 4 and 5 focused on the sub-research questions, and Chapter 6 reanalysed the two preceding chapters using a more quantitative approach.

Figure 7.1

The research questions and responses

Related concepts

Literature Review	Response framework	
Chapters 1 and 2	Chapter 4	Type of learning at firm level Firms' competencies Firms' efforts to acquire technology Firms' development of technological capabilities

Internal and External sources of capacity building in the Mexican auto-parts industry

Main research question

How do SMEs in the Mexican automotive industry upgrade their technology?

- Technological capabilities
- Absorptive capacity and competencies
- National Learning Systems

Complementary research questions

How do SMEs in the Mexican automotive industry upgrade their technology through interactions with larger firms in the global value chain?

How do SMEs in the Mexican automotive industry upgrade their technology through interactions with other actors in the National Learning System?

Response framework	
Chapter 4	• Technology transfer between foreign firms and local suppliers Activities involved in the supply chain
Chapter 6	• Quantitative approach through PCA • Technological capabilities encountered in the surveyed SMEs • Foreign firms' technology transfer

Response framework	
Chapter 6	• Active NLS versus passive NLS (comparative macro-analysis) •Agents' efforts to transfer technology in the car industry

7.3. Research questions and answers

Main research question:

- *How do SMEs in the Mexican automotive industry upgrade their technology?*

This research question aimed to examine the internal and external sources that contribute to the SMEs' technology upgrading in Mexico. I approached this question by developing a firm-level analytical framework that integrates the firm's competencies, absorptive capacity, and technological capabilities together with the firms' interactions in the NLS to understand the process of technology upgrading. I aimed to answer this question using semi-structured interviews with a set of questions related to competencies, (Von Tunzelmann, 2009), absorptive capacity (Cohen and Levinthal, 2001, Figueiredo, 2003; Malerba, 1992), and technological capabilities (Ben and Pavitt, 1993, 1994; Kim, 1998,1999; Lall, 1992, Romijn, 1997). These questions focused on how technology was absorbed and assimilated in order to decode it and apply it in the firm. The questions referred to the founders' and workers' competencies (level of studies), firms' dominant type of learning (Malerba's category), the type (production, investment, innovation, linkage capabilities) and complexity of technological capabilities (basic, medium, advanced), the influence of other sources for the continued development of technological capabilities, and the efforts exerted to acquire technology. To examine the firms' interactions in the NLS, the following two sub-questions were elaborated:

- How do SMEs in the Mexican automotive industry upgrade their technology through interactions with larger firms in the global value chain?

- How do SMEs in the Mexican automotive industry upgrade their technology through interactions with other actors in the National Learning System?

The first sub-question looked at interactions with the SMEs' customers (assemblers). The aim of this question was to help understand the extent and influence that foreign firms have for technology upgrading over their local suppliers in developing countries. It also aimed to examine the transfer of technology between assemblers and suppliers in the car industry. To respond to this question, I included a set of questions related to the type of relations in the supply chain (Mentzer et al., 2001) and activities in the supply chain (Lall, 1980). I also examined the transfer of technology and creation of knowledge in the value chain (Ivarsson and Alvstam, 2009; Lundvall, 2002; Morrison, 2008; Wu, 2008), as well as spill-overs in the supply chain (Atallah, 2002; Feldman and Kelley, 2006). These questions also identified and confirmed the literature on structures in the car industry in developing countries (Alternburg, 2000; Humphrey, 2003) and the relations established between large firms and SMEs in developing countries (Rothwell and Dodgson, 1991).

The second sub-question looked at the interactions established in the NLS. The purpose of this question was to examine the involvement of SMEs in the NLS and the efforts exerted to acquire technology in the system. I also looked at the impact of other actors for the firms' absorptive capacity and their role in establishing linkages in the value chain. I attempted to answer this question using a set of questions related to technology transfer in the system (Sandhya, 2002), the role of authorities regarding relations in the supply chain (Atallah, 2002; Feldman and Kelley, 2006), Mexico's efforts towards technology upgrading (Enos, 1991; Nelson, 1993; Viotti, 2002), and the functions of institutions (Edquist, 2006; Radosevic, 1999).

The SMEs in the Mexican automotive industry upgrade their technology through different sources. From the surveyed SMEs, I observed that competencies play an important role in the further understanding and decoding of technology. The founders' competencies and the number of white- and blue-collar workers are strongly related with the type of firm (software house or manufacturing firm) and these are also related with the main type of learning in the firm (Malerba's taxonomy of type of learning at the firm level). The surveyed software houses mainly learn from advances in science and technology. The founders of these firms are highly educated (holding technical diplomas, MsC or PhD) and over 60 percent of their workers are white collar. These findings confirmed the literature on competencies and absorptive capacity for the development of technological capabilities. The complexity and type of technological capabilities were assessed to observe the firms' technology upgrading. The surveyed software houses have developed advanced production capabilities and innovative capabilities. The linkage capabilities for these firms were observed in their relations with universities, research centres and central government agencies. Those firms with higher number of linkages in the systems were considered as active agents for the technology upgrading of the car industry. Most of the surveyed software house firms showed weaker linkages with foreign firms. These firms mainly upgrade their technology through intensive absorptive capacity, ambitious investments in competencies and acquisition of technology (up-to-date machinery and equipment), and intensive efforts to establish linkages in the system.

In contrast to the surveyed software house firms, the manufacturing firms rely heavily on the transfer of technology from foreign firms. For these firms, the structures of the value chain and the activities of the supply chain were clearly identified and confirmed the literature on these issues. The manufacturing firms have received technology in the form of product/processes specifications, technical requirements/assistance, production techniques, training, quality management, advice on tooling and maintenance, etc. The establishment of relations with foreign firms and the duration of these relations have been monitored by central authorities who have influenced the transfer of technology from foreign firms to local suppliers. For the surveyed manufacturing firms, the absorptive capacity and the main type of learning is based on the development and accumulation of tacit knowledge through doing, using and spill-overs. The technology upgrading for these firms has mainly been observed through the development of investment capabilities, medium-to-advanced production capabilities, and strong relations in the system with government agencies and foreign firms.

I identified those surveyed firms (software house and manufacturing) with few or null relations in the system. These firms were observed in a passive role for technology upgrading in the car industry and have made minimal efforts to acquire technology through interactions in the system. Of the software house firms, Soluciones_di has mainly upgraded its technology through learning by spill-overs and strong interactions with its customers (foreign firms). The founders of Soluciones_di worked in the car industry during the establishment of their firm and have access to up-to-date technology through their employers (assemblers). Of the manufacturing firms, Interauto and Flextech have established recent linkages with other actors in the car industry. These firms were founded by foreign investors and were established in Mexico to supply specific assemblers. The technology upgrading for these firms has been mainly observed through the transfer of knowledge received from their parent companies.

The intensity of efforts is important for the technology upgrading. Therefore, these efforts were assessed by establishing linkages to acquire technology in the system for the surveyed firms and the efforts exerted by the countries to enhance the national absorptive capacity, competencies and acquisition of technology. I developed a comparative approach in order to position Mexico in the category offered by Viotti of passive and active countries for technology upgrading. According to the NLS literature, Mexico is a passive system in terms of undertaking technology upgrading and has focused its efforts mainly on the absorption of technology rather than creation. Like other Latin American countries, Mexico have exerted recent efforts in the car industry. Similarly, the surveyed foreign firms displayed passive behaviour with regard to enhancing their technology upgrading in the car industry. These firms have established few or no relations in the car industry, and these few relations have been established through government involvement. These firms mainly established relations with other foreign firms.

7.4.Research contributions and findings

The contributions of this thesis are theoretical, empirical and methodological. The theoretical and empirical contributions are important in light of the small number of studies that have focused on absorptive capacity for SMEs and technology upgrading in developing countries. The literature has stressed the importance of technical change, which misses the process of upgrading for late industrialised economies in which the access to technology is hindered by the failures of the country. Along the same lines, the traditional literature has focused on the development of technological capabilities (an important determinant of technology upgrading) in large firms that possess the resources to undertake significant changes and catch up. The literature also ignores technological capability building in small firms, which lack sources and rely mainly on their absorptive capacity and indigenous skills to assimilate new technology. In developing countries, small firms have indigenous capabilities embedded in the national efforts and institutional frameworks that are required for industrialisation. For these countries, whose economies are often based on and dependent on foreign subsidiaries, attention and policies aimed at small firms are important for building technological knowledge based on national indigenous capabilities.

Another significant contribution of the thesis is the primary data collected and analysis of the empirical findings on absorptive capacity in developing countries. This enabled exploration of specific aspects of firms' interactions and the influence of other actors within the NLS, as well as many of the structural characteristics of these firms. These characteristics include the skills of managers and founders, which help define the potential for these firms to build in-house competences and capabilities. This process involved collecting information on firms that were not considered in the development of policies for the automobile industry. In addition, the thesis stresses the importance of NLSs for developing countries, where systems learn through absorbing technology from industrialised economies.

The findings from this research contribute to the discussion on the importance of SMEs in the economy for the development of policies in developing countries that are on a path of industrial catch-up. It contributes to the capabilities literature on small firms in developing countries, as well as the literature of technology upgrading. The main bodies of literature used in the development of the present research are: i) technological capabilities and absorptive capacity, ii) global value chains, and iii) NLSs. The framework developed in this study places the small firm at the centre of the analysis of technology upgrading and expands it to the study of the influence of interactions with foreign firms and actors in the NLS to adopt and assimilate new technology in developing countries. The main findings of the research are summarised below.

7.4.1. Technology upgrading in developing countries

The main contribution of this research is its study of the process of technology upgrading through absorptive capacity, development of technological capabilities and the transfer of technology in the global value chain and NLS. The process of technology upgrading is important for developing countries because explains how late-industrialised economies with innovation shortcomings undertake incremental changes to achieve industrialisation. The following sections summarise the main contributions and findings that this thesis offers to the literature of technology upgrading in developing countries.

i) Absorptive capacity in developing countries

An important methodological contribution that this research makes is its approach to the study of absorptive capacity in small firms in developing countries. My analytical approach of absorptive capacity involved theories of learning at the firm level, acquisition of competencies, and development of efforts to acquire technology. These efforts were observed through interactions in the NLS and the transfer of technology with foreign firms.

Chapter 4 presented the case study of the surveyed SMEs, in which I described the main types of learning in the firm, the efforts to assimilate new technology, the relations established with foreign firms and the transfer of knowledge, and the efforts exerted to acquire new technology through interactions in the NLS. This chapter summarises the different types of learning observed for the surveyed firms and concludes that software houses learn different from manufacturing firms, which means that the technology upgrading has taken different paths. For software houses, the founders' competencies are important in terms of shaping the firms' type of learning. Similarly, I cannot dismiss the possibility that the nature of the product requires different types of learning. For manufacturing firms, the relations with foreign firms have been important for the firms' technology upgrading.

In order to understand the context of the surveyed firms in Chapter 4, Chapter 5 presented the country's efforts to enhance the national absorptive capacity in Mexico and the role of the different actors in the NLS to enhance technology upgrading in the car industry.

Chapter 5 positioned Mexico in the NLS literature and presented indicators of the country's efforts in the categories of competencies, development of sources for technological learning, and technology acquisition and patents. Chapter 5 also presented the role of the different actors of the NLSs in the car industry and described the activities that the Mexican government has undertaken to enhance the development of relations between foreign firms and local suppliers. Chapter 5 concluded that, despite the efforts of the Mexican government to enhance the absorption of technology in the car industry, most of the efforts directed at local suppliers are quite recent (since 2009).

Chapter 6 presented a quantitative approach through the use of PCA and concluded that absorptive capacity heavily relies on the type of learning, competencies and efforts exerted for the acquisition of technology. Foreign firms are also an important source of technology transfer and most firms have been set up as result of spill-overs of these firms in the car industry.

ii) Development of technological capabilities

An important contribution that this thesis makes to the literature is its approach to the study of technology upgrading. The research focused on the development of technological capabilities as a main determinant of the process of technology upgrading at the firm level. To observe the development of technological capabilities, the research looked at the absorptive capacity and efforts exerted for the firms to adopt and apply the technology acquired for the firms' own purposes. To validate this, the fieldwork collected information related to the accumulation of tacit knowledge and some indicators that lead me to believe that firms have developed new capabilities regarding technology. The proxies of technological capabilities were taken from the reviewed literature.

Another important contribution that this study makes to the literature is its taxonomy of capabilities by function presented in Chapter 1 and the differences encountered from various scholars. The literature has paid more attention to production, investment and innovation capabilities than to the importance of linkage capabilities or strategic marketing capabilities for small firms. The present thesis aimed to stress the importance of linkages capabilities for the acquisition of technology in the industry. Linkage capabilities were observed through the relations established with other firms and the science and technology infrastructure. Chapter 4 introduced the number of linkages and purposes of these linkages for the acquisition of technology, before Chapter 7 presented a taxonomy of technological capabilities adapted for the automobile industry. The technology upgrading has been observed in different ways for the surveyed firms. Software house firms have developed advanced production capabilities and innovation capabilities, while manufacturing firms have been more concerned with upgrading their production capabilities to satisfy customers' requirements in terms of production. Tacit knowledge has also played an important role in the development of technological capabilities for the surveyed firms, which confirms the literature on the development of technological capabilities at the firm level.

iii) Transfer of technology in the global chain

The literature has acknowledged the importance of foreign firms for technical change in developing countries. In this regard, this thesis has provided insights into the role that foreign firms play in the transfer of technology in the car industry and the extent of their involvement in developing countries. I found that foreign firms have little or no participation in the car industry and do not interact with local suppliers (Chapter 4). The Mexican government has played an important role in the development of interactions between foreign firms and local suppliers. The surveyed foreign firms showed the behaviour of global mega suppliers (Humphrey, 2002). These firms follow their customers around the world and have close and strong relations with a small number of foreign firms. Despite these findings, I cannot dismiss the importance of foreign firms for local suppliers. The surveyed SMEs have mainly learnt the basis of their business through spill-overs from foreign firms. The SMEs' founders worked in the car industry learning about design, production and certifications (quality standards) before establishing their own firms. Another important role of foreign firms in Mexico is that these firms certify local suppliers to integrate them into the car industry. To do so, foreign firms transfer technology to local suppliers and this is the most important source of technology upgrading for some surveyed SMEs. Another important finding in terms of this research was the perception of foreign firms over local suppliers. It is difficult for foreign firms to interact with these firms because of the considerable efforts involved in upgrading them. According to foreign firms, local suppliers lack the capability to catch up with the technology they are providing. However, this thesis also showed that the surveyed SMEs have been successful in adopting and assimilating the technology they have received from foreign firms.

iv) Transfer of technology in the NLS

This thesis stresses the importance of NLS in the literature focused on developing countries. The concept of learning through absorption has not been widely used in the literature of systems of innovation. Instead, the literature on systems of innovation has focused largely on the interactions between firms, universities and government agencies to diffuse technology and respond to the signals of innovation. For developing countries, the concept of national innovation systems has ignored the shortcomings existing in the system to respond to the signals of innovation. Studies focused on developing countries have acknowledged these shortcomings and have concluded that the national innovation system does not look at the process of technical change (learning through absorption and incremental change) that occurs in late industrialised economies. This research aims to contribute to the literature on developing countries by providing a different view of technical change through technology upgrading and by providing another view of national systems of innovation by using the concept of national learning systems. In addition, the methodological contribution in the study of NLS was its approach, in which firms are the centre of the analysis; this makes it possible to understand the weaknesses and strengths of industry policies.

This thesis has looked at the interactions established by SMEs in the NLS for the acquisition of technology. In this regard, an important empirical finding for this research is that government plays an important role to enhance the absorption of technology between foreign firms and local suppliers. However, many of the efforts in the literature related to this matter have been quite recent and no policies have focused on SMEs in the car industry. For the surveyed central agencies, the car industry consists only of foreign firms that have the resources to create employment in Mexico. Similarly, chambers of commerce and industry have limited their services to large firms. In this regard, stronger efforts to involve

SMEs were observed in regional industrial clusters where these firms receive more significant technology in the form of training, information and establishment of linkages with regional foreign firms. Also, SMEs acknowledged the importance of being involved in regional clusters. Chapter 6 discussed the efforts undertaken in Mexico for technology upgrading and posits that Mexico is a passive system given its minimal efforts to catch up. In contrast to more active systems, Mexico has lacked ambitious policies for technology acquisition and innovation. In 2003, for instance, the gross domestic expenditure on R&D from businesses for industrial production and technology in South Korea (active system) was 13 times greater than that of Mexico, while South Korea's government expenditure was six times greater than that of Mexico. The country's efforts to enhance the absorption on technology in Mexico have mainly been through the development of competencies (education and training of labour force).

7.5.Policy implications

This thesis has provided insights into the process of technology upgrading in developing countries such as Mexico. It has also revealed imbalances in the development of interactions within the industry and inequalities in policies oriented to SMEs. In this regard, government efforts exerted in regional clusters have succeeded in reducing the imbalances that exclude SMEs from policies in the car industry. In this regard, other studies on Latin America have also acknowledged the importance of industrial clusters to strengthen the weakest firms and to the strengthen institutions in charge of development of science and technology (Giuliani et al., 2005, Padilla, 2006). In line with these studies, I propose some recommendations on technology upgrading in developing countries.

i) Enhancement of absorptive capacity at the country level

The empirical evidence based on the surveyed SMEs and the comparative country analysis in Chapter 5 showed that competencies (education and training of the labour force) are important for technology upgrading at the firm level. In this regard, some shortcomings in this matter are related to the labour force. In this regard, the firms involved in the automotive AERI have voiced this problem to central government representatives and are also exerting efforts through regional clusters to update the knowledge on basic science in the region. According to the surveyed founders of the software houses, they make huge investments in upgrading the knowledge and skills of their workers. As one interviewee stated: “Now the curricula has changed and introduced marketing instead of mathematics III and the students are losing motivation to learn mathematics and basic science. Currently, students do not have any motivation to study some technological degree and they are learning that embedded systems are a black box that they cannot understand.” The surveyed software house firms located in Chihuahua are working with regional high schools to upgrade mathematics and physics education. They are also holding workshops on basic programming for third-year tertiary students.

ii) Enhancement of technological capabilities through industrial clustering

The evidence showed that firms involved in industry clusters establish stronger interactions in the industry. Foreign firms encompass higher levels of technological knowledge in the region. These firms make deliberate efforts to upgrade the capabilities of their suppliers, which include numerous SMEs.

Foreign firms involved in regional clusters develop a sense of community and attempt to work with domestic firms and regional agents. As a manager of one multinational firm told me, “We do not have to work with small firms; it is not a Prerequisite for the firm, but we do it because we are Mexicans and we are located in Mexico.” An example of this situation is the electronic cluster of Jalisco, which is contributing to the regional technical change (see Padilla, 2006 and Chapter 6 of this thesis). In this regard, research centres such as CINVESTAV are actively responding to the signals of innovation in the system. CINVESTAV has also diffused technology to small local firms.

Policy makers should attempt to enhance the growth of regional clusters in order to foster technology transfer in the industry. An example of such efforts by local government agents is the cluster of Nuevo Leon. The region’s main objective is to enhance the growth of the regional industry to attract more multinational firms, and this has involved small firms in the cluster. The main intermediary between large firms and small firms is the industry association CLAUT. This organisation is in charge of integrating universities, large firms and domestic firms in the region with the purpose of enhancing technological capabilities in the cluster. CLAUT was set up in 2007, and by 2010 the chamber created groups focused on firms' needs (local suppliers); these practices involve multinational firms that transfer technology through workshops and trainings. However, not all industry clusters have achieved the same success as Nuevo Leon or Jalisco. As one interviewee stated: "To be honest, this chamber [CLAUT] is growing very quickly. I have worked in similar chambers in other regions and they have not achieved the goals we have achieved in this chamber. Perhaps one reason for this is the high interest of local government representatives in this industry." Small firms also confirmed that being involved in organisations in the regional cluster brings more benefits than being involved in central automobile industry organisations because national efforts are only directed at foreign firms (see Chapter 6).

The data collected from the surveyed central and regional government agencies confirmed that policies are oriented towards multinational firms in order to attract FDI and increase employment. However, the presence of multinational firms does not guarantee absorption of technology. It is important that the government monitors and promotes the transfer of technology from foreign firms to local suppliers. Similarly, policies cannot ignore the presence of small firms in the automotive industry and it is necessary to have policies oriented to these firms' needs.

7.6.Further analysis

Based on the empirical findings and contributions to the literature mentioned above, this research deserves to be expanded in a historical study of the paths of technology upgrading in active and passive NLS. In such case closer cases to the Mexican auto-parts industry can be considered such as Turkey. With this understanding, policies based on the idiosyncratic structures of Mexico can be formulated to support the process of technology upgrading. A case study of the interactions between the surveyed SMEs and their current customers (foreign firms) is also important in order to understand the linkage capabilities embedded in foreign firms to transfer technology in the industry.

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The main limitations in this research include a lack of information about SMEs in the Mexican car industry. In Chapter 3, I described the efforts that have been made to collect information on these firms. Also, the government programmes on technology transfer were only implemented quite recently (one year before the fieldwork) and were not properly assessed given their newness. Technology upgrading is a long-term process and a longer-term perspective is needed to corroborate the effectiveness or ineffectiveness of these programmes.

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APPENDIX

Worldwide auto-parts suppliers: Tier 1

Name	Revenue	System	Sub-system
Robert Bosch GmbH	51,328		Art lights, brake systems, batteries, wiper blades, starters and air filters.
Denso Corporation	29,132	Engine Management	Gasoline engine management, Diesel engine management, Starters, Alternators, Radiator, Front-end module
		Climate Control	Car air conditioning system, Ejector Cycle
		Body Electronics	Head-Up displays, Instrument clusters, Parking aid system, Remote Keyless entry system, passive entry and start system
		Driving control & safety	Airbag sensing system, Adaptive cruise control system, Pre-cash safety system, Adaptive front-lighting system, Discharge headlamp system, Electric power steering system
		Hybrid vehicle components	Battery ECU, DC-DC converter, Integrated starter generator, Electric compressor
		Info&Communication	Car navigation system, Electronic toll collection system, Data communication module
Johnson Controls Inc	27,479	Seating	Metal structures and mechanisms (foam, trim), Climate systems, Safety systems, Front seats, Rear seats
		Interiors	Cockpits & instrument panels, Door panels & door systems, Beltline up, Floor consoles
		Electronics	Human machine interaction (HMI) design, Driver information (Intruments clusters, displays, compass systems, clocks, park-distance warning displays), Body electronics (body control modules, access control systems, immobilizers/anti-theft systems, tire pressure monitoring systems, interior control modules), Energy management (battery management systems, intelligent electronic power distribution modules)
Delphi Corporation	26,947	Body & Security	Body electronics, security and vehicle access systems
		Driver interface	Displays and Mechatronics, switches and controls.
		Entertainment & Communications	Audio systems, mobile video, connectivity
		Electrical and Electronic architecture	Cables and wiring, Connection systems
		Fuel Cells	
		Hybrid and Electric vehicle products	Battery pack systems, controllers, DC to DC converter, Electric vehicle charging systems, Evaporative emissions systems, High voltage wiring

Name	Revenue	System	Sub-system
Delphi Corporation		Powertrain systems	Diesel engine management systems, Evaporative emissions systems, Fuel handling systems, Gasoline engine management systems, Transmission management systems
		Sensors	Chassis, Engine and transmission
		Thermal systems	Heating and cooling (compressors, HVAC controls, HVAC systems, powertrain cooling)
Bridgestone Inc.	24,340	Tyres	
Magna International Inc	22,811	Body & chassis systems	Body systems, chassis systems
		Powertrain systems	Driveline & chassis control systems, Fluid pressure & controls, Stampings, Die castings, Engineering services & system integration
		Exterior and interior systems	Front and rear end fascia systems, Greenhouse and sealing systems, Exterior trim, Vehicle enhancemente packages, plastic body panels, Roof systems, Engineered glass
		Seating systems	Seat complete, seat mechanisms
		Exteriors & Interiors	Sidewall and trim systems, Cockpit systems, Cargo management systems, Overhead systems, Carpet and Loadspace systems.
		Vision systems	Interior mirrors, Exterior mirrors, Actuators, Electronic vision systems, Door handle & overhead console technologies
		Closure systems	Door modules, Window systems, Power closure systems, Latching systems, Handle assembles, Driver controls, Obstacle detection systems
		Roof systems	
		Electronic systems	Driver assistance & safety systems, Intelligent power systems, Body electronics and HMI, Lighting systems, Liquid sensors
		Fuel systems	Tank components, Fuel systems
Goodyear Tire & Rubber Co.	19,723	Tyres	
Aisin Seiki Co. Ltd	19,376	Drivetrain related products	Automatic transmissions, Manual transmissions
		Brake & chassis related products	Rear drum, Master cylinder with brake assist booster, Disc brake, ABS modulator
		Body related products	Door components; Roof exterior, and structural components; seat components

Name	Revenue	System	Sub-system
Aisin Seiki Co. Ltd		Engine related products	Cylinder head cover, Intake manifolds, Variable valve timings, Timing chain cover, Oil pumps, Water pumps, Pistons
		Information related products	Car navigation system, Keeping assist system, Parking assist system, Intelligent parking assist
Michelin Group	19,300	Tyres	
Continental AG	17,130	Chassis and safety systems	Electronic bake systems, Hydraulic brake systems, sensors, Driver assistance systems, chassis components
		Interiors	Body and security systems, Visual display systems, control elements, Radios and multimedia systems
		Powertrain systems	Engine systems, Hybrid, Transmission, Sensors and Actuators, Fuel supply
Lear Corporation	17,089	Seating systems	
		Electronic systems	Electrical distribution systems, Terminal and connectors, Junction box, Gateway modules, Seating modules, Body control modules, Interior LED electrocnics, Exterior LED electronics. Adaptative Front Lighting systems,
		Environmental systems	Power distribution, Charging systems, Energy management
Visteon Corporation	16,976	Climate Control	Climate systems, Clymate controls, Fluid transport systems, Compressors, Heat Exchangers, Battery cooling module, Airflow management,
		Electronics	Audio systems, Analog/digital instrument cluster,
		Interiors	Door trim, Instrument panel, Floor console
		Lighting	Front and rear lighting systems

Name	Revenue	System	Sub-system
Toyota Industries Corporation	13,760	Engines	
		Compressors	Fixed-displacements type compressors, Continuos variable-displacement type compressors, Electrically-driven compressors, Aluminum die-cast products
		Electronics	Charging systems, Converters and Inverters for the battery system
		Stamping dies	
Faurecia	13,592	Acoustic package	
		Seating systems	
		Door system	
		Cockpit	
		Emssions control systems	
		Front / End systems	
ZF Group	13,411	Transmissions	Dual and manual transmissions, Automatic transmissions, Mechatronic module transmissions
		Driveline components	Dual clutch system, Torque converter, Dual mass flywheel
		Axle systems	Front and rear axles, Corner modules,
		Chassis components	Electronic damping system, Sensitive damping control, Leveling system, Sensor module
		Steering	Electronic steering, Steering pump, Steering columns, Active steering
		Electronic components	Electronic control units, Sensors, Swithpacks, Component carrier
TRW Automotive Holdings Corporation	12,643	Cognitive safety integration	Driver assistance systems, Lateral support, Adaptative cruise control, Integrated active and passive safety systems
		Steering systems	Hydraulic and electric steering, Lightweight linkages
		Braking systems	Electronic stability control, Electric park brake, Foundation brakes, Hybrid systems

Name	Revenue	System	Sub-system
TRW Automotive Holdings Corporation		Occupant safety systems	Airbags, Adaptative front restraint system, Side and curtain airbags, Frontal airbags, Seat belt systems, Steering wheels, Inflators
		Electronic systems	Sensor technologies, Radar technologies, Camera technology, Integated electronics, Airbag control unit & remote sensor, Crash sensors,
Valeo SA	12,297	Powertrain systems	Electrical systems, Transmission systems, Enine management systems, Air management systems, Hybrid and electric vehicle systems.
		Thermal systems	Climate control, Powertrain thermal systems, Compressors and Front-end modules
		Comfort and driving assistance systems	Driving assistance, Interior controls, Interior electronics, Access mechanisms
		Visibility systems	Lighting systems, Wiper systems and Wiper motors
Eaton Corporation	11,115	Engine valves, Lifters and Valve actuation	
		Superchargers	
		Differentials and locking differentials	Electronic limited slip, Mechanical locking differentials, Electronic locking differentials, Limited slip
		Gears	
		Advanced machining products	
		Powertrain controls	Transmission valves, Transmission manifold assemblies
		Fluid convenyance	Active suspension systems, Oil cooling assembly, Quick connectors, Air conditioning
		Fuel emissions controls	Grade vent valve, Roll-over valve, Fuel limit valve

Name	Revenue	System	Sub-system
Eaton Corporation		Plastics	Cylinder head cover, Oil pick-up pipe, Air intake tubes, Engine noise cover, Oil pan, Radiator tank, Belt cover, Fan shroud
Arvin Meritor Inc.	8,903	Axles	
		Brakes and safety systems	
		Drivelines	
		Suspensions	
		Light vehicle body systems	
Dana Corporation	8,699	Drivetrain related products	Axles, Driveshafts, Drivetrain systems
		Sealing products	Air ducts, Cylinder head covers, Fuel cell products, Transmission sealing pan module, Gaskets, Heat shield and thermal acoustical, Valve stem seals
		Thermal systems	Charge air, Engine oil, Fuel, Hybrid-engine cooling, Power steering oil, Small engine cooling, Transmission oil, Fuel cell products
GKN plc	6,612	Driveline	Sideshafts
		Cylinders	
		Powder metal components	Sintered structural parts,
		Land systems	Clutches, Gearboxes, Linkage systemdriveline components
Federal-Mogul Corporation	6,286	Powertrain energy	Pistons, Piston rings, Power cylinder system, Ignition
		Powertrain sealing and bearings	Bearing, bushings and washers gaskets, Thermal and acoustic heat shields, Seals
		Safety and protection systems	Friction, Systems protection, Lighting, Wipers, Fuel
Autoliv Inc.	6,205	Safety and protection systems	Frontal and side-impact airbags, Active seatbelts, Buckle, Height adjuster, Load limiter, Pretensioners, Retractor
		Electronics	Night vision, Electronic control unit, Satellite sensor
		Steering wheels	Fixed-hub

Source: Own elaboration

INTERVIEWS FOR AUTO-PARTS SMEs

GENERAL COMPANY INFORMATION			
NAME OF THE COMPANY			
LEGAL ENTITY			
LOCATION (Old and current location)			
TELEPHONE NUMBER			
EMAIL ADRESS		WEB ADRESS	
INTERVIEWEE NAME		POSITION	
YEAR OF FOUNDATION			
MAIN MANUFACTURED PRODUCTS WITH THEIR TOTAL % OF PRODUCTION.			

MANAGER´S BACKGROUND			
How many persons set up the company?			
What is the highest level of studies of the manager (partners) of the company? (For the case of university and postgraduate degree, please mention the university´s name and the first degree)			
Does the manager of the company have previous working experience in: (More than one answer is permitted)			
Car producers (area)____________________	☐ Years: ______________ Job		
Multinational automotive components manufacturer (area)____________________	☐ Years: ______________ Job		
Multinational components manufacturer (area)____________________	☐ Industry_____________ Years: ______Job		
Maquiladoras (area)____________________	☐ Industry_____________ Years: ______Job		
Local large firms (area)____________________	☐ Industry_____________ Years: ______Job		
Small and medium firms (area)____________________	☐ Industry_____________ Years: ______Job		
Other			
Has the previous experience influenced in the following kind of knowledge? (More than one answer is permitted) Self Partner 1 Partner 2			
Knowledge of product-centered technology	☐	☐	☐
Knowledge of process and organization technology	☐	☐	☐
Knowledge of markets	☐	☐	☐
Other (please specify):			
What are the master skills of the manager and **how did the manager develop** them?			

HUMAN RESOURCES		
	Number of employees	Master skills
Blue collar workers		
Supervisors		
Technicians		
Engineers		
Administrative personnel		
Others (please specify)		

How many employees does the firm have with the following educational level?	
No schooling	
Elementary school	
High school (first three years)	
High school (six years)	
Technical education	
University degree	
Postgraduate studies	
Other (please specify)	
Over the last three years has the firm recruited qualified workers?	Yes ☐ No ☐
If yes please comment it (e.g. educational background, master skills, working experience)	
Does the firm provide training to the employees?	Yes ☐ ° External ☐ Where ____________________________________ Number of hours__________ ° Internal ☐ Number of hours__________ No ☐
If yes please comment **the kind of** training **and who** carry it out.	
What skills are aimed to develop with those trainings?	

Which of the following sources does the firm use to recruit its employees?
Universities ☐ Recruitment agency ☐ Research centre ☐ Other
What kind of employees does the firm seek?
Does the firm find the qualified employees in this region? Yes ☐ No ☐
Is the firm receiving training or consultancy from universities, research centers, large firms or industrial associations?
Yes ☐ Who____ No ☐
If yes please comment the aims of those trainings or consultancy.
What activities is the manager doing to increase his knowledge and skills related to the firm?

SUPPLY CHAIN

MAIN CUSTOMERS

NAME	SUPPLIED PRODUCT	%TURNOVER	LOCATION	NATIONALITY	YEARS OF RELATIONSHIP

What your large consumers consist of? (Please tick the options more than one answer is permitted)

Car producers ☐
Multinational automotive components manufacturer ☐
Multinational components manufacturer ☐ Industry ________________________________

Maquiladoras	☐
Large suppliers from Mexico	☐
International large suppliers	☐ Nationality_______________________________
Local firms	☐ Industry__________________________________
Small supplier of automotive components	☐
Other	
Is the firm involved in exporting activities?	Yes ☐ No ☐
If yes what are the international markets?	
What kind of consumers does the firm seek?	

MAIN SUPPLIERS OF PRODUCTS				
NAME	SUPPLIED PRODUCT	LOCATION	NATIONALITY	YEARS OF RELATIONS HIP

Does the firm import capital goods?	Yes ☐ Where____________________ No ☐ Kind of capital goods_______________________________________
Does the firm import products?	Yes ☐ Where____________________ No ☐ Kind of goods____

INVESTMENT CAPABILITIES				
How many machines does the firm have?				
Machine	Originally new	Second hand	Supplier	Nationality of the supplier
	☐	☐		
	☐	☐		
	☐	☐		
	☐	☐		
	☐	☐		
	☐	☐		
	☐	☐		
Is your machinery behind or ahead the average of the industry in this region?				

☐ Ahead ☐ Behind ☐ Average ☐ Not known.	
For how many years ahead or behind?	
Has the firm received from any of the following institutions or large firms machinery or equipment? (More than one answer is permitted)	
University Who____	☐
Large firms Who____	☐
Research centre Who____	☐
Industrial associations Who____	☐
Technology suppliers Who____	☐
Other	
If yes please explain the kind of collaboration.	
How important has been that collaboration for the firm and why?	
Has the firm received any kind of support from the government in order to acquire machinery or equipment?	Yes ☐ No ☐
If yes please explain the kind of collaboration.	
How do you asses this support from the government and explain why this answer?	
What activities is the firm doing in order to acquire knowledge related to the firms' activities (process and production)?	

Over the last three years has the firm made adaptations to local conditions?	☐ Yes ☐ No
If yes please explain it.	

TECHNOLOGICAL CAPABILITIES

BACKGROUND

What was the production capacity when this **firm was set up** and what is the production **capacity now**? (e.g. product, number of machinery, kind of machinery, production process, kind of client, consumers)?

What problems have affected the **technological** and **managerial** improvements within the firm?

What activities have influenced for the improvement of your machines/equipment?

PRODUCTION CAPABILITIES

Does the firm work with any of the following techniques?

Control parameters	☐ Yes ☐ No
Internal manuals	☐ Yes ☐ No
Inventory control	☐ Yes ☐ No
Lead time	☐ Yes ☐ No
Just in time	☐ Yes ☐ No
Maintenance of equipment	☐ Yes ☐ No
Preventive maintenance	☐ Yes ☐ No
Production schedule	☐ Yes ☐ No
Quality control standard	☐ Yes ISO_______________/______________/_____________ Other____ ☐ No

Testing of final product	☐ Yes ☐ No
Trouble shooting	☐ Yes ☐ No
Others	

Has the firm been involved with institutions, universities, large firms or others in order to develop the previous techniques?	
☐ Yes ☐ No	
If yes please explain who did you received it from and the kind of collaboration.	
What of the previous techniques were developed by the firm itself?	
Please explain the position of the employees involved in the development of these techniques?	
Has the company changed any of the techniques stated previously over the last three years?	☐ Yes ☐ No
If yes please explain it.	

MANUFACTURING CAPABILITIES
What are the manufacturing capabilities of the firm?(e.g.)
Could you comment about the development of these manufacturing capabilities?

STRATEGIC MARKETING CAPABILITIES	
Does the firm have other subsidiaries?	☐ Yes

	☐ No
Has the firm introduce new products into the market over the last three years?	☐ Yes ☐ No
What activities is the firm doing in order to develop and improve its market channels?	
Has the firm been involved with industrial associations, chambers or public institutions in order to foster its market channels?	
☐ Yes ☐ No	
If yes please explain the kind of collaboration that you received from them.	
What are the marketing strategies that the firm has developed?	
Which of the following issues have influenced in the development of the previous marketing strategies?	
☐ Large firms ☐ Multinationals ☐ Universities ☐ Industrial associations ☐ Governmental public institutions ☐ Others	
What is the firm doing in order to foster its marketing strategies?	
INNOVATION CAPABILITIES	
Does the firm invest in R&D?	☐ Yes External ☐ %_____Supplier_____________ In-house ☐ %____ ☐ No
If yes, how many people are involved in the R&D department?	
Total of number of people____ Internal people____ Other____	
About the people working in the R&D department mention the following characteristics:	
Educational background____ Working experience____ Number of years working in the firm_____________________________________	

Number of years working in the R&D department_____________________________ Other____	
When was the R&D department set up ?	
Did the firm receive external support to set up or improve the R&D department?	☐ Yes ☐ No
If yes, please comment who provided this support?	
Explain about the support provided (e.g. kind of collaboration, how did the firm know about that external support?)	
How many projects has the firm developed in this R&D department over the last three years?	
Explain about it.	
Are these projects related to? (More than one answer is permitted)	
Product design ☐ Production methods ☐ Process technologies ☐ Manufacturing techniques ☐ Production technologies ☐	
In any of those R&D projects has the firm worked in collaboration with the following actors?	
Universities ☐ Large firms ☐ Multinational companies………... ☐ Research centre ☐ Industrial associations ☐ Governmental central institutions ☐ Other	
If you ticked any of the previous, explain about the kind of collaboration.	
Have you developed patents?	☐ Yes ☐ No
If yes explain about it. (e.g. kind of patent, who were involved?)	

What are the R&D projects the firm wants to develop in the next years?	
What are the sources fostering the innovation?	
What are the problems hindering the development of innovations?	
LINKAGES CAPABILITIES	
What are the requirements that you need to fulfill in order to supply your large firms consumers?	
How is the relationship with your large firms or multinationals consumers? And explain it.	
How are you improving your consumer relationships with large firms? Explain it. (e.g. if you provide them a service)	
Who are your more collaborative large firm consumers? And explain why.	
Have you had new large firm consumers over the last three years?	☐ Yes How many__________________ ☐ No
What kind of relationship is the firm seeking from large firms or multinational consumers?	

What of the following areas have been improved as a result of interacting with large firms consumers?
Tick the best option, 1= not influence at all and 5= very strong influence)

Product design	1	2	3	4	5
Production process	1	2	3	4	5
Market channels	1	2	3	4	5
Technological systems (e.g. quality control systems, internal manuals, lead time)	1	2	3	4	5
Master skills related to technology and equipment	1	2	3	4	5
Others____	1	2	3	4	5

Has the consumer relationship with large firms influenced in the firm´s development of technology and innovation?
And explain why.

Mention the projects about technology, machinery and others where the firm received collaboration from large firms.

What are the skills that the firm has developed as a result of working with large firms and multinational companies?

Does the firm believe that is more important to develop technological skills before customers arrive or when they are around?

What is your experience working with large firms consumers or multinational companies?

Please tick the sources of technology that the company has used in the last three years.
(Rank the source according to the company´s importance: 5= very important, 1 = not important and NR = not relevant for the company)

SOURCE	TECHNOLOGY	IMPORTANCE
Bench marketing to competitors	☐	1 2 3 4 5
Chambers of commerce	☐	1 2 3 4 5

Name_____________________________			
Consultancies	☐		1 2 3 4 5
Large firms	☐	☐	1 2 3 4 5
Large firms such as consumers			1 2 3 4 5
Fairs, trade, exhibitions	☐	☐	1 2 3 4 5
Governmental schemes Name_____________________________	☐	☐	1 2 3 4 5
Industrial associations Name_____________________________	☐	☐	1 2 3 4 5
Licensing	☐	☐	1 2 3 4 5
Public research centers_________________________________ __	☐	☐	1 2 3 4 5
Recruitment of highly-qualified personnel	☐	☐	1 2 3 4 5
Universities Name__________________________________ ___	☐	☐	1 2 3 4 5
Others__________________________________ _______________	☐	☐	1 2 3 4 5

I. INTERVIEWS FOR LARGE FIRMS *Company's background*

1. Name of the company:
2. Year of foundation:
3. Location:
4. Number of employees:
5. What are the three main products?

6. Does the firm export?

☐ Yes ☐ No

If yes please explain the extent of the market.

7. Does the firm have other subsidiaries?

☐ Yes ☐ No

If yes, please explain where.

II. Interactions in innovation system

8. Who are the company's three main SMEs suppliers of manufactured goods?

Company's name	Location	Years of relationship	Type of supplier	Type of product

9. What kind of SMEs suppliers does the company seek?

10. How many small and medium suppliers of automobile components has the company acquired in the last three years?

Is still the company working with these previous suppliers?

☐ Yes ☐ No

For any answer please explain why.

11. Does the company have commercial relations with other type of SMEs?

☐ Yes ☐ No

If yes please explain **what** kind of relationship and **how many** years of relationship does the company have with those?

12. What is the percentage that small and medium suppliers represent from your total number of suppliers?

13. Who of the following firms are important suppliers of material goods for the firm? (Please tick the best choice: 1- very important supplier, 5: not at all important supplier)

Suppliers	Level of interaction				
Multinational companies	1	2	3	4	5
Local large firms	1	2	3	4	5
Small and medium auto-parts suppliers	1	2	3	4	5
Small and medium service firms	1	2	3	4	5
Others	1	2	3	4	5

III. Transfer of technology and knowledge

14. Which of the following has the company used with small and medium suppliers and users firms in the last three years?

Transferring of non-propietary technology	☐ Yes ☐ No
Licensing to suppliers	☐ Yes ☐ No
Information to suppliers	☐ Yes ☐ No
Training to suppliers	☐ Yes ☐ No
Technical assistance	☐ Yes ☐ No
Others	

If yes in any of those, please explain it. (e.g. how it was carried out, who carried it out and the reason to carry it out)

15. What are the requirements that SMEs suppliers have to fulfill in order to supply material goods to you?

In the case that the SMEs do not fulfill the requirements to be your supplier, how does the company behave with them?

16. Does the company concern to upgrade the technology for its SMEs suppliers of material goods? (Please tick the best choice)

The company is very concern and develop schemes aimed to improve the technology for its suppliers	☐
The company is concern but is not involved in improving the technology for its suppliers	☐
The company is not concern because its suppliers have to fulfil its company´s requisites	☐
The company is not concern at all	☐

If the company is concerned about its SMEs suppliers, please explain how has the company upgrade the technology for its SMEs suppliers of automobile components? (e.g. training based on technology, transfer or equipment, visits to small firms, consultancy, etc)

Networks

Suppliers

17. Has the company been involved in any public scheme?

☐ Yes ☐ No

If yes please explain it (since when is the firm involved in, how are these interactions?, what is the purpose of being in these schemes?)

18. Has the company been involved in a public scheme to involve small and medium local firms in its supplier's network?

☐ Yes ☐ No

If yes please explain it.

19. What are the obstacles and challenges that the company has to face in order to work with small and medium suppliers of automobile components?

20. From your experience, how does the company rank the SMEs suppliers´ performance? (e.g. good, bad, not sure)And please explain why.

i) Local

21. Has the company cooperated with any of the following institutions in the last three years?

Industrial associations	☐ Yes	☐ No
Chambers of commerce	☐ Yes	☐ No
Universities	☐ Yes	☐ No
Research centre	☐ Yes	☐ No
Public institutions	☐ Yes	☐ No
Others		

If yes in any of those please explain it.

Thanks for your time and consideration

- Name of the interviewee:
- Position
- Date

INTERVIEWS FOR GOVERNMENT AGENCIES

IV. Agency's background

22. Name of the agency

23. Year of foundation

24. Location

25. Number of employees:

Central agency	
Department of automobile industry or department of SMEs.	

26. Agency´s misión

27. Agency's goal

V. Interactions in innovation systems.

28. Number of firms that have been assisted by this agency:

Multinational companies	
Local large firms	
Foreign firm	
Medium firms	
Small firms	
Others	

29. Does the agency have local agencies

☐ Yes ☐ No

If yes please explain:

If yes please comment where these local agencies are.

If yes please comment the purpose to set up those local agencies.

30. What programmes focused on SMEs has the central agency developed over the last three years?
(Explain about these programmes and the annual budget)

31. What programmes focused on the automobile industry has the central agency developed over the last three years? (Explain about these programmes and the annual budget)

32. What programmes focused on innovation and technology development has the central agency developed over the last three years? (Explain about these programmes and the annual budget)

VI. Transfer of technology and knowledge

33. Does the association collaborate with other associations, governmental agencies or universities?

☐ Yes ☐ No

If yes please comment it

34. What programmes related to the automobile industry or SMEs have been developed in collaboration with public or private institutions?

35. Which of the following has the association used in the last three years?

Consultancy programmes to firms	☐ Yes ☐ No
Training	☐ Yes ☐ No
Technical assistance	☐ Yes ☐ No
Transferring of technology	☐ Yes ☐ No
Transferring of information (bulletin, magazine, events, etc)	☐ Yes ☐ No
Recruitment of personnel	☐ Yes ☐ No
Others	

If yes in any of those please explain **how** it was carried out**, who** carried it out, **who** the beneficiary was (size of the firm, type of university, etc.) and the **areas** involved.

I. Governmental policies in developing countries

36. How is the central agency working to integrate local firms or SMEs in the system of the automobile industry?

37. How is the central agency developing or fostering innovation and technology in SMEs of the automobile industry?

38. What are the challenges and problems that this agency faces in order to integrate local firms in the systems of the automobile industry?

39. What policies is this agency developing in order to strength local firms in the automobile industry?

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40. Regarding the programmes mentioned before, who (public or/and private sector) is funding these programmes?

41. Do academia, private sector or industrial agencies collaborate in the planning and designing of public policies of the automobile industry?

☐ Yes ☐ No

If yes please explain it.

Thanks for your time and consideration

- Name of the interviewee:
- Position
- Date

INTERVIEWS FOR UNIVERSITIES

VII. University's background

42. Name of the university

43. Website

44. Year of foundation

45. Location

46. Public ☐ Private ☐

47. Number of students:

Business, management and economics	
Engineering	
Informatics	
Law, politics	
Pure sciences	
Others	

48. University's mission

VIII. Interaction in innovation systems

49. Does the university have formal or informal links with any of the following automobile actors?

Foreign firms	☐ Yes	☐ No
Industrial associations	☐ Yes	☐ No

Local firms	☐ Yes	☐ No
Local public agencies	☐ Yes	☐ No
Multinational companies	☐ Yes	☐ No
Universities	☐ Yes	☐ No
Others	☐ Yes	☐ No

If yes in any of those please explain **who** and **what** kind of relationship does the company have with them?

50. Does the university have incubator firm?

☐ Yes ☐ No

If yes please explain:

- Who are in charge of the incubator?
- Participant's features,
- Over the last three years how many projects related to the automobile industry did the university have?
- How do these projects carry out?

IX. Transfer of technology and knowledge

51. Which of the following has the university used in the last three years?

Consultancy projects related with the automobile industry	☐ Yes ☐ No
Development of symposiums or congresses related with the automobile industry	☐ Yes ☐ No
Development of technology related with the automobile industry	
Licensing of technology, equipment or laboratory	☐ Yes ☐ No
Technical assistance to firms	☐ Yes ☐ No
Training to firms	☐ Yes ☐ No
Transferring of nonpropietary technology	☐ Yes ☐ No
Others	

If yes in any of those please explain **how** it was carried out and **who** carried it out.

52. Does the university develop research related to the automobile industry?

☐ Yes ☐ No

If yes please explain **what** kind of research and **who** the beneficiary was.

53. Which of the taught programmes are related with the automobile industry?

Name of programme	Number of teaching staff	Number of students

54. How many laboratories related with those taught programmes does the university have?

55. Did the university interact with any private firm in order to develop any of those programmes?

☐ Yes ☐ No

If yes please explain how it was carried out and who carry it out.

56. Does the university interact with automobile firms in order to modify the taught programmes?

☐ Yes ☐ No

If yes please explain **how** it is carried out and **who** carry it out.

57. The university has with the automobile industry any of the following:

Donation of equipment or machinery	☐ Yes ☐ No
Exchange of researchers	☐ Yes ☐ No
Internships	☐ Yes ☐ No
Job recruitment	☐ Yes ☐ No
Scholarships	☐ Yes ☐ No
Others	

X. Capabilities

58. What activities does the university have in order to accomplish its mission?

Thanks for your time and consideration

- Name of the interviewee:
- Position
- Date

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INTERVIEWS FOR CHAMBERS OF COMMERCE AND INDUSTRY

XI. Association's background

59. Name of the association

60. Year of foundation

61. Location

62. Number of employees

63. Association's mission

64. Does the association work with any public scheme?

☐ Yes ☐ No

XII. Interactions in innovation systems

65. Number of members:

Multinational companies	
Local large firms	
Foreign firm	
Medium firms	
Small firms	
Others	

66. Does the association work with other associations, governmental agencies or universities?

☐ Yes ☐ No

If yes please explain **which** and **what** kind of relationship.

XIII. Transfer of technology and knowledge

67. Which of the following has the association used in the last three years?

Consultancy programmes to firms	☐ Yes ☐ No
Training	☐ Yes ☐ No
Technical assistance	☐ Yes ☐ No
Transferring of technology	☐ Yes ☐ No
Transferring of information (bulletin, magazine, events, etc)	☐ Yes ☐ No
Recrutiment of personnel	☐ Yes ☐ No
Others	

If yes in any of those please explain **how** it was carried out**, who** carried it out, **who** the beneficiary was (size of the firm, type of university, etc.) and the **areas** involved.

68. Over the last two years how many events did the association have? (Please explain the **purpose** of the event, the **participants** (who and how many), and **how** it was carried out)

69. Does the association develop research?

☐ Yes ☐ No

If yes please explain **what** areas are involved it, **how** it is carried out and **who** carry it out.

70. Does the association promote the integration of SMEs in the automobile supply chain?

☐ Yes ☐ No

If yes please explain **how** it is developed and **who** carry it out.

71. What activities does the association have in order to accomplish its mission?

XIV. Governmental policies in developing countries

72. From your point of view what are the main problems that the association faces in order to protect its participants' interests?

Thanks for your time and consideration

- Name of the interviewee:
- Position
- Date

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