

**Technological globalization and intra-company coordination in the
automotive sector:
The case of Delphi-Mexico¹**

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Introduction

The purpose of this paper³ is to describe⁴ the process of technological globalization⁵ within the context in Mexico, specifically in one of the most important autoparts firms: Delphi.

In the current debate around the process of technology globalization, we can identify two groups, with two different positions. In the first group, Patel (1995) maintains that there is no systematic evidence to suggest greater technological globalization. He asserts that the most internationalized sectors are not those that manufacture high-tech products,⁶ but rather, products that must be adapted to local needs are those in which globalization processes can be witnessed.⁷

“One reason for this could be that in these “high tech” products, links between R&D and design, on the one hand, and production, on the other, are particularly important in the

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⁴ The essential aspect of the description presented here is not the exactness with which reality is reconstructed—creating an image that, furthermore, will always be incomplete— but rather the analytical perspective offered. It is necessary to distance ourselves from theory as a mirror of reality, and from the theory of truth corresponding to or copying reality (Rorty, 1979; 2000). Therefore, while a great deal of valuable information is presented, the objective is not for this paper to become a source of evidence, but rather to propose an analytical scheme developed within evolutionary epistemology (Kuhn, 2000).

⁵ We can distinguish three categories of technological globalization, as proposed by Archibugui and Michie (1995):

- a. Global technological exploitation: Exporting innovative products; transfer of licenses and patents; production of “new” goods or components in foreign countries.
- b. Global technological cooperation: Joint investment ventures to develop innovative projects; agreements for joint production in which information and equipment are exchanged.
- c. Global technological production: R&D and innovative activities in both the corporate headquarters and in host countries. Acquisition of R&D laboratories or construction of R&D laboratories (*greenfield*) in host countries.

⁶ Some examples of R&D-intensive products are aeronautics products, computers, instruments and electrical equipment.

⁷ The need to adapt technologies to local needs is particularly based on differences in consumer tastes (food, drinks and tobacco), differences in government regulations (construction materials and pharmacies) and specific technology for exploiting natural resources (food, mines and oil).

launching of major new products and benefit from geographical proximity” (Patel: 1995:151).

In Japan, the United States, Italy, France and Germany, more than 85% of corporations’ research activity is carried out within the “home countries.” Therefore, at best, the process can be understood as a “triad” (US, Japan and Europe) process, but not as the “globalization” of technology. Also, evidence based on the patenting activities of the world’s 569 largest companies illustrates that an overwhelming majority of them produce their technology in their home countries.

After analyzing the patenting activities of the world’s 686 largest companies, Patel and Pavitt (1992) confirm that technology production by these companies is a clear case of “non-globalization.” Based on varying quantitative measurements, other authors agree with these results, specifically Howells (1990) and Dorrenbacher and Wortman (1991), who use databases of the number of personnel assigned to Research and Development (R&D), and Patel and Pavitt (1991) and Cantwell (1992), who analyze patenting activities.

There is a second group of studies —based on analysis of cases of companies, industries and countries— that maintains, to the contrary, that R&D activities are indeed going through a globalization process. These results indicate that R&D activities are being carried out in host countries in relation to adapting products and processes to the conditions of each local market and corresponding legislation (Pearce and Singh, 1992). This research also indicates that there is a set of political factors influencing companies in their decisions to locate activities in countries other than the home country (Hakanson, 1992).

Casson (1991) and Dunning (1992) maintain that transnational corporations generally establish R&D laboratories as a consequence of direct foreign investment.⁸ Cantwell analyzes the patenting activity of 857 companies during the 1920-1990 period, and discovers an important finding: that it is no longer possible to accept the existence of a single center, when the globalization process indicates the existence of multiple centers, “and even lower-order or less developed centers can still be sources of innovation” (Cantwell, 1995:172).

Our research can be included in this second group of studies. And from this perspective, we have posed the following questions:

What were the factors and conditions that encouraged the globalization of Delphi’s productive activities in Mexico? Was it viable for Delphi to continue to expand its division of labor in Mexico under a hierarchical scheme that was highly dependent on R&D activities carried out in the United States? How did the creation of a technical center in Mexico affect the interaction among the divisions and establishments located in that country? To what degree were the forms of control and monitoring in the various divisions

⁸ Dunning (1996) interviewed 144 executives from the world’s 500 largest transnational corporations. The study reveals that the competitive advantage for transnational corporations originates, to a significant degree, from their foreign bases. From the viewpoints of these executives, the more transnational the corporation, the more its competitiveness depends on its foreign companies.

and establishments located in Mexico modified with the creation of a research and development center in that country?

We have formulated four hypotheses in this study:

i. The Delphi-Mexico Technical Center (MTC) was created in 1995, as part of three structural modifications in the automotive sector: a) the transition from an integral design to a modular design; b) the creation of global supplying; and c) the ongoing increase in the electronic content of automobiles. These general factors operated in a particular way in Mexico.

ii. In the case of Mexico, the globalization of R&D activity is expressed in two particular processes: the decentralization of manufacturing activity, and the decentralization of R&D activity, both occurring in a *diachronic* manner. Thus, as local technological capacities evolve, it becomes “viable” to create an R&D center in Mexico that will permit the *synchronization* of R&D and manufacturing activities at regional and global scales.

iii. Economic, technological and organizational factors all play a part in the globalization of technology production. Therefore, the intention here is to reconstruct MTC’s identity within the history of the business units preceding it: in other words, the history of the accumulation of business units already established in Mexico when MTC operations began in 1995.

iv. Delphi’s quantitative and qualitative growth in Mexico is critically dependent on its local capability in managing the processes in its various divisions and establishments. Delphi becomes involved in R&D activities outside its host country when it perceives a set of technological, administrative, organization and financial advantages in its foreign subsidiary companies. But it also invests in R&D to “create” or acquire advantages, and combine them with those already existing in the context of the transition from combustion motor technology to new technologies: electric/electronic vehicles; fuel cell; and hybrids.

This article is composed of three sections. In the first section, we will describe Delphi’s global geographic configuration. In the second section, we will present the characteristics of this corporation’s globalization process in the NAFTA region. And in the third, which focuses on the main part of this study, we will describe and analyze two growth accumulation patterns in Delphi business units: i) one that is monocentric (a single R&D center) and the other, polycentric (more than one R&D center). And finally, we will present our conclusions.

1.- Globalization and regionalization: The case of Delphi

Delphi separated from General Motors (GM) in 1995, under the name of *Delphi Automotive Systems*, as a corporation specializing in autoparts production. In 1999 it became totally independent from GM.⁹ By 2001 it employed more than 193,000 persons around the world.

⁹ Delphi’s sales to GM in 2001 reached a total of US \$17.6 billion, representing 68% of total sales (In-house newsletter, Delphi Automotive Systems, January 17, 2002).

It was operating 198 manufacturing plants, 53 sales and service centers, 31 technical centers, and 44 joint ventures, located in 43 countries. In short, Delphi is a global corporation.¹⁰ In 1999, its 27 technical centers were distributed in the following way: 14 in the United States and Canada; 7 in Europe, Middle East and Africa; 4 in Mexico and South America; and 2 in Asia/Pacific.¹¹ The firm is made up of seven divisions: 1. Delphi Chassis Systems; 2. Delphi Delco Electronics Systems; 3. Delphi Energy & Engine Management Systems; 4. Delphi Harrison Thermal Systems; 5. Delphi Interior & Lighting Systems; 6. Delphi Packard Electric Systems; and 7. Delphi Saginaw Steering Systems. In this article, we will refer to these seven divisions in their abbreviated forms, as Chassis, Delco, Energy, Harrison, Interior, Packard and Saginaw.

By the year 2000, Delphi was operating 252 manufacturing establishments, technical centers, service centers, and joint ventures located in 25 countries and distributed in the following way: 87 plants in 13 countries throughout Europe and the Middle East; 67 in the South American region;¹² 57 establishments in two North American countries;¹³ and 41 in the Asian and Pacific region¹⁴ (**Table 1**). The division with the greatest number of establishments around the world was Packard, with 117, including exclusive and joint ventures as well as suppliers, and distributed throughout 29 countries. The second division with the most establishments was Delphi Energy with 52 in all (exclusive and joint ventures, and suppliers) located in 19 countries. The third division, Chassis, had 29 plants distributed in 15 countries (**Table 1**).

This listing of Delphi resources gives an idea of the immense area the corporation must cover in its efforts to coordinate, integrate and communicate throughout its extensive network of business units. The panorama is complex, given that global corporations must construct global objectives for multi-division companies, with heterogeneous institutional, cultural and national conditions, but must also work to promote adaptations to local niches.¹⁵ Is it possible to find a balance between these seemingly contradictory needs —of homogenization (global) and fragmentation (regional) (a process also known as globalization) —while promoting a single R&D center?

The first question that arises with respect to this enormous range of geographic areas where Delphi operates is the following: Is it possible to coordinate supplying, R&D activity, manufacturing, distribution and services throughout this entire global structure from a single geographic point? Decentralizing R&D activity particularly responds to the limits of

¹⁰ In 2001 Delphi's sales totaled US \$26.1 billion. This corporation is a world leader in the production of portable electronic accessories, transportation components and technology systems. According to Fortune, it is one of the world's 100 most important corporations.

¹¹ Global Presence, Delphi Automotive (1999).

¹² In Delphi's classification, Mexico is considered to be part of South America, while only Canada and the United States are included in North America. In the section of this paper dedicated to analyzing the NAFTA region, we include Mexico, Canada and the United States in the North American region.

¹³ United States and Canada.

¹⁴ Source: Delhi Automotive Systems, internal document, 2002.

¹⁵ To compete especially for highly qualified human resources distributed in different regions of the world.

human rationality and of any center in administering a complex network of business units in a centralized way.¹⁶

The interesting piece of information in this description of the global distribution of Delphi technical centers is not the fact that more than 50% of these centers are located in the United States. This can be explained by the simple reality that Delphi is a US corporation, and its growth process and historic trajectory have been carried out on the basis of resources provided in its region. Rather, what is novel about this case is that there are other technical centers located around the world that fulfill increasingly complex and interdependent tasks associated with the development of new processes and products. This claim will be further developed in another section of this paper, particularly in relation to the technical center in Mexico.

2.- Delphi in the NAFTA region¹⁷

In the year 2000, of the 136 Delphi establishments located in the NAFTA region, almost 50% were located in the United States (48.9%) while nearly all the rest in Mexico (47.8%), and only 3.3% in Canada. In terms of employment volume, Mexico was in first place with 52.2% of the total personnel, followed by the United States with 47%, and then Canada, with barely 0.7% (**Table 2**).

Mexico plays a very important role in the Delphi divisions having more plants and more employment. Of the 69 establishments in the Packard division, 65.2% are located in Mexico, with 33.3% in the United States and only 1.4% in Canada. In the 24 establishments in the Energy division, 58.3% are in the US, with 37.5% in Mexico, and 4.2% in Canada (**Table 3**).

In the year 2000 a total of 66 establishments were located in Mexico: 45 of them in the Packard division; 9 in Energy; 3 in Delco, 3 in Chassis, and 2 in Harrison. Packard was the division generating the most employment (44,741 jobs), followed by Delco (11,399) and Energy (5,233) (**Table 3**).

Most of the Delphi plants in the United States were concentrated —just as in Mexico— in the Packard division, with a total of 23 establishments. It was followed by the Energy division with 14, Saginaw with 9, Chassis with 8, Delco with 5, Interior with 4, and Harrison with 3. The Energy division contributed the most to total employment with 12,893 employees, followed by the Chassis division, with 9,883 employees, and in third place, the Harrison division with 8,495 employees (**Table 2**).

In Canada, there are 4 establishments in all. Two of them are in the Chassis division, one in Energy and one in Packard. The latter two employ only 325 and 245 workers, respectively (**Table 2**).

¹⁶ Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

¹⁷ Free Trade Agreement between the United States, Canada and Mexico.

A set of important observations can be extracted from this description. First, we can see the unequal, highly selective way in which productive globalization processes have taken place. Activities with a higher degree of globalization are those associated with production that is labor intensive, specifically involving unskilled workers, and an example is the production of electrical parts and subsystems in the Packard division. A second observation, and for the same reason as just mentioned, is that the country with the most Packard plants is Mexico. The main explanation is the wage gap between Mexico and the United States/Canada (with wages approximately ten times cheaper in Mexico). By the year 2000 Delphi personnel was distributed in the following way: 7% in Canada, 47% in the host country, the United States, and 52% in Mexico (**Table 2**).

It is important, however, to not limit this analysis to only the role of wage costs in the globalization process. While wages are an important part of production costs, there are other relevant costs, especially those associated with coordination (transaction costs), which are important to include. These costs will be analyzed in the following section.

3.- Delphi in Mexico

The way Delphi's history evolved can be reconstructed in two stages, with one period from 1978 to 1994, and a second period from 1995 to 2002. The division between the two periods corresponds to the beginning of operations of a technical center in Mexico in 1995, modifying the way in which coordination was carried out among the Delphi divisions located in Mexico. We will refer to the first period as "growth under the monocentric learning and coordination model" (1978-1994), and the second period, the "polycentric model" (1995-2002), when more than one R&D center was established to support the development of business accumulation.

3.1 Monocentric growth and coordination model: 1978- 1994.

In this section we will describe the history of the Delphi divisions located in Mexico, to contribute toward a somewhat detailed understanding of the characteristics of Delphi's configuration and coordination in the country. The following table synthesizes some of the characteristics at the time when Delphi was beginning its operations in Mexico (**Box 1**).¹⁸

By 1995, the year when MTC began to function, Delphi employed 51,069 persons in 51 plants in Mexico. The Packard division employed 57% of the total in 21 plants, Delco employed 18%, in 7 plants; Delphi Interior, 13% in 3 plants; and finally, Delphi Energy employed the fewest workers, with 10% in 2 plants.¹⁹

Box 1
BEGINNING OF DELPHI DIVISIONS IN MEXICO

¹⁸ It is necessary to clarify that from 1978 to 1995, and strictly speaking, up until 1999 when Delphi formally separated from GM, these establishments belonged to GM.

¹⁹ Source: ELM (1995).

A. Packard Electric. Delphi began its operations in 1978 in Ciudad Juárez, Chihuahua,²⁰ and the first establishment to be created was *Río Bravo Eléctricos*, part of the *Packard* division.²¹ This plant specializes in assembling, welding and inserting cables in automotive harnesses. From the beginning, this division of establishments has specialized primarily in assembly activities, intensive in unskilled labor.

B. Delphi Interior & Lighting Systems. In 1978, *Delphi Interior* built a plant in Ciudad Juárez, Chihuahua to specialize in sewing and assembling car seats. In 1979 and 1980 two new plants were built in Matamoros, Tampoico. One of them specializing in plastic injection and molding parts of products such as: instrument panels, covers, steering wheels, and sun visors. And the second plant specializing in molding plastic products.²² The latter division is capital intensive (plastic injector machines) and involves intensive use of raw materials (plastic).

C. Delphi Energy & Engine. In 1979 in Ciudad Juárez, Chihuahua, this division began its activities in assembly, welding, plastic processing and cables for products such as: solenoids, turn signals and motor controls. In 1984 production began in another plant specializing in assembly, cable assembly and processing of products such as: ignition switches, turn signals and oil pumps. A labor intensive division.

D. Delphi Chassis Systems. This division has only one establishment in El Salto, Jalisco which began operations in 1995, employing 1,000 workers. The activity it carries out is assembling shock absorbers and struts. A labor intensive division.

E. Delco Electronics. This division began operations in Matamoros, Tamaulipas in 1979, specializing in cable assembly for electrical and electronic products for audio and steering wheel control systems. Between 1984 and 1987 two new plants were built in Reynosa and Matamoros. The first specializing in assembly and cable assembly for products such as: climate control, audio systems, cellular telephones, driver information systems, head up display, instrumentation cluster, and steering wheel control. The second plant specializing in instrumentation cluster and display electronics. In comparison with the other Delphi divisions in Mexico, Delco is the division with the most technological content and the most intensive in more highly skilled labor.

Packard is clearly the most dynamic division in this process of establishing the cluster of Delphi companies in Mexico, both in terms of employment volume as well as in the number of establishments specializing in harness production²³. The history of the cluster of autoparts companies in Chihuahua is closely associated with Packard's history.²⁴ It is

²⁰ Located at Mexico's northern border, across the border from El Paso, Texas.

²¹ At that time Packard belonged to GM.

²² Such as bumpers, fascias, door beam supports and body molding.

²³ According to USITC, harnesses consist of multiple, isolated electrical conductors that are assembled with terminals, connectors, sockets and other cable products (Carrillo and Hinojosa, 2001).

²⁴ Lara, 2001; Carrillo and Hinojosa, 2001.

important therefore to describe the characteristics of this division's technological, organizational and economic history.

In the period from 1978 to 1994, 22 plants were created in the Packard division, employing 29,174 workers by the last year. Of these establishments, 19 are exclusive GM suppliers, and three produced harnesses for various automotive clients.²⁵ The 12 plants located in Chihuahua are the largest. The largest of all²⁶ employed 4,800 workers in 1994.

Packard's expansion during this period was characterized by a process of exploring efficient and flexible organizational forms for producing higher volumes of harnesses within the required standards and quality. By the mid-1970s, there was a need to produce a greater volume of harnesses with the technology, quality and flexibility demanded by competition, plus at low costs. As a result of this pressure, the US automotive industry moved numerous harness plants to northern Mexico, taking advantage of regulations applying to maquiladoras²⁷ (Carrillo and Miker, 1997; Lara, 2000a; Carrillo and Hinojosa, 2001).

The intense competition between US and Japanese corporations forced GM, and Packard in particular, to rationalize processes, improve product reliability, incorporate new technologies and lower costs in the introduction of harnesses (Helper, 1998; Russo, 1994; Lara 2000b; Guillet 1999). The response from GM in the United States and from Packard was to migrate toward southern Mexico in the search for lower wages and more flexibility and adaptability.

Packard had to build a considerable number of establishments in a relatively short amount of time, since more harnesses per vehicle were required due to the introduction of new technologies. One of the effects from the integration of electrical and electronic (E/E) components and systems in automobiles has been the need for more harness subsystems, which in turn demands the creation of plants specialized in the manufacturing of specific harnesses (Koido, 1992; Lara, 2000b). Added to this growing demand for harnesses, another factor came into play: the increasing sales of utility vehicles and mini-vans requiring a greater number of more complex harnesses per vehicle.

In addition to these tendencies there was a counter-tendency, specifically the transition from an integral design to a modular design beginning in the late 1980s (Helper and McDuffie, 2000; Lara, 2000a; Carrillo, 2000) which led to a reduction in the number of harnesses per vehicle. Because of these two tendencies of an increase/decrease in the number of harnesses, it became "critical" to design productive organizations increasingly flexible in technological, economic and organizational terms.

²⁵ One plant for Toyota and GM; another for Subaru – Isuzu; BMW; and another plant for Cami: Nummi and Freightliner.

²⁶ Electrical Wiring Systems and Circuits.

²⁷ These regulations permit inputs and components to be imported and re-exported without paying taxes, except the added value tax. In reality, these regulations also permit the hiring, use and mobility of a flexible labor force. According to a number of researchers, maquilas located at Mexico's northern border are, from a certain point of view, synonymous to "freedom from unions" and "low costs" for global corporations (Quintero, 1998).

In the initial process of the building of new plants in Mexico, we can see Packard's strategy of moving the assembly of the more labor intensive processes from the United States to Mexico. But we can also see the need for creating domestic labor markets with the capability for adapting to quantitative and qualitative harness variations. A domestic labor market relatively rigid in terms of hiring and dismissing workers, as in the United States, is not very functional from this perspective. Industrial (management/union) relations at Packard plants in the United States —characterized by confrontation— also led to moving harness-producing establishments out of the country (Russo, 1994; Helper, 1998; Guillet, 1999; Lara, 2000b; Carrillo and Hinojosa, 2001).

Due to the growing complexity of harnesses, it became essential to form work teams that would continually integrate new and increasing specifications associated with changing conditions in design and in the market. Institutional conditions (freedom in hiring and firing), as well as the cooperative tradition and numeric flexibility in Mexico's labor market, turned maquiladoras into a suitable scenario for taking harness manufacturing from the first generation, to the second, and to the third generation (Lara, 2000b). The labor atmosphere in Mexico is relatively more cooperative and less confrontational than in the United States. And one of the central objectives in the expansion of the Packard division in Mexico was to build plants that take advantage of economies of scale, but without weakening the forms of cooperation between engineers, supervisors and workers.²⁸

In addition to the increasing complexity of harnesses, promoting an extensive division of labor and elevated technological specialization in the maquiladoras became indispensable (Lara and Constantino, 2000d). As a result, numerous and varied establishments specializing in manufacturing specific harnesses were gradually created, and were associated with different models of automobiles and different clients. With so many maquiladoras manufacturing harnesses, it became necessary to exchange increasing volumes of information regarding new designs, demand conditions, quality and logistics (just-in-time). This situation in turn brought unexpected contingencies and "bottlenecks," especially when new designs were introduced. And when a critical problem emerged, it was necessary to seek assistance from the Packard engineering center located in Warren, Ohio.

Engineering activities were essentially concentrated in the United States, and this meant that coordination processes and the resolution of critical problems had to be frequently transmitted to personnel located in each of the countries. Having engineering support located so far away implied costs, time and difficulties in overcoming language and geographic barriers between the engineering communities and personnel located in Mexico. With these conditions characterizing the monocentric model, it was expensive in terms of time and money to cross the border from Ciudad Juárez to the United States and then board an airplane to cross a significant portion of the country, to finally resolve "bottleneck" problems.²⁹ This model of monocentric learning and coordination functioned when there

²⁸ Together, these factors explain in part why the average size of establishments built in Mexico is smaller than for those in the United States (Lara, 2000b).

²⁹ Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002. For more on this point, see Carrillo and Hualde, 1997.

were only a few companies and when the harness was simpler. And, in general, this model functioned as long as autoparts systems were basically simple, and the need to decrease design times was not very urgent.

But in the late 1980s the automotive sector began to confront new forms of technological competition in the framework of the integration of E/E subsystems and of modular architecture—which tended to significantly modify prices, routines and the various forms of the company’s authority as a whole, as well as the value chain, including that of suppliers. In this atmosphere, what difficulties does a company experience in creating patterns of coordination and cooperation within its various business units?³⁰ The intensity of coordination forms will decisively depend on two key factors: first, the level of profoundness and similarity / complementariness of the technological capacities of a company’s productive units, and secondly, the nature of contingencies—occurring internally, but especially externally—which alter patterns of interdependence within a company’s business units.

It is necessary however to recognize the administrative difficulties that occur when there is interdependence between various business units—and these difficulties intensify when a cognitive nucleus for control and monitoring is lacking, as in the monocentric growth model. A set of common obstacles to the coordination of business units can be identified, and some of the most important ones³¹ are the following:

a) Resistance to coordination among business units, when it is perceived that benefits may be distributed asymmetrically. Resources and capacities are distributed unequally within an organization, and consequently, the motivation for investing in coordination processes will not be the same among the different business units. It is important to recognize the appropriability problems that arise in coordination processes.

b) Improving coordination processes among business units frequently implies creating significant interrelationships, which can lead to considerable resistance on the part of managers, who wish to avoid a real or perceived loss of autonomy.³² The autonomy of management groups can be modified in the following ways:

- ❑ More intense coordination processes can lead to the centralization of certain management functions, and thus modify the control exercised by managers within their “organizational fields.”
- ❑ Business units frequently resist coordinating purchasing-sales activities, for fear of modifying their relationships with their clients.

³⁰ We could answer that, as proposed by Williamson (1976), the mechanism for coordination within the company is authority, but this explanation would be much too simple in relation to the complex processes of coordination and cooperation that take place within companies.

³¹ Porter (1987).

³² Interview with human resources manager at Delphi-MTC, Ciudad Juárez, March 2002.

- ❑ Seeking more intense coordination among business units may create conditions for negotiating more closely with business units within the corporation, to the detriment of relations with companies outside the corporation.³³
- ❑ Greater coordination among business units implies creating common criteria as to the priority assigned to different shared activities, and this often produces conflicts. In particular, conflicts arise when there is an attempt to designate minimal resources, in terms of engineer time, specialized infrastructure, etc.³⁴
- ❑ Managers of business units view being evaluated according to the results of joint, coordinated activities as risky. And this can lead to a preference by these managers to place the most emphasis on activities over which they have more control.

c) Another source of resistance to coordination and cooperation among business units depends a great deal on the type of corporate incentives established.³⁵ If the compensation system for managers is strongly associated with the productivity of their own business units, both because it is relatively easier to quantify the performance of each business unit, as well as due to the difficulty in measuring the productivity of coordination and cooperation-based activities, this incentive system can therefore lead to limited willingness to share resources with other business units.

The types of incentive systems that most frequently hinder coordination and cooperation efforts are those in which the performance of individual units is usually valued highly, while contributions to other units in the corporation are not.

Often, business units use different methods for calculating income, costs and thus, income distribution. More homogenous incentive systems are needed, and conflictive situations will continue until they are implemented.

d) Each business unit has its own history, and its own highly specific circumstances in its organization and region, and consequently, the different units have different identities.³⁶ In addition, different cultures and languages within the business units, as well as administrative differences, varying procedures and geographic distance are other factors that can inhibit communication and coordination among business units.

Coordination among business units is strongly influenced by the company's history and organizational configuration. In companies that are highly diversified, achieving

³³ To work with a related unit is viewed as limiting the business unit to an adverse position for negotiating (Porter, 1987: 400). This friction presents itself especially when business units are more limited in changing from one internal client to another, for example, than when an external client is involved. In this situation the costs involved in internal transactions are greater than those in external transactions.

³⁴ As pointed out by one engineer at Delphi: "Although some regions' management believed the design for the manufacturability process (DFM) was a cost saving and quality improvement tool, they were somewhat reluctant to add full time DFM engineers to accomplish this task." Cited in Lara (2000b).

³⁵ Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

³⁶ Frequently managers identify more with the business units than with the corporation.

coordination and cooperation is part of a long process of negotiations and conflicts that consume time and resources.

As more plants were built in Mexico, an increasingly critical situation was created in relation to the geographic distance and communication between: 1) plants located in Mexico and those in the United States; and especially, 2) the “technological, economic and organizational” distance between plants located in Mexico. Geographic distance signifies time, transportation costs, and learning communities that are not cohesive or only occasionally integrated. Was it possible, under the monocentric model of technological development, to promote technological diversification and quantitative growth – similar activities? Was it possible to bring into harmony the incentives of the actors involved and of the company within the organizational structure and heterogeneous forms of rationality fragmented in geographical space? Was it possible to reduce innovation and development costs for a cluster of companies lacking a geographic nucleus that was cognitively “close” to R&D? These are some of the questions we will attempt to answer in the following section.

3.2.- Emergence of the polycentric model of growth: The birth of the Delphi-Juárez technical center³⁷ (1995-2002)

The functions assigned to the Delphi-Juárez technical center must be viewed as part of a highly specific economic, technological and organizational process that will be described below.

The Delphi technical center was established in 1995, with 714 employees. This event marked the transition from the monocentric growth model to the polycentric growth model. What were the pressures exerted to establish a technical center in Mexico, especially those coming from the dense network of companies, establishments, plants and actors in the country? How can the growth in both the technical center as well as in the accumulation of Delphi business units in Mexico be explained? Is the creation of MTC an expression of the need for evolution in the accumulation of Delphi divisions, dormant during the 1976-1994 period? And, to what degree does the creation of MTC become a powerful lever for the growth and diversification of Delphi’s productive structure in Mexico?

In order to respond to these questions, we will describe MTC’s most important functions, aspects and effects in Mexico:

1.- Intensive use of engineering, and a reduction in innovation and development costs. Intensive use of human resources, when the concentration of the divisions makes it possible to participate in different projects,³⁸ but especially, the reduction in innovation costs due to the relatively low wages of engineers and personnel in Mexico with respect to those in the

³⁷ Research by Carrillo and Hualde (1997), Lara (2000a) and Dutrenit, Vera-Cruz, Alvarez and Rodríguez (2001) reconstructed the MTC, particularly emphasizing its internal autonomy. In this paper we have sought to reconstruct the MTC, incorporating the functions performed in addition to R&D, especially coordination activities, from an evolutionary perspective.

³⁸ Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

United States. 85% of MTC's engineers are Mexican. Low wages prevailing in many countries where Delphi engineering centers are located, such as Mexico, has made it possible to hire more engineers without increasing R&D costs, and at the same time, to increase sales linked to engineering and development by 6%.³⁹ According to Battenberg, the fact that wages are low in many technical centers "enriches our strategy to do engineering on a global basis."⁴⁰

2.- Construction of modern, complex technological infrastructure. This took place according to the expansion plan for each division. In 1995 Delco-Remy finished moving its engineering area in sensors and actuators to Mexico, including design, product, process and testing engineering, and performance and durability laboratories. In 1996 Delphi-Saginaw installed temporary certification and testing laboratories. In 1998 Delphi E&C established a process development and methods laboratory. That same year Delphi-Harrison installed packing laboratories. And in 1999 the center's phase II was initiated.⁴¹ That same year Delphi-H established global manufacturing systems. And the year 2000 marked the opening of laboratories for electronic manufacturing and testing, and systems and software testing.

MTC makes it possible to reduce innovation costs since it uses more intensively the expensive technological infrastructure specializing in product and process development.⁴² The concentration of the divisions in a limited space permits creating economies of scale in the processes of searching for and exploring variations (innovation). In this sense MTC uses common technological infrastructure that makes it possible to carry out a number of R&D functions.⁴³

3.- Centralization of administrative functions. Unlike other Delphi centers located in other parts of the world, MTC is the only center that integrates six of the seven Delphi divisions in a single administrative unit.⁴⁴ In 1996 the process of moving the financial activities of Mexican subsidiary companies to MTC began, and by 1998 most were concentrated there. In the year 2000 a project for implementing a Common System of Inventory Control⁴⁵ was initiated in the technical center. At the end of 2001, a process of concentrating and homogenizing compensation systems was initiated. Therefore, the technical center is progressively becoming a nucleus of concentrated technological and administrative capacities which transforms it into a gravitational axis of resources in a cognitive

³⁹ Delphi (2001): "A world of challenges: Engineering is a global enterprise."

⁴⁰ Ibid.

⁴¹ Before the expansion the total area was 203,000 square feet, and with the expansion it increased to 447,000 square feet.

⁴² Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

⁴³ R&D functions such as: engineering and development; computational analysis; design; materials engineering; test vehicle fleet; electronics laboratories; and process development. In terms of engineering and development, they have high-tech infrastructure for carrying out "tests" in developing technological components and subsystems.

⁴⁴ Interview with maintenance manager at Delphi-MTC, Ciudad Juárez, March 2002. In addition to the seven divisions (see footnote no. 9), there is also an area specializing in the parts market.

⁴⁵ This is a combined effort among the Saginaw, Delco, Energy, Chasis, Harrison and Interiors divisions, and also information systems management. It is worth mentioning here that an important effect of concentrating administrative activities in the technical center is that the number of administrative employees is thereby increased. Interview with human resources manager at Delphi-MTC (2002).

framework, and in the control and monitoring of the six divisions and the establishments located in Mexico (**Map 1**). The concentration of administrative, control and monitoring activities in a single geographical area makes it possible for MTC to reduce the costs of internal transactions, by reducing the costs of coordination between business units.

Integrating the various Delphi divisions and business units makes it possible to share tangible and intangible activities among them, due to common buyers, communication channels, technology and other factors. In early 2000, MTC began a process of centralizing the purchasing of direct and indirect materials, as well as information infrastructure.⁴⁶ While in 1997 the center spent US \$30 million in direct materials, the amount spent in 2000 increased to US \$250 million. Also, in 1998 MTC spent US \$150 million on indirect materials, and by 2000, that amount rose to US \$202 million.

4. – Productive capability and potential market. There is no doubt that Mexico is part of a global production and distribution platform, due to the advantages associated with the region. Mexico has become an important platform for importing and producing cars, light and heavy vehicles, and original and replacement autoparts destined primarily for the United States and Canada (97% of cars and 99% of light and heavy vehicles were exported to those countries in 2001) (AMIA, 2002). According to Bancomext (2002), the following establishments were located in Mexico in the year 2001: eight assembly companies with 20 final assembly plants and 875 autoparts companies (150 1st tier, 250 2nd tier, 50 3rd tier suppliers, and 425 replacement autoparts producers). In addition to this productive structure, there were 1,000 distribution agencies. In that same year, US \$28 million in automotive components from the United States and Canada crossed Mexico on a daily basis, equivalent to a total of US \$7 billion.⁴⁷

5.- Modular design. The transition from an integral design to a modular design has been unavoidable. According to Delphi's president, the 31 technical centers⁴⁸ distributed around the world are prepared to meet the needs of any OEM. Battenberg states: "We believe it is very important to have a technical capability close to the customer and close to its manufacturing centers around the world....But in particular, we want to provide systems integration capability because modules are what the OEMs want. These global tech centers allow us to do that. They also help us as we recruit engineers."⁴⁹ As part of a global network, MTC and the automotive sector are in a process of transition from an integral design to a modular design (Baldwin and Clark, 2000; Lara, 2001b).

6.- Technological changes. New technologies make it necessary to create porous borders between the various divisions or functional departments. Technical changes are bringing down barriers between sectors and between segments of sectors. Technological convergence is bringing profound consequences that cannot be administered by a single center in an isolated manner.⁵⁰ Today, the scheme of a single R&D center, dependent on the

⁴⁶ Interview with director of indirect purchases at Delphi-MTC, Ciudad Juárez, March 2002.

⁴⁷ Delphi (2001). "Delphi en México," Corporate Affairs, Mexico.

⁴⁸ The technical centers are located primarily in the United States, France, Luxemburg, Germany, Poland, Japan, Singapore, India, Brazil and Mexico.

⁴⁹ Delphi (1991). "Delphi moves toward a more electronic portfolio."

⁵⁰ Interview with applied engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

engineers market—a monocentric scheme—is not viable in the automotive sector. According to Delphi’s president, the dependence of engineers on a single source is not part of Delphi’s strategy, since not all the regions and countries of the world possess the abilities required by this firm.⁵¹

We can see this in Delphi’s need to create a new identity in terms of sector and technology. Very recently, specifically in March 2002, the corporation decided to change its name from Delphi Automotive Systems, to simply Delphi. This change in name indicates a new global economic and technological strategy aimed at initiating relations with clients in various markets to offer various products. This process of diversification undertaken by Delphi as an automotive firm began in May 1999 with the search for new market segments such as: aerospace, medical equipment, computers, entertainment and commercial vehicles. Other market segments in the high tech category include: connection systems, consumer electronics, and electronic sensors and controls.⁵²

7.- Accumulation of capabilities. The establishment of a technical center was the result of the growing accumulation of capabilities in each business unit, and of the pressure for building an institutional platform that would systematically assure the integration of the various communities of engineers in the divisions established in Mexican territory.⁵³

The geographic concentration of divisions for jointly carrying out R&D activities has made it possible to transfer and integrate: i) administrative knowledge possessed by the various divisions; ii) technological and organizational abilities and information; iii) synergy among the different work groups; and iv) joint activities for developing more coherent diversification strategies, with the capabilities and trajectories of the cluster of divisions in Ciudad Juárez. The objective is to make use of the interrelationships between the different businesses to allow for sharing tangible and intangible assets and competitive interrelationships.⁵⁴ The monocentric model is “clearly inferior” to this polycentric scheme.

8.- Learning trajectory. MTC is characterized by an increasingly productive trajectory: 130 inventions, 44 patents applied, 8 patents awarded, 8 defending publications and 2 industrial secrets.⁵⁵ There are engineers at this center from more than a dozen countries, 11 languages are spoken, and most employees are bilingual. The technical center has a global culture, and English is the predominant language.⁵⁶ Approximately 100 engineers from Mexican operations have been promoted to leadership positions and have been designated for contributing with their qualifications to other global technical centers. The community is composed of primarily electrical engineers, since MTC is developing electrical-electronic

⁵¹ Delphi (2001). “A world of challenges: Engineering is a global enterprise.”

⁵² Delphi (2002). “Delphi drives tomorrow’s technology beyond ‘Automotive Systems’.”

⁵³ Interview with human resources manager, Delphi-MTC, Ciudad Juárez, March 2002.

⁵⁴ Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

⁵⁵ Delphi Corporation, Mexico, 2001. From 2000 to 2001 the number of patents and innovations produced by Delphi doubled, since in 2000, Delphi had registered 71 inventions, and had applied for 21 patents. MTC-Delphi, 2000.

⁵⁶ Interview with engineering manager at Delphi-MTC, Ciudad Juárez, March 2002.

systems for replacing manual and hydraulic systems.⁵⁷ As a result, the number of employees at this center has been continually growing since it was established (**Table 5**).

9.- MTC's integration in the Delphi network. The community of Mexican engineers and employees working at MTC belong to a global community of more than 16,000 engineers.⁵⁸ Delphi has 6,000 patents and an annual budget of US \$1.5 billion designated for R&D activities through its 31 engineering centers around the world.⁵⁹

Conclusions

To conclude this paper, it is necessary to return to the initial question posed in this study: From a Mexican perspective, how can the process of globalization and coordination of R&D activities be explained in the case of a company in the autoparts sector?

The answer has been an attempt to integrate two sources: empirical evidence from the process, and the creation of images of the company from an evolutionary epistemological framework. Given the difficulties of gathering information regarding the existing problems of coordination within the company studied, a set of plausible conjectures was developed. Not all of them necessarily fit the object of this study. And coming close to reality is not the same as the truth. All things considered, the purpose of this exercise based on evolutionary epistemology is to reconstruct the plurality of worlds within which processes of globalization and coordination take place. It is necessary to open the "black box" of intra-company coordination and seek guidelines for interpretation.

In this study, the importance of MTC's creation was emphasized, as well as its technological, organizational and regional economic "specificity." The history and rhythm with which that history unfolded are "important," not as simple anecdotal details, but as the place "from which" what is explained about the object of the study and history becomes intelligible. Technological evolution signifies accumulation, stability, variability, velocity, direction, bifurcation, indetermination and uncertainty —and all of this in the framework of agents which do not have "identical interests" and which fundamentally make decisions with restrictions (limited rationality). These are the key concepts on which we have based our attempt to reconstruct the history of the globalization process and the need for intra-company coordination in the Delphi corporation. Consequently, the globalization of production is viable in a context of great uncertainty and complexity, only if global capabilities are created in R&D production distributed in the various regions.

In order to coherently explain MTC's creation, it is necessary to incorporate two essential characteristics of the study's object: i) the nature of the technological trajectory of the automotive sector characterized by time acceleration, bifurcation, complexity and

⁵⁷ Battenberg points out: "We're trying to get our mechanical engineers to think out of the box, not only in terms of getting rid of wiring, but also hydraulics so we can move to brake by wire, steer by wire —actuation by wire." Delphi, 2001.

⁵⁸ Of which more than 5,000 engineers work in the areas of electronics and software.

⁵⁹ Delphi (2001). "Delphi moves toward a more electronic portfolio."

uncertainty; and ii) the history (path-dependence) of the dense, extensive network of related business units within which the technical center was constructed. Both characteristics make up the framework within which the nature and strength of coordination activities fulfilled by MTC can be more intensely assessed.

It is impossible to characterize MTC's creation and development, while limiting ourselves to studying only its activities in designing and developing products, ignoring its historic and systemic determinations.⁶⁰ The various Delphi divisions located in Mexico gradually accumulated a set of technological and organizational capabilities that made it possible to explore and make use of new technological opportunities, however because of the decentralization of operations it was not very viable. The need to create an R&D center in Mexico was, therefore, due to the imperative of integrating the capabilities accumulated over time, as well as the resolution of problems or "bottlenecks" in the plants located throughout the country. It would be difficult to confront this latter point in the context of geographic and cultural distance, in a monocentric growth model.

It is important to capture the complexity of coordination processes in global corporations which are multi-plant, multi-division and multi-technology. From this perspective, MTC's function is not only to design new processes and products, but also to coordinate the accumulation of Delphi business units. In addition to the activity of developing new processes and products, MTC fulfills intra-company functions at a regional level in the areas of administration, finances, engineering support and coordination.

Lastly, the way in which business units and agents are coordinated is crucial, in the context of limited rationality and divergence of interests. The problem of coordination becomes more complicated when an important part of monitoring and control depends on the cognitive capabilities of the actors to fully carry out their roles. In these circumstances it is possible to understand that creating a R&D center can have multiple objectives, for example, controlling and monitoring productivities such as incentive systems, but especially mutation and technological conversion processes in the various divisions making up the firm. Coordinating means creating order, but also promoting change, and bringing individuals and the organization into harmony. Therefore, the polycentric growth model for developing global technological capabilities presents itself as a requirement for building a division of labor that is extensive, complex and subject to unexpected contingencies.

⁶⁰ It would be limiting, for example, to reduce the explanation of MTC functions to the "more innovative," successful activities, such as sensors, since that would lead to a reduced understanding of this organization's complex evolutionary dynamics.

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