

# Technological capability accumulation in the 'maquila industry' in Mexico<sup>1</sup>

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## Abstract

From the mid-1960s, 'maquila' plants were established in the Mexican Northern border. The Mexican model was based on foreign firms establishing their own assembly plants. Even though this model was less successful than that of East and South East Asian in terms of several techno-economic indicators, it has largely contributed to employment generation. However, as a result of internal learning process and changes in the global firms strategies, several 'maquilas' operating in Mexico have undergone important qualitative changes. During the 1990s there was a change in the nature of their productive and technological activities towards more complex products and more innovative technological activities. In contrast, other dimensions have evolved slowly, such as the engagement of Mexican suppliers in global supply chains. The aim of this paper is to discuss an analytical framework to help study the technological capability accumulation in the 'maquila' industry in Mexico. Based on that the paper seeks to examine levels of technological capability accumulation of three maquilas, and to bring to light some stylized facts of the accumulation process in this industry. The analytical framework proposed draws on the taxonomy of technological capabilities proposed by Bell & Pavitt (1995) for the manufacturing industry in developing countries and its further adaptations and applications carried in Figueiredo (2001) and Ariffin & Figueiredo (2003, 2004). This paper adapts it to the particularities of the 'maquila' industry in Mexico. The new taxonomy includes technical functions that are relevant to this industry and redefines activities that correspond to various levels of accumulation. This paper is based on a case study methodology. The cases are the business lines of three maquilas in Ciudad Juarez: Thomson Multimedia, Philips Corp. and Delphi Corp. Two business lines correspond to the consumer electronics industry and the third is specialized on electronic products for the auto-parts industry. The evidence was collected between April 2001 and October 2002 in Ciudad Juarez. The main source of information are interviews conducted on the personnel of different hierarchical positions within each 'maquila'.

Key words: Technological capabilities; maquila industry in Mexico.

## Introduction<sup>2</sup>

A group of countries of East and South East Asia achieved important successes in their processes of industrial and technological progress from the development of local suppliers of the manufacture industry. Based on processes of learning and accumulation of technological capability these local suppliers could advance rapidly from simple assembly activities in the 1960s and 1970s, toward product design in the late 1980s and finally to introducing their own brands in the international markets and carrying out R&D activities for new products in the 1990s.<sup>3</sup>

The industrial relocation process toward the northern border of Mexico began in the mid-1960s. On one side, the Mexican model was different to the East and South East Asian one, transnational firms established their

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<sup>3</sup> See for instance, Hobday (1995) and Kim (1997).

own assembly plants in the northern border, which were denominated maquilas.<sup>4</sup> On the other side, the evolution in Mexico has been less successful in terms of national industrial and technological development.

As consequence of the conditions and restrictions under which these plants were established, and of the poor attempt by the maquilas to form links with different Mexican industrial and governmental organizations, the stereotype that they were technologically poor establishments, where workers were submitted to repetitive and inhuman exploitation processes, was consolidated.

During the decade of the 1990s, the maquila industry consolidated its role as an employment generator in the manufacturing industry. Between 1990 and the year 2002, it created employments at an annual rate of over 10%. In the 2002, the 1,087,487 workers employed in the 3,251 plants of the maquila industry represented 30% of the total personnel working in the whole manufacturing industry.

However, the evolution of the maquila industry was not limited to the growth of the number of establishments and employees. As a result of internal learning processes and changes in the strategies of global firms, various maquilas in Mexico have experienced important qualitative changes. Although there is no precise data to evaluate the depth and magnitude of such transformation, recent studies confirm that during the 1990s a change occurred in the nature of the productive and technological activities of a group of maquilas towards more complex products and more sophisticated technical activities.<sup>5</sup> On the contrary, there are dimensions that have evolved more slowly, like the linking of national firms to their suppliers chains, particularly of components.

The aim of this paper is to present an analytical framework to help study the technological capability accumulation in the maquila industry in Mexico, based on that to analyze the levels of technological capability accumulation of three maquilas, and to bring to light some stylized facts of the accumulation process in this industry.

The analytical framework proposed draws on the taxonomy of technological capabilities proposed by Bell & Pavitt (1995) for the manufacturing industry in developing countries, and its further adaptations and applications carried out in Figueiredo (2001) and Ariffin & Figueiredo (2003, 2004). This paper adapts such framework to the particularities of the maquila industry in Mexico, in this sense the new taxonomy adds technical functions that are relevant to this industry and redefines activities that correspond to various levels of accumulation.

It is important to highlight that the framework focuses on intrafirm accumulation processes; it reveals the paths, processes and strategies of accumulation. However, it is less suitable to explain the links between these internal processes and the external context. Therefore, it is important to consider that the characteristics of the firms' capability paths depend on internal and external factors. Among the internal factors stand out the particularities of the firms foundation, their organizational and technological culture, and the business and technological strategies. These factors affect the building of organizational routines which shape the path of technological capability build-up. The most relevant external factors are associated with the economical and social environment in which firms operate, and with the characteristics of the local and national innovation systems.

The analysis of the accumulation processes of the maquilas in Mexico is placed in a national environment which has been characterized over decades by a macro economical instability and by the existence of an immature national innovation system, with a fragile structure of linkage among the different agents. Additionally, the maquilas were initially placed in localities in the northern border with little manufacturing tradition, a young educational system, inexistent R&D centers, an immature local institutional structure, etc. In these localities it was impossible to talk about a local innovation system, a local productive system was barely being conformed. This affects both the accumulation of the maquilas and the development of local suppliers. This local environ-

<sup>4</sup> From the mid-1960s, the Mexican government established a border industrialization program ("Programa de Industrialización Fronteriza") with the purpose of cutting down the high unemployment rates in the northern border of the country. This program had the purpose of attracting foreign investment, mainly from the US, to establish a 10 miles strip from the northern border. The plants created under this scheme were denominated maquilas. See Lowe & Kenney (1999), Buitelaar (2000), Barajas et al (2002).

<sup>5</sup> Carrillo & Hualde (1997), Lara (2000), Dutrénit & Vera-Cruz (2002).

ment has evolved slowly since the maquilas have established very few external links. In fact, the local environment has been transformed into a binational regional environment, which increases the number of actors and opens spaces for further links. The locality of Ciudad Juarez is a representative case for the analysis of the maquila industry. It concentrates approximately 8% of the plants and 20% of the employment.

This paper is based on a case study methodology. The cases are the business lines of three maquilas in Ciudad Juarez: Thomson Multimedia, Philips Corp. and Delphi Corp. Two business lines correspond to the consumer electronics industry and the third is specialized on electronic products for the auto-parts industry. The evidence was collected between April 2001 and October 2002 in Ciudad Juarez. The main source of information were interviews conducted with managers, engineers, and technicians of different hierarchical positions within each maquila.

This paper is organized in five sections. Section 2 presents the analytical framework to assess the levels of technological capability accumulation in the maquila industry. Section 3 analyzes the trajectory of technological capability accumulation of the three cases being analyzed. Section 4 compares the trajectories of accumulation of the three maquilas. Finally, Section 5 presents some stylized facts of the technological capability accumulation processes in the maquila industry.

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### **A taxonomy of technological capabilities of the maquila industry**

Since the beginning of the 1980s, a group of authors have contributed to the gradual build-up of an analytical framework to help analyze the processes of accumulation of technological capabilities by firms in developing countries.<sup>7</sup> The basic idea is that capabilities represent abilities to do things, and technological capabilities reflect the dominion of technological activities. Based on empirical research at firm level, this literature has elaborated taxonomies to help describe the gradual processes of accumulation, from a stage that reflects minimum levels of knowledge (needed for the routine operation) to the stage of advanced innovative capabilities. In this section we present a new version of the taxonomy of technological capabilities adapted to the particularities of the maquila industry in Mexico. An index of technological capabilities that measures the results of the accumulation processes is also presented.

The design of the taxonomy of technological capabilities for the maquila industry draws on the analytical framework proposed by Bell & Pavitt (1995), which gathers up the advances of knowledge in this area,<sup>8</sup> and on the adaptations carried out by Figueiredo (2001) and Ariffin & Figueiredo (2004). The philosophy of the taxonomy is kept but, based on the evidence of the characteristics of the accumulation processes at the maquila industry, new technical functions are added and some of the activities corresponding to each level of accumulation are redefined.

The files group out the main technological capabilities according to the degree of innovativeness, including four levels of accumulation: a level of routine production technological capabilities, and three levels of innovative technological capabilities – basic, intermediate, and advanced. By columns, the taxonomy distinguishes the technical functions in which firms can develop technological capabilities. There are three groups of technical functions: (i) investment functions that refer to the creation of technical change and the administration of its implementation during large investment projects; (ii) production functions that refer to the generation and management of technical change in the processes, the production organization, and the products; and (iii) supporting functions that consist of the development of links and interactions necessary for innovative activity.

The taxonomy of technological capabilities in the maquila industry has the following particularities:

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<sup>7</sup> Dahlman & Westphal (1982), Katz (1984), Dahlman et al. (1987) and Lall (1992).

<sup>8</sup> A critical description of this taxonomy is presented in Dutrénit et al. (2003).

1. It is defined for the activities of the maquilas in Mexico, so it shows the accumulation of technological capabilities in each plant, business line or the whole operations in Mexico, independent to the technological capabilities of the global firm.
2. Three technical supporting functions were defined: internal linkages, external linkages and equipment modification.
3. The difference between activities of internal and external linkages was due to the fact that they reflect two relevant aspects of the relationships of the maquilas: intrafirm links and links with the context. These dimensions have evolved differently.
4. Following Figueiredo (2001), the technical function of equipment modification was added since it is relevant in many firms in developing countries.

Table 1 presents the taxonomy of technological capabilities for the maquila industry. In each stage of accumulation of each technical function, the most characteristic activities of that level are listed.

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Table 1. Taxonomy of technological capabilities for the maquila industry

Capability Level	Investment functions		Production functions		Supporting functions		
	Decision making and control	Project preparation and implementation	Processes and production organization	Product centered	Developing external linkages	Developing internal linkages	Equipment modification
Basic Operative Capabilities	<ul style="list-style-type: none"> <li>Engaging primary contractor</li> <li>Payment estimation</li> </ul>	<ul style="list-style-type: none"> <li>Preparation of initial project outline</li> <li>Construction of basic civil works</li> <li>Simple plant erection</li> </ul>	<ul style="list-style-type: none"> <li>Replication of process specifications</li> <li>Routine operation of simple and/or more complex assembly process</li> <li>Improvement in the workstations based on supervision systems and/or quality control</li> <li>Basic process engineering</li> </ul>	<ul style="list-style-type: none"> <li>Replication of product specifications</li> <li>Routine quality control based on quality control processes</li> </ul>	<ul style="list-style-type: none"> <li>Relationship with suppliers, clients and institutions through the headquarter</li> </ul>	<ul style="list-style-type: none"> <li>Relationship with the headquarter to receive authorizations for inputs, technical specifications of products and processes, and investment projects</li> </ul>	<ul style="list-style-type: none"> <li>Routine maintenance of equipment</li> <li>Simple replication of plant specifications and simple machinery parts.</li> <li>Basic maintenance without planning</li> </ul>
Basic Innovative Capabilities	<ul style="list-style-type: none"> <li>Active monitoring and control of: <ul style="list-style-type: none"> <li>-feasibility studies</li> <li>-technology choice/sourcing</li> <li>-project scheduling</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Feasibility studies</li> <li>Standard equipment procurement</li> <li>Simple ancillary engineering</li> </ul>	<ul style="list-style-type: none"> <li>Minor adaptations to assembly process based on times and movement studies <ul style="list-style-type: none"> <li>-Shaining and Taguchi methodologies</li> <li>-Implementation of Poka-yokes in critical stations</li> </ul> </li> <li>Forming of workgroups</li> <li>Layout improvement, scheduling</li> <li>Total productive maintenance</li> <li>Scaling of assembly process and/or manufacture of pieces of different size</li> </ul>	<ul style="list-style-type: none"> <li>Minor adaptations to market needs</li> <li>Increasing improvements in product quality</li> </ul>	<ul style="list-style-type: none"> <li>Relationship with clients through the product specifications</li> <li>Searching and negotiating with suppliers of indirect materials</li> <li>Search of links with local institutions for personnel training</li> </ul>	<ul style="list-style-type: none"> <li>Establishing workgroups to help build links between plants, design centers, divisions and the headquarter</li> </ul>	<ul style="list-style-type: none"> <li>Copy and minor adaptations of specifications of existing test equipment</li> <li>Reconstruction of small equipment without technical assistance</li> <li>Basic programmed maintenance</li> </ul>
Intermediate Innovative Capabilities	<ul style="list-style-type: none"> <li>Search, evaluation and selection of technology/ sources</li> <li>Tenders negotiations</li> <li>Overall project management</li> </ul>	<ul style="list-style-type: none"> <li>Detailed engineering</li> <li>Equipment acquisition</li> <li>Environment assessment</li> <li>Project scheduling and management</li> <li>Designation of the workgroup</li> <li>Training and recruitment</li> <li>Starting up</li> </ul>	<ul style="list-style-type: none"> <li>Redesign and/or design of parts of the assembly process and/or manufacture</li> <li>Validation of processes according to the product</li> <li>Stretching capacity based on line balancing</li> <li>Slim manufacture, quality systems and continuous improvement</li> </ul>	<ul style="list-style-type: none"> <li>Incremental product design</li> </ul>	<ul style="list-style-type: none"> <li>Technology transfer to local suppliers to increase efficiency, quality and local supply</li> <li>Attract suppliers of direct material to the region</li> <li>Joint projects with universities for professional training</li> </ul>	<ul style="list-style-type: none"> <li>Delegation on behalf of the headquarter in the decision-making about process designs, clients, suppliers and institutions</li> </ul>	<ul style="list-style-type: none"> <li>Adaptations of large equipment</li> <li>Reverse engineering</li> <li>Engineering and building of test equipment</li> <li>Preventive maintenance</li> </ul>
Advanced Innovative Capabilities	<ul style="list-style-type: none"> <li>Developing new production systems and components</li> </ul>	<ul style="list-style-type: none"> <li>Basic process design and related R&amp;D</li> </ul>	<ul style="list-style-type: none"> <li>Innovation in processes and related R&amp;D</li> </ul>	<ul style="list-style-type: none"> <li>Design of basic characteristics for new products</li> <li>Product innovation and related R&amp;D</li> </ul>	<ul style="list-style-type: none"> <li>Links with universities and R&amp;D centers for technological developments</li> <li>Collaboration in technological development with suppliers, clients and partners</li> </ul>	<ul style="list-style-type: none"> <li>Autonomy in the decision-making related to production, supply of components and indirect materials, new products</li> </ul>	<ul style="list-style-type: none"> <li>Design and building of equipment and components</li> <li>R&amp;D for new components</li> </ul>

Source: Adapted from Bell & Pavitt (1995), Figueiredo (2001), Figueiredo & Ariffin (2003, 2004) and Dutrénit et al., (2003).

### 3. Accumulation of technological capabilities in the maquila: empirical evidence

Based on the framework described above, this section analyzes the trajectory of technological capability accumulation of three maquilas: Delphi Corp, Philips Corp, and Thomson Multimedia.

Since there exist differences in the technological capability accumulation processes per maquila's business line, in each case the most representative line of the process of technological capability accumulation in Mexico was chosen. In the case of Delphi we analyze the business line of sensors and actuators, as it is the line that has had the most advanced trajectory of technological capability accumulation in Mexico. In the case of Philips the business line of televisions is analyzed, with which it started activities in Mexico and which has worked like a seed for the rest of the activities in this country. In the case of Thomson we analyze the business of televisions, decoders and cable modem, where the 4 plants of Ciudad Juarez are integrated.

#### *Delphi Corp.: business line of sensors and actuators*

Delphi Corp is an autopart producer, specialized in mobile electronics and transportation components and systems technology, organized in 6 divisions. It is a firm oriented towards global integrated production that makes the decisions in different parts of the world.<sup>9</sup> In 2001 it had approximately 192.000 employees and was operating in 42 countries. Its headquarters are located in Troy, Michigan, USA, and it has regional headquarters in Paris, Tokyo and Sao Paulo.<sup>10</sup>

Delphi was first established in Mexico as Delco Remy, under de maquila regime in 1979. In the year 2001 it had 72.000 employees, 50 productive plants in 14 states, 8 co-investments, 3 technology licenses and a Technical Center. In that year the production in Mexico represented 14.9% of the total sales of the group.

The Mexican Technical Center (MTC) was established in Ciudad Juarez in 1995 with 714 employees who came from the plants in Mexico, other facilities of Delphi in the United States, and of the hiring of personnel in both Mexico and the United States.<sup>6</sup> It is Delphi's biggest Component Engineering Center. Initially Delphi transferred to the MTC the engineering area of sensors and actuators. Gradually all the divisions have established areas of engineering and different laboratories in the MTC. In 2002 they had 2097 employees, of which approximately 1100 were engineers.

Most of the activities at the MTC are oriented to make developments for production. Only 3 of the 6 divisions operating at the MTC carry out product design activities. The most advanced division is Delphi Energy & Chassis Systems,<sup>7</sup> which carries out product design and advanced engineering. Inside this division, the largest capabilities in terms of R&D are in the business of sensors and actuators.

The sensors and actuators are produced in 6 plants all over the world: 1 in Ciudad Juarez, 2 in Chihuahua, 1 in Brazil, 1 in Portugal and 1 in China. It participates in the sensors and actuators market at international level with an 8.8% of the total. The engineering, design and development activities are located at the MTC. Here there is a group of advanced engineering of sensors and actuators with 6 doctors, 13 masters and 1 engineer. This group is in charge of developing the technology in the business line of sensors and actuators at world

<sup>9</sup> Delphi was a part of General Motors Company. In 1999 it separated and became an independent industrial group, Delphi Automotive System Corp. In 2002 it changed its name to Delphi Corp.

<sup>10</sup> Delphi concentrates its activities in North America (United States, Mexico and Canada), where 78% of the sales are generated. Europe represents the 18.4%, South America the 1.5% and other areas, that include China, the 2.3%. (DELPHI, 2002).

<sup>6</sup> The establishment of the MTC in Ciudad Juarez replied to different motives: (i) closeness with the plants to reduce the costs of line installation, response time and communications cost, (ii) restrictions to grow in the US by the 'Head Counter'; (iii) search to reduce operation costs, through reducing the cost of labor. (Interview at the MTC)

<sup>7</sup> Delphi-E&C belongs to the Dynamic and propulsion business sector and has 14 business lines, sensors and actuators is one of them. It has two lines of products: sensors and actuators, these combine in a subsystem that allows to create intelligent modules of control. The modules combine sensors, actuators, electronics and software.

level. The activities carried out at the MTC are the following: (i) part of the necessary applied research, (ii) all the advanced engineering, and (iii) the strategic and technological planning.<sup>8</sup> To carry out development projects they interact with Delphi Technology Inc., which carries out part of the basic and applied research required, and with universities, mainly American, who provide basic research for the projects.<sup>9</sup>

From the analysis of the productive and technological history and of the structure of its links, three stages of evolution of Delphi's business line of sensors and actuators were identified. The definition of the beginning of a new stage is associated with a jump in the process of technological capability accumulation.<sup>10</sup> Table 2 and 3 summarizes the main features of the accumulation at each stage and the accumulation levels in the technical functions according to the taxonomy of technological capabilities.

*Table 2. Main features of the accumulation process of Delphi's business of sensors and actuators*

<b>Stage I. Simple assembly of few components, 1978-88</b>	<b>Stage II. Complex assembly of product families, 1989-94</b>	<b>Stage III. Product design, 1995-2002</b>
<ul style="list-style-type: none"> <li>• Simple assembly of components and manufacture processes</li> <li>• Few products</li> <li>• 1979: first plant in Ciudad Juarez (SEC-plant 35)</li> <li>• 1986: second plant in Chihuahua-Chihuahua</li> <li>• Basic engineering of processes</li> <li>• System of conventional drive manufacture.</li> <li>• American managers</li> <li>• Foreign inputs and other components</li> <li>• Minimum links with the local and regional context</li> </ul>	<ul style="list-style-type: none"> <li>• Complex assembly of components and automatized manufacture processes</li> <li>• Various families of products</li> <li>• 1990: third plant in Chihuahua-Chihuahua</li> <li>• Engineering of assembly processes</li> <li>• System of synchronized manufacture with the client, multi-functional work cells in U, 1 engineer every 2-3 cell, sub plants per families of products</li> <li>• Statistical controls</li> <li>• Development of Mexican managers in sub plants</li> <li>• Global suppliers</li> <li>• Late 1980's: transfer of the indirect material buys area to the MTC</li> </ul>	<ul style="list-style-type: none"> <li>• Complex assembly of components and subsystems, complex manufacture processes and manufacture of pieces for test and production equipment</li> <li>• Creation of a technical center (MTC)</li> <li>• From engineering of sensors and actuators toward advanced engineering and R&amp;D activities</li> <li>• Lean manufacturing</li> <li>• Equipment improved through the 6 sigma, documented quality control (PIBAB)</li> <li>• MTC makes some decisions locally</li> <li>• 90% of direct material is bought in US, 10% locally</li> <li>• Various Mexican managers</li> <li>• Global suppliers and some national</li> <li>• Major links with the local and regional context: agreements with regional universities for professional formation, incipient links with Mexican research centers</li> </ul>

Source: Derived from the empirical study.

<sup>8</sup> Additionally the planning of sales, marketing and investment are carried out. (MTC, 2000; and interviews at the MTC).

<sup>9</sup> One of the most important results of the innovative activity is the register of the intellectual property. In 2001, the advanced engineering group obtained 88 record of investments, presented 55 applications of patents, was granted 15 patents, and realized 7 defensive publications and 3 industrial secrets. (Interview at the MTC).

<sup>10</sup> Arias (2002) presents a description of the three stages.

Table 3. Accumulation levels of Delphi's business of sensors and actuators

Stages	Technical Investment functions		Technical Investment functions		Technical supporting function		
	Decision making and control	Project preparation and implement.	Processes and production organiz.	Product centered	Developing external linkages	Developing internal linkages	Equipment modifi-cat.
<b>Stage I</b>	Operatives	Operatives	Operatives	Operatives	Operatives	Operatives	Operatives
<b>Stage II</b>	Basic Innov.	Basic Innov.	Intermed. Innov.	Basic Innov.	Basic Innov.	Operatives	Basic Innov.
<b>Stage III</b>	Intermed. Innov.	Intermed. Innov.	Advanced Innov.	Advanced Innov.	Advanced Innov.	Intermed. Innov.	Intermed. Innov.

Source: Derived from the empirical study.

#### Philips Corp: business line of televisions

Royal Philips Electronics was founded in 1891 to produce incandescent lamps and other electric products. Its headquarter is located in Amsterdam, Holland. It has seven business sectors: Lighting, Consumer electronics, Electro domestic equipment and personal care, Medical systems, Components, Semiconductors, and Miscellaneous. It is oriented towards globally integrated production. In 2001 it had approximately 229.000 employees and operated in over 60 countries. It has regional management offices in Europe; Asia, Middle East and Africa; Latin America (Brazil); and North America.

Philips began its operations in Mexico in 1939 as a wholesaler of imported products from Europe with the name Philips Mexicana, S.A. de C.V. In 1973 the first plant of Royal Philips Electronics was established in Ciudad Juarez under the regime of maquila. In 2002 Philips Mexico had a total of 15 plants all over the country, of which 12 were maquila plants of different products, and counted with 11.500 employees. At present Philips Mexico belongs to the Latin American region with headquarters in Sao Paulo, Brazil.

The business of televisions belongs to the sector of Consumer Electronics. Philips assembles and manufactures televisions in different parts of the world. The activities of engineering, design and development of this line are located in Singapore, Bruges and Knoxville.

As in the previous case, three stages of evolution of the business of televisions in Philips were identified.<sup>11</sup> Table 4 and 5 summarizes the main features of the accumulation in each stage.

<sup>11</sup> Urióstegui (2002) presents a description of the three stages.



Table 4. Main features of the accumulation process of Philips's business of televisions

Stage I. Simple assembly of components (1973-83)	Stage II. Assembly of chassis (1984-86)	Stage III. Assembly of televisions (1987-2002)
<ul style="list-style-type: none"> <li>• Simple assembly of components and manufacture processes</li> <li>• Few products</li> <li>• 1973: first plant (SESA)</li> <li>• 1974: first line of assembly of chassis</li> <li>• Creation of several plants of sub assembly and components</li> <li>• Basic engineering of processes</li> <li>• 1973: machining workshop at the plant SESA</li> <li>• Foreign managers</li> <li>• Minimum links with the local and regional context</li> </ul>	<ul style="list-style-type: none"> <li>• Assembly of more complex products and manufacture processes</li> <li>• Creation of several plants of sub assembly and components</li> <li>• Engineering of assembly processes</li> <li>• Design engineering: original proposal of the manufacturing process for the televisions</li> <li>• Plant engineering: development of capabilities in large investment projects</li> <li>• Reconstruction of small equipment</li> <li>• Some few Mexican managers</li> <li>• Components bought from Knoxville (US) with global suppliers</li> <li>• 1980-97: "Program for the Development of Local Suppliers" of indirect material, integration of a limited group of local suppliers</li> </ul>	<ul style="list-style-type: none"> <li>• Assembly of televisions and complex manufacture processes</li> <li>• 1987: plant 5 for final assembly of televisions (previously SESA)</li> <li>• 2000: plant 10 for assembly of chassis for all kinds of televisions</li> <li>• 2001: line of televisions PTV</li> <li>• Evolution of the capabilities in equipment modification: technical support for all the plants in Ciudad Juarez (1991), new business line (1997) and new plant (1998)<sup>12</sup></li> <li>• Various Mexican managers</li> <li>• Global suppliers and some national suppliers</li> <li>• Major links with the local and regional context: creation of a public-private training center - CENALTEC- oriented to the training of technicians in machine-tools</li> </ul>

Source: Derived from the empirical study.

Table 5. Accumulation levels in each stage of accumulation of Philips's business of televisions

Stages	Technical Investment functions		Technical Investment functions		Technical supporting function		
	Decision making and control	Project preparation and implementation.	Processes and production organiz.	Product centered	Developing external linkages	Developing internal linkages	Equipment modification.
Stage I	Operatives	Operatives	Operatives	Operatives	Operatives	Operatives	Operatives
Stage II	Basic Innov.	Basic Innov.	Basic Innov.	Operatives	Operatives	Operatives	Basic Innov.
Stage III	Intermed. Innov.	Intermed. Innov.	Intermed. Innov.	Basic Innov.	Basic Innov.	Basic Innov.	Intermed. Innov.

Source: Derived from the empirical study.

<sup>12</sup> In 2001 Philips decided to sell Enabling Technologies Group (where this business was located) because it was not considered a central business. This led to reorient the activity of this plant toward the business of plastic moulds for injection, stopping the process of accumulation in equipment modification. (Interview at Philips)

***Thomson Multimedia: the business of televisions, digital decoders and cable modem***

Thomson Multimedia is a firm of consumer electronics products whose headquarter is located in Bologna, France. It was founded in 1879 under the name Compagnie Francaise Thomson-Houston. It has five business sectors, the sector of Consumer Products represents the 62.7% of its sales. It manages three large brands: Thomson, RCA and Technicolor. It is oriented toward global integrated production. In 2001 it had approximately 73.000 employees, operated in over 30 countries and has 31 production plants. In 2001 Asia represented 33% of the sales, America 40% (18% corresponding to the US) and Europe 27%. America includes the United States, Canada, Mexico and Brazil.<sup>13</sup>

The history of the beginning of Thomson's operations in Mexico is linked with RCA. In 1952, RCA established a plant of assembly of radios, kinescopes and cannons for television in Mexico City. In 1969 an assembly plant is established in Ciudad Juarez (Chihuahua) to carry out assembly processes of electronic components for radios and televisions produced in the US under the regime of maquila. At present, Thomson Multimedia's activities in Ciudad Juarez correspond to Thomson Consumer Electronics, it has four plants that assemble components and final products and one plant for the rebuilding of products of the RCA brand. From 1998 to 2002 it had a Support Center. Additionally Thomson has a plant in Torreón (Coahuila) and a plant in Mexicali (Baja California). Like in the previous two cases, three stages of evolution of the business of televisions, decoders and cable MODEM were recognized.<sup>14</sup> Table 6 and 7 below summarizes the main features of accumulation in each stage.

<sup>13</sup> [www.thomson-multimedia.com](http://www.thomson-multimedia.com)

<sup>14</sup> Sampedro (2003) presents a description of the three stages.

Table 6. Main features of the accumulation process of Thomson's business of televisions, decoders and cable MODEM

Stage I. Simple assembly of components (1969-80)	Stage II. Complex assembly and equipment modification (1981-92)	Stage III. Final assembly and design (1993-2002)
<ul style="list-style-type: none"> <li>• Simple assembly of components and manufacture processes</li> <li>• 1969: plant RCA.</li> <li>• Basic engineering of processes</li> <li>• Test technology was introduced, ATE (automatic test equipment)</li> <li>• Development of capabilities to modify test and assembly equipment</li> <li>• American managers</li> <li>• Minimum links with the regional context</li> </ul>	<ul style="list-style-type: none"> <li>• Assembly of more complex products and manufacture processes</li> <li>• Engineering of manufacture</li> <li>• Redesign of processes and assembly lines</li> <li>• Increasing improvements to the basic product design according to the production needs and clients' requirements</li> <li>• 1981: the small, more sophisticated manuals and the semiautomatic ATES were built in Ciudad Juárez</li> <li>• Plant engineering: development of capabilities in large investment projects</li> <li>• Incorporation of Mexican managers</li> <li>• Global suppliers</li> </ul>	<ul style="list-style-type: none"> <li>• Final assembly of televisions, decoders and cable MODEM, and complex manufacture processes</li> <li>• 1993: plant TTM to begin the final assembly of televisions, decoders and cable Modem</li> <li>• 1998: plant MASA to increase the assembly of digital televisions</li> <li>• Division of work between the three plants but they all have flexibility to change their assembly lines</li> <li>• 1996-98: a support center is created to turn it into a fourth global design center for basic televisions of 19" and 27",<sup>15</sup> in 2002 the global strategy changes, the support center is closed and some activities are decentralized to the plants</li> <li>• 2000 a team of software design for decoders GLA is created and located in a plant</li> <li>• Design and manufacture of test equipment, design of tools to adjust processes, and export of these equipment to Brazil</li> <li>• Global suppliers and some national suppliers of machining pieces, packaging and simple welding.</li> <li>• Various Mexican managers</li> <li>• Major links with the local and regional contexts: professional formation and training</li> </ul>

Source: Derived from the empirical study.

<sup>15</sup> In 2002 there was a change in the strategy of the global firm, it decided to turn Thomson into a global organization, thus, it was no longer profitable to have another engineering group in design development in Ciudad Juarez.

Table 7. Accumulation levels in each stage of accumulation of Thomson's business of televisions, decoders and cable MODEM

Stages	Technical Investment functions		Technical Investment functions		Technical supporting function		
	Decision making and control	Project preparation and implementation.	Processes and production organization	Product centered	Developing external linkages	Developing internal linkages	Equipment modification.
<b>Stage I</b>	Operatives	Operatives	Operatives	Operatives	Operatives	Operatives	Operatives
<b>Stage II</b>	Basic Innov.	Basic Innov.	Intermed. Innov.	Basic Innov.	Basic Innov.	Basic Innov.	Intermed. Innov.
<b>Stage III</b>	Intermed. Innov.	Intermed. Innov.	Intermed. Innov.	Intermed. Innov.	Basic Innov.	Basic Innov.	Advanced Innov.

Source: Derived from the empirical study.

### Comparison of the accumulation of capability levels in the case-study maquilas

The analysis of the technological capability accumulation trajectories of Delphi, Philips and Thomson put forward some common features as well as certain differences. In this section the trajectories of technological capability accumulation of the three maquilas are compared and the similarities and differences extracted.

Tables 3, 5 and 7 present the level of technological capability accumulation of Delphi, Philips and Thomson in Mexico. In each case three stages of accumulation were identified, these were defined in function of jumps observed in the evolution. The first stage starts in the first years in Mexico, the second is a stage of transition, and the third reflects the present profile.

In the three cases there was a gradual accumulation of technological capabilities, the three maquilas evolved fruit of changing from having basic operative technological capabilities to having each time more innovative technological capabilities. In the first stage they all acquired basic operative technological capabilities, necessary for efficient production, and in the second predominates the development of basic innovative technological capabilities. In the present stage Philips and Thomson advanced toward intermediate innovative technological capabilities while Delphi obtained advanced innovative technological capabilities in most of its technical functions.

Differences in the level of accumulation can be observed in each stage of accumulation. In the third stage Delphi reached a highest level of accumulation in most of its technical functions because it transferred the product design of the sensors and actuators business line to Mexico, and the group of advanced engineering at the MTC began to carry out also R&D activities. Philips presents the lowest level of accumulation, in fact Philips' present stage corresponds to the stage 2 of Delphi and Thomson, this because Philips did not advance toward product design and also desaccumulated in the equipment modification activities.

The differences observed in the evolution are associated both with the specificities of the process of internal accumulation in each maquila, and with their corporate strategy. In this sense, the transfer of the product design activities of Delphi's sensors and actuators line to Mexico is the result of a corporate decision based on the accumulation of local technological capabilities in this business line. The slow evolution of Thomson toward design activities is more associated with a corporate decision to concentrate the design in the three existing global centers, than with a scarce internal accumulation of technological capabilities.

Aside from the differences in the specific years in which the jumps in the accumulation processes took place, it can be established that the stages are as follows: (i) First stage: early 1970s – early 1980s; (ii) Second stage: early 1980s – early 1990s; and (iii) Third stage: early 1990s – 2002.

Although there has been an advance in the accumulation of innovative technological capabilities locally, the three cases show that the evolution has been slow, particularly in relation to East and Southeast Asia. It took Delphi 19 years to advance toward product design, the first plant was established in 1979 and the group of advanced engineering was not established until 1997. Thomson took 31 years to advance toward product and software design, since the creation of the plant of RCA in 1969 until the constitution of the first product design group in 2000; these activities are still incipient. Philips has accumulated engineering capabilities, but has not accumulated neither design capabilities nor R&D locally.

The accumulation was gradual, but the technical functions evolved differently, in fact in some functions the accumulation was faster than in others, thus the level of innovativeness reached was different. As shown in Table 8, there are certain similarities in the characteristics of the accumulation per technical function.

*Tabla 8. Comparison of the technological capabilities accumulation in the three maquilas*

Maquila	Technical Investment functions		Technical Investment functions		Technical supporting function		
	Decision making and control	Project preparation and implementation.	Processes and production organization	Product centered	Developing external linkages	Developing internal linkages	Equipment modification
<b>Delphi 1995-2002</b>	Intermed. Innov.	Intermed. Innov.	Advanced Innov.	Advanced Innov.	Advanced Innov.	Intermed. Innov.	Intermed. Innov.
<b>Philips 1987-2002</b>	Intermed. Innov.	Intermed. Innov.	Intermed. Innov.	Basic Innov.	Basic Innov.	Basic Innov.	Intermed. Innov.
<b>Thomson 1993-2002</b>	Intermed. Innov.	Intermed. Innov.	Intermed. Innov.	Intermed. Innov.	Basic Innov.	Basic Innov.	Advanced Innov.

Source: Derived from the empirical study.

The technical functions where the accumulation was faster in the three maquilas were: (i) Centered in processes and production organization, (ii) Equipment modification, and (iii) Decision making and control, and Project preparation and implementation. In the three maquilas these functions reached intermediate innovative technological capabilities in the second stage of accumulation. These technical functions are based mainly on accumulation processes at plant level, needed to assure efficient assembly processes given the local specificities. In contrast, the functions where there was less accumulation, or the accumulation was slower were: (i) Product centered, (ii) Internal linkages, and (iii) External linkages. These technical functions depend on decisions that transcend the plants and are made at firm level. In this sense, the activities of product design and the buys of key components are made globally. Also, as plant level is transcended, other kind of interactions are established between different units of the firms.

Important differences can be observed in the accumulation of the three maquilas in the function centered on the product. Delphi and Thomson progressed toward intermediate or advanced innovative technological capabilities in the third stage, this because Delphi began to carry out product design activities, and Thomson software design activities. The slow evolution of the technical function of external linkages reflects the existence of few local links for innovation, the stronger links are for professional formation and training. Delphi's higher accumulation shows that, although it is a global firm, it is difficult to prevent a disintegration of the basic activities

to ensure the constant renovation of the competitive advantages. In addition to that, carrying out activities of design and R&D raises the need of some links with local, regional and international institutions for innovation. It is important to point out that external links are with the region, defined bi-nationally.

Finally, Delphi accumulated more in all its technical functions, which is related to the transfer of a global line, and not just a plant, to Ciudad Juarez. Thus, a more important part of the decision center is in Ciudad Juarez.

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### Final remarks

The analysis carried out in this study allows us to identify some common features in the process of technological capability accumulation in these three case-study maquilas in Mexico. These common features in the accumulation processes suggest the existence of some stylized facts.

- The accumulation process differs in each business line, given the specificities of the process of internal accumulation and the corporate strategy of the global firm.
- As plants learn, they spread in technical activities with a high degree of innovativeness and develop innovative technological capabilities.
- The learning processes in the plants lead to the accumulation of technological capabilities locally in order to shorten the distance between the production and technology functions. This generates pressure on the headquarters to acknowledge the technological capabilities accumulated and allow them to develop technical activities of higher innovativeness.
- Local accumulation is a necessary condition, although not sufficient, for global firms to transfer technical activities to Mexico; the global logic governs over the internal accumulation of technological capabilities.
- The maquilas in Mexico are not firms, initially they were simply plants, so that they learnt and accumulated in the technical functions related with plants. Thus there has been a faster process of accumulation in the technical function centered in processes, in the modification of test equipment, and in the investment functions in large projects.
- The headquarters maintain the power of decision on the technical functions centered on the products (design and R&D), internal linkages, and in the links with the suppliers of components that correspond to the function of external linkages.
- Some maquilas evolved in the sense of attracting global business lines, which allowed accumulating in technical functions related with product innovation, internal linkages, and external linkages.
- The development of managerial abilities among Mexicans has been slow because of the lack of opportunities to assume positions of high level locally. As they assume positions of higher responsibility, they look to strengthen the development of more innovative technological activities and integrate Mexican suppliers.
- The maquilas have followed an evolution related with the pressures of international competition. Beyond the efforts to develop national suppliers, the logic of businesses is radically different, moreover the gap between the types of firms has accentuated.
- The limited external links are associated with three factors: (i) the decision center above key factors outside is the locality, (ii) the profile of the activities at the plant – more productive than technical – that has demanded mostly links for training, and (iii) the weaknesses of the local production and innovation system, which do not have the capacity to respond to links for innovation.
- In general, the fragility of the production and innovation system, and of the social weave has not facilitated the linking processes of the local agents with the maquila.

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