

Changes in the adoption of Learning Mechanisms under a New Economic Environment: A Case Study of Mexican Auto Parts Firms[♦]

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Abstract

This paper provides interesting findings on changes in the adoption of different learning mechanisms before and after the implementation of NAFTA, based on a multivariate probit model that tests a panel of 193 Mexican automotive firms. The results obtained provide useful insights into the composition of learning mechanisms and trends used by the auto parts sector in the process of building technological capabilities under the new competitive market conditions. The results go beyond the Mexican context and are relevant to other developing countries experiencing a changing economic environment.

1. Introduction

Similar to other industrializing countries, in Mexico the traditional manufacturing firms were originally established to produce goods for a small fraction of the domestic market. These firms operated within a protected environment produced by government infant-industry schemes within an import substituting industrialization (ISI) strategy. Most of these firms were using second hand machinery and equipment discarded by foreign countries as their production plants were upgraded.

During the 1980s, in order to try to become internationally competitive, Latin America underwent important macroeconomic transformations¹. Structural adjustment programmes recommended by the International Monetary Fund and the World Bank were implemented. The new economic paradigm, which the Economic Commission for Latin America and the Caribbean (ECLAC) called the New Economic Model (NEM), is defined as “a strategy aimed at penetrating large and growing international markets on the basis of specialization and comparative advantage...where resource allocation is determined by the interplay of free and unregulated prices...[and] where the private sector is the key agent of dynamism in the economy (Ramos 2000). Ramos (2000) in his study considers NEM as the set of economic characteristics in Mexico resulting from trade liberalization in the late 1980s (in which government protection still played a role) and the new economic environment under NAFTA in 1994, which gave no more room for protection.

This paper presents an empirical study of firm behavior under a particular changing environment, namely that created by the confluence of the NEM and NAFTA. The analysis is based on a panel of automotive firms for the years 1991 to 2000². The automotive sector historically has been an important and dynamic contributor to the Mexican economy, and has had an effect on other economic sectors. Data from the liberalization period prior to NAFTA (1985-1994) indicate that there were very few structural changes within the manufacturing sector during this period (Dijkstra 2000); the share of the machinery and equipment sector increased only slightly with manufacturing output increasing from 22.06% to 25.17% (INEGI).

In 1989 government decided to modernize the industry and set it on a market liberalization course based on the new economic trend favored by government at that time. The 1989 –automotive decree was designed to integrate Mexico with the global automotive sector through increasing exports and gradually reducing protection from external competition. Under this decree the import of cars and trucks was allowed; it reduced the

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local content input requirements to 36%, and lifted the restrictions on foreign ownership participation for firms in the sector³. These were the first steps in opening the automotive sector to external competition, both from foreign firms already located within the country and firms in other countries.

Mexico's NEM pathway was reinforced in 1991 by the proposal to establish a free trade agreement – NAFTA - between Mexico, the United States and Canada, which came into force in 1994. The new legal environment resulted in a more liberalized trade regime, in which domestic firms were exposed to greater external competition as the ownership and domestic integration requirements disappeared. One of the most important changes brought about by NAFTA was the homogenization of automotive production towards worldwide standards. Consequently auto firms needed to adapt their strategies and their production plants to meet international requirements⁴.

During the first five years of NAFTA (1995-2000) the automotive sector in Mexico increased its participation in manufacturing from 23.76% to 32.12% (INEGI). The automotive sector experienced the highest growth rates within manufacturing, its share increasing from 39.5% in 1993 to 49.2% in 1999, which represents some 14% of manufacturing GDP (Presidencia 2001). By 2000 the automotive sector was the most important sector within the Mexican manufacturing industry, with a contribution of close to 3% of the national GDP (Presidencia 2001).

Since the late 1990s the automotive sectors has been second largest exporting sector in Mexico, mainly oriented towards the USA. Between 1990 and 1999, 11.6 million vehicles were assembled in Mexico; 4.7 million units for the domestic market and 6.9 million units for export (INA 2000). In 2001 Mexico was the world's ninth largest producer and exporter of vehicles and the seventh largest exporter of engines (Bancomext 2000).

Under the new conditions institutionalized by NAFTA, domestic firms could become integrated into the automotive value chain based solely on their competitiveness and performance. This highlighted the importance of building and strengthening learning capabilities to allow firms to achieve a basic level of absorptive capacity and enhance their production chains while climbing the ladder towards more complex innovation and technical change.

The analysis in this study is designed to show how the organizational and learning mechanisms in the firms in this sector changed as a result of trade liberalization, and to demonstrate the effort made to upgrade their knowledge competences to achieve a higher technological level. Although NAFTA to some extent created a *divide* between Mexican market liberalization and the economic structures of the rest of Latin America, there are lessons from its implementation that are applicable to other developing economies, especially those that are trying to move their industrial sectors towards free-market trade regimes. The empirical exercise conducted in this study tests the following hypotheses: i) the nature and direction of automotive suppliers' learning mechanisms has changed under NAFTA compared to the previous economic regime; ii) the learning mechanisms of auto parts firms are strongly associated with firm size, ownership structure and supplier tier level. Based on these hypotheses we examine complementary insights at two different levels of aggregation -the meso and micro - of the auto parts sector; and achieve a more qualitative perspective of the behavior of firms in the industry under a changing environment. The analysis is based on data from a panel of 193 firms in the automotive sector, obtained from the *National Survey on Employment, Salaries, Technology and Training* (ENESTyC), for surveys carried out both before and after the implementation of NAFTA.

The paper is organized as follows: Section 2 provides a brief review of the literature related to the relevance of learning in strengthening and building firms' technological capabilities. Section 3 describes the methodology used in the empirical analysis. Section 4

presents the data and variables analyzed. The descriptive results of the learning mechanisms and explanatory variables analyzed are provided along with preliminary insights on changes in trends followed by firms in the period before NAFTA and after it was instituted. Section 5 presents the results of the multivariate probit model and examines the degree of association between critical firm-level variables and choice of learning mechanisms or processes. Section 6 describes the main findings and some implications of the analysis.

2. Theoretical Framework

In order to survive and respond positively to the new competitive and economic conditions produced by free trade agreements (e.g. NAFTA), firms need to make explicit efforts to build *technological capabilities*. These capabilities are acquired through a cumulative learning process and include the necessary skills, knowledge and information to use, adapt and operate technology, processes and standards at a similar level to firms at the technological frontier (Dahlman, Ross-Larson et al. 1987). They include the skills, knowledge, institutional structure and linkages required to manage and generate technological change efficiently (Bell and Pavitt 1993). *Technical change* is the process by which new technologies are incorporated into a firm's *production capacity* – which includes the resources used to manufacture industrial goods at given levels of efficiency and given input combinations (Bell and Pavitt 1993).

Firms acquire and build their technological capabilities through different *learning mechanisms*, which typically involve repetition and experimentation, and which enable them to perform tasks more quickly and efficiently and to identify new production opportunities (Teece, Rumelt et al. 1994). It is through these mechanisms that firms build, supplement and organize information about their activities and their culture. They are the specific ways by which firms learn, and they contribute to improving the skills of their workforce and to up-grading the firms' technological capabilities (Arrow 1962; Young 1991; Young 1993; Benarroch and Gaisford 2001).

These mechanisms or activities are an important ingredient of firms' *technological efforts* –which are the inputs of firm learning- required to move towards higher learning and capability building (Dahlman and Westphal 1982; Romijn 1999; Jonker, Romijn et al. 2006). Among the mechanisms referred to in the literature we can identify certain dynamic learning processes that enable firms to acquire external knowledge, such as *learning through training* (Dahlman and Fonseca 1987; Figuerero 2001). One of the most common forms of learning, learning by changing which creates an upward spiral of greater understanding and confidence, which in its turn promotes further improvements (Figuerero 2001)- includes *learning by innovating or by research and development (R&D)* (Katz 1973; Cohen and Levinthal 1989) and *learning by exploring* (Teubal 1984). Firms also *learn by using* the technology embodied in their machinery and equipment (Rosenberg 1976). Other important mechanisms through which firms acquire and upgrade their technological capabilities are those related to *learning by searching*, which involves external upgrades to capabilities as firms establish technology contracts with foreign consultants or equipment suppliers to engage in technology transfer (TT) or to acquire technological packages (Bell 1984; Dahlman and Fonseca 1987).

A large body of empirical work has examined the role of learning in building firms' technological capabilities. Empirical studies have shown that the acquisition of these capabilities is influenced by different firm-specific characteristics, such as size, age and ownership structure (Biggs, Manju S. et al. 1995; Cameron G., Proudman et al. 2005; Jonker, Romijn et al. 2006; Oyelaran-Oyeyinka and Lal 2006). However, the results of these studies differ, and there is for more empirical studies in this area, especially in the context of developing economies. Table 1 presents a selection of indicators and findings

from case-studies that analyze the relationship between firm-level characteristics and learning in firms in developing economies.

Table 1. Empirical Studies on the relationship between firm-level characteristics and learning in firms.

Authors	Country	Data	Variables used	Technique	Results
(Katz 1987)7)	Latin America (LA)	Individual firm and industry studies from the IDB/ECLAC/UNPDPogramme.	Engineering activities, industrial organization and production planning (technological efforts),	Statistical Descriptions of case studies	Market size and shortages of human capital limit vertical integration in manufacturing firms in LDC. Technological search efforts in LA follow a wide variety of objectives and firms' idiosyncrasy.
(Biggs, Manju S. et al. 1995)5)	Ghana, Kenya, Zimbabwe all of them undergoing structural reforms.	Primary data at the firm-level; 3 countries, 4 industries	Learning Mechanisms (training, R&D, supplier-buyer relationships, firms-interaction, industry networks, hiring of local/foreign consultants); Technological Efforts; Technological Capabilities; Total Factor Productivity	Descriptive //Stochastic Frontier Methods for levels of efficiency	Learning Mechanisms constitute the most important category of technological capabilities. Technological capabilities are the results of deliberated efforts carried out by firms.
(Figuereiro 2001)1)	Brazil	Meetings, (two firms)	Investment, product technology and production organization, and machinery and equipment (variety, intensity and functioning)	Comparative case-study	Functioning of learning processes in catching-up firms in late-industrializing economies. Efforts to manage knowledge acquisition by the firm should be done in parallel with organizational learning. Efforts on the intensity and functioning of learning processes are crucial to technological capability accumulation.
(Oyelaran-Oyeyinka 2003)3)	Nigeria	Micro-level data from 33 firms in the Nigerian brewing sector.	Institutional actors, size of firm, ownership nature, technical skills of labor force, foreign/domestic technical assistance.	Qualitative Analysis. Descriptive Statistics	Size, manufacturing skills and ownership are important factors in the innovation success –seen as introduction of new processes or products, organizational changes and undertaking R&D- of firms that survived and prospered under a changing industrial environment.
(Shefer and Frenkel 2005)5)	Israel	209 industrial firms- personal interviews	R&D expenditure depending on firms' size, industrial branch, ownership type and location.	Analysis of Variances, difference of means 't-test', and multiple regression analysis	R&D negative and significantly related to firm size in high-tech firms. R&D expenditures are explained by innovation, industrial branch, total revenue, export orientation and age of firm.
(Jonker, Romijn et al. 2006)6)	Indonesia (West Java)	29 individual paper machines and their' operators across six firms.	Technological efforts (level of education of managers, training, machine check-ups, job rotation, linkages); technological capabilities (net production, horizontal and vertical product differentiation, ISO certification preparation); Economic Performance (gross value added).	Pearson or Spearman rank correlations for linkages between efforts, capabilities and performance.	No significant positive correlation between technological efforts and technological capabilities. Significant and positive relationship between capabilities and performance.

3. Methodology

In considering learning as a systematic process that occurs through different channels, the econometric analysis estimates the probability of firms learning through six different mechanisms, each of which reflects the differences in the firms themselves and the area of investment in learning. The model assumes that learning mechanisms do not operate in isolation, and that when faced with a choice of knowledge acquisition mechanisms, the adoption of one type of mechanism will influence the probability of adoption of the others⁵. Thus, variables related to training, or the acquisition of machinery and equipment by firms, themselves contribute to the accumulation of capabilities for purchasing embodied technology, acquiring technological packages, receiving knowledge transferred from headquarters or conducting R&D, and vice versa⁶. Therefore, the multivariate probit model is the appropriate econometric tool to analyze correlated discrete dependent variables as it avoids any efficiency losses that may be incurred were the correlation of dependent variables not taken into account.

The multivariate probit model used in this analysis explains the effect and relevance of critical firm-level characteristics on the firm's probability of adopting the learning mechanisms analyzed. Formally, the model is written as

$$y_{ij}^* = \beta_j x_{ij} + \varepsilon_{ij}, \quad i=1, \dots, N, \quad j = 1, 2, \dots, J,$$

where y_{ij}^* can be interpreted as firm i 's incentive to adopt learning mechanisms and is unobservable, x_{ij} is an observable vector of explanatory variables, β_j the associated vector of parameters to be estimated and ε_{ij} the unobservable variables affecting firm i 's incentive to adopt learning mechanisms. The dependent variable y_{ij} is observed to be 1 if firm i 's incentive to adopt learning mechanisms is sufficiently high ($y_{ij}^* > 0$), and 0 otherwise. The multivariate probit is performed for the year 1991 (pre-NAFTA), in which case $N = N_{1991}$ and for the years 1994, 1998 and 2000 (under NAFTA), in which case $N = N_{1994} + N_{1998} + N_{2000}$ with $N_{1991} = 193$, $N_{1994} = 164$, $N_{1998} = 181$ and $N_{2000} = 192$. Finally, J is the total number of learning mechanisms considered in this study, four in 1991 and five under NAFTA.

3.1. Maximum Likelihood Estimation

In order to estimate the model, we assume the error terms ε_{ij} to have a standard normal distribution, and for a different learning mechanism $k \neq j$, $\text{corr}(\varepsilon_{ij}, \varepsilon_{ik} | x_{ij}, x_{ik}) = \rho_{jk}$. Hence, the individual likelihood function is written as

$$L_i = \int_{l_{i1}}^{u_{i1}} \dots \int_{l_{iJ}}^{u_{iJ}} f(\varepsilon_{i1} \dots \varepsilon_{iJ}) \partial \varepsilon_{i1} \partial \varepsilon_{iJ}$$

where $f(\cdot)$ is the J -variate standard normal probability density function for ε with mean vector zero and $J \times J$ positive definite covariance matrix.

As numerical approximations perform poorly in computing high order integrals, we use the Geweke-Hajivassiliou-Keane (GHK) smooth recursive simulator to approximate these integrals⁷. The approximation is obtained by averaging a set of R replications obtained by transforming draws produced by a random number generator (Hajivassiliou, McFadden et al. 1996). The simulated likelihood estimator is consistent as R goes to infinity (Greene 1997).

3.2. Marginal Effects

Because the model measures probabilities, the absolute scale of the coefficients obtained from the multivariate probit analysis can provide a misleading picture of the response of the dependent variables to changes in one of the explanatory regressors.

Therefore, after the final results of the multivariate probit model are obtained, it is necessary to estimate the marginal effects of the explanatory variable x_{ij} in order to observe the proportional change in the dependent variable, y_{ij} . This procedure is done using the standard normal density function ϕ as the scale factor that translates the raw parameter estimates obtained for the multivariate probit model into marginal effects.

The marginal effects in the probit model are equal to: $\delta E[y_{ij}|x_{ij}] / \delta x = \phi(\beta x'_{ij})\beta$ where $\phi(\beta x'_{ij})$ is the standard normal density function.

As $\beta x'_{ij}$ becomes increasingly positive, $\Phi(\beta x'_{ij})$ approaches 1, $\phi(\beta x'_{ij})$ approaches 0, and the marginal effects therefore approach 0. Similarly, as $\beta x'_{ij}$ becomes increasingly negative, $\Phi(\beta x'_{ij})$ approaches 0, and $\phi(\beta x'_{ij})$ and the marginal effects again approach 0.

The discrete effect of the dummy variables included in the explanatory variables is obtained by taking the difference in the predicted probability with and without that dummy variable being equal to 1. Given the normalizations described above, this results in the following simple relationship for the discrete probability effect of a dummy variable: $E[y_{ij}|d = 1] - E[y_{ij}|d = 0] = \Phi(\beta x'_{ij} + d) - \Phi(\beta x'_{ij})$, where, d is the estimated parameter for the dummy variable.

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

4. The Data

The analysis is based on firm-level data on the automotive sector obtained from the ENESTyC surveys covering 1991, 1994, 1998 and 2000. Although there are some differences in the structure of the survey data, their objectives and main methodology were maintained, which permits a comparative analysis. The ENESTyC surveys include variables measuring firms' technological characteristics and absorptive mechanisms from 52 different manufacturing activities⁸. After extensive screening work, we selected 193 firms belonging to different tier-levels of the auto parts sector, excluding assembler firms. These firms constitute panel data for 1991 to 2000. Due to the survey sampling methodology, a few firms are randomly missing for 1994 and 1998; thus the analysis is based on an incomplete or unbalanced panel of firms.

Furthermore, as is the case in many developing countries, the ENESTyC surveys are unequally distributed in terms of time. There is a three year gap between the 1991 and 1994 surveys, a four-year gap between the 1994 and 1998 surveys, and a two year interval before the 2000 survey. Thus, not only is our panel unbalanced, it is also unequally spaced.

To try to resolve these complications, we estimated a multivariate probit model based on a cross-sectional estimation for 1991 (before NAFTA), and a pooled data model allowing for different intercepts over time (for the period post NAFTA)⁹. Below we describe the methodological analysis and the preliminary results and findings.

4.1 Dependent Variables

First we describe how the variables for whether or not a firm adopts the various learning mechanisms were constructed.

a) Learning by training

Training in firms is divided across subject areas ranging from employee motivation seminars to quality control issues. In our study we confined it to training related to quality control and training related to the use and repair of machinery and

equipment¹⁰. As the training is related specifically to the technologies used by the firm, limiting our definition to these two categories gives a better approximation of the efforts made by the firm in relation to production improvements. Thus, we have:

- *Operational Training activities*, a binary variable indicating whether the firm conducted training or not in the use, repair and maintenance of machinery and equipment.
- *Quality Control Training activities*, a binary variable indicating whether the firm conducted training in quality control issues or not.

b) Learning by innovating

In the ENESTyC surveys firms were asked whether or not they conducted the following three activities: i) design of new products, including increasing the variety of products that firms produce; ii) process and product quality improvement, including the adoption of new or improved productive processes that contribute to increases in productivity and changes in quality control; and iii) design/improvement/manufacture of machinery. The variable capturing the presence of R&D activities in the firm –although the set of activities covered under this category are not only limited to R&D activities in the formal sense of the activity- is constructed by assigning the value 1 if at least one of these activities was carried out in the firm and 0 otherwise.

c) Learning by searching

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

d) Learning by using

Although the acquisition of machinery and equipment is not an actual learning mechanism, we assume here that it entails learning processes to enable workers to operate it efficiently and consequently contributes to firms' learning. We consider equipment procurement to be an important aspect of sector modernization after the implementation of NAFTA: it represents one of the several technological (and financial) efforts that firms need to make in order to be competitive¹¹. This variable is subdivided into the categories of new or used. It takes the value 1 if the firm acquired machinery or equipment –in whichever category- and 0 otherwise. The acquisition of manual machines or equipment was not considered as a positive value in either of these categories.

4.2. Explanatory variables

The explanatory variables fall into three categories: firm characteristics, organizational strategies adopted by firms, and time effects for the period under NAFTA.

4.2.1. Firm characteristics

Firm size

This study uses number of employees as a measure of size. This variable is expected to have a positive relationship with a firm's probability of undertaking training, R&D activities, acquiring new machinery and equipment, acquiring technological packages or receiving TT from headquarters. As in other analyses natural logarithm is used for the number of employees (Biggs, Manju S. et al. 1995; Yasuda 2005).

Ownership

This variable is the participation of foreign equity the firm and is expected to have a positive relationship on the probability of firms engaging in learning. It is calculated dividing the percentage of foreign ownership by 100.

Experience of the firm

To measure the firm's experience, we use the natural logarithm of the number of years since the firm began actual manufacturing activity. Assuming that firms retain a memory of the environment in which they were founded and operated, it is expected that

this variable will be negatively correlated with the probability of conducting more complex learning activities.

Tier supplier level

A binary variable of technological specialization with the value 1 if the firm belongs to the first-tier supplier level and 0 otherwise was created. This variable is expected to have a positive relationship with the probability of conducting learning activities as the degree of specialization required increases as firms become more closely related to assemblers.

4.2.2. Organizational Strategies

Adoption of mechatronics in the production process

The coupling of electronic functions with traditional mechanical engineering routines, namely *mechatronics*, results in relatively complex machinery with routines that tend to demand higher and sometime specialized skills. The implications for firms are two-fold. First additional learning efforts are required to master the new electronic functions embedded in mechatronics. Second a reorganization of the workplace function is often required, because digital-based technologies do not stand-alone and often work within networks. The adoption of mechatronics in the production process is expected to be positively associated with firms' likelihood of conducting any of the learning mechanisms analyzed. This variable is measured by the proportion of computerized machine tools (CMT) and robots in the total machinery and equipment used in the production process.

Level of education of the workforce

There is no doubt that a more skilled workforce facilitates firms' efforts and investments to upgrade their capabilities. Ratios reflecting the proportion of white and blue-collar workers with a university education and postgraduate education are considered to have a positive effect on the dependent variables analyzed. In addition, as all decision-making is concentrated in the firm's management, we included a variable measuring the number of managers with post-graduate education divided by the total number of managers in the firm. This variable is expected to have a positive and significant association with firms' likelihood of engaging in more complex learning mechanisms.

Adoption of Just in time (JIT) or Total quality control (TQC)

This variable has the value 1 if the firm has adopted in its organizational management either JIT or TQC methods, and 0 otherwise. As the combination of these two proxies is one of the main characteristics of the worldwide industry flexible production model, we expect a positive relationship between this variable and the probability of the firm adopting any of the learning mechanisms in our analysis.

Adoption of Computerized Process Control

A binary variable for computer-aided programs used in production takes the value 1 if the firm uses statistically or computerized process controls and 0 otherwise. This variable is expected to have a positive relationship with the probability of the firm conducting the learning mechanisms analyzed.

4.2.3. Time Effects

NAFTA

The analysis aims to compare the learning mechanisms chosen by this group of firms before and after NAFTA. Therefore we divided the sample into the two periods, prior to the agreement (1991) and after NAFTA, the years 1994, 1998 and 2000. Two dummy variables for the years 1998 and 2000 were incorporated in the analysis to enable

comparison with 1994. We assume that by 2000, firms have adjusted to the structural changes produced by NAFTA.

4.3. Descriptive Statistics

Tables 2 and 3 presenting descriptive statistics show that there have been some important changes over time in the learning mechanisms adopted by firms. The columns showing the means of the dependent variables indicate that firms' propensity to conduct operational training in both periods, pre and under NAFTA, has changed only slightly.

Table 2. Descriptive statistics during the period prior to NAFTA (1991)

Variable	Mean	Std. Dev.	Min	Max
<i>Number of firms=193</i>				
Dependent Variables				
Operational training	0.5803	0.4947	0	1
Training in Quality Control	0.2227	0.4172	0	1
Learning from changing (R&D)	0.6839	0.4661	0	1
Learning by searching (technological packages/transfers)	0.3108	0.4640	0	1
Learning by using-new (acq of new machinery/equipment)	0.5699	0.4963	0	1
Learning by using-used (acq. used machinery/equipment)	0.1139	0.3186	0	1
Independent Variables				
Size of the firm (number of employees in log)	5.8388	0.8488	3.0910	8.7631
Foreign equity participation (%)	0.2283	0.3682	0	1
Experience of the firm (number of years in log)	3.0524	0.5731	1.3863	4.1744
Tier supplier level (dummy)	0.1761	0.3819	0	1
Adoption of mechatronics in production (%)	0.0479	0.1226	0	0.9000
Participation of workforce with graduate studies (ratio)	0.0017	0.0051	0	0.0436
Participation of workforce with university studies (ratio)	0.0931	0.0823	0	0.4899
Participation of managers with graduate studies	0.2131	0.3371	0	1
Adoption of JIT or TCQ (dummy)	0.0829	0.2764	0	1
Adoption of statistical process control (dummy)	0.1813	0.3863	0	1

Table 3. Descriptive statistics during the period under NAFTA

Variable	Mean	Std. Dev	Min	Max
<i>Number of firms= 537</i>				
Dependent Variables				
Operational training	0.5810	0.4938	0	1
Training in Quality Control	0.5065	0.5004	0	1
Learning from changing (R&D)	0.4674	0.4994	0	1
Learning by searching (technological packages/transfers)	0.3798	0.4858	0	1
Learning by using-new (acq of new machinery/equipment)	0.6481	0.4779	0	1
Learning by using-used (acq. used machinery/equipment)	0.1240	0.3299	0	1
Independent Variables				
Size of the firm (number of employees in log)	5.8329	0.8398	3.1781	8.7013
Foreign equity participation (%)	0.2838	0.4109	0	1
Experience of the firm (in log)	3.2282	0.5748	0	4.3176
Tier supplier level (dummy)	0.1750	0.3803	0	1
Adoption of mechatronics in production (%)	0.1204	0.2005	0	0.9300
Participation of workforce with graduate studies (ratio)	0.0027	0.0073	0	0.0636
Participation of workforce with university studies (ratio)	0.1273	0.1535	0	2.0454
Participation of managers with graduate studies	0.1637	0.2675	0	1.1428
Adoption of JIT or TCQ (dummy)	0.5195	0.5000	0	1
Adoption of statistical process control (dummy)	0.4171	0.4935	0	1

1998 (dummy)	0.3370	0.4731	0	1
2000 (dummy)	0.3575	0.4797	0	1

These two tables show that there was a noticeable increment in the number of firms offering employees training in quality control issues under NAFTA, which may be related to an increase in firms' capabilities in production processes involving more elaborated organizational changes and technological updates. There is also a significant reduction in the number of firms conducting R&D under NAFTA. These results tally with those of (Archibugi and Pietrobelli 2003) who found that in Latin America, the level of in-house R&D activities for both domestic and foreign firms is very low. Table 4 shows the decrease in R&D activities in foreign firms after NAFTA. Probably due to legal regulations in Mexico, foreign firms prefer to conduct their R&D activities in subsidiaries in other countries or in their headquarters.

Table 4. Firms' R&D interaction with Knowledge Agents (% of firms in which R&D=1)

R&D location	NAFTA							
	1991		1994		1998		2000	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
In-house	30.6%	33.3%	55.9%	70.6%	82.1%	69.2%	80.3%	52.4%
National HQ/branches	19.8%	47.6%	32.4%	17.6%	7.7%	11.5%	7.9%	4.8%
Foreign HQs/branches	18.0%	19.0%	8.8%	11.8%	9.0%	15.4%	7.9%	42.9%
Universities	1.8%	0.0%	2.9%	0.0%	0.0%	3.8%	1.3%	0.0%
National consultant	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%
Foreign consultant	1.8%	0.0%	0.0%	0.0%	1.3%	0.0%	1.3%	0.0%

Like most other developing countries, Mexico's manufacturers depend on the acquisition of technology from foreign countries. For firms in the sample, unsurprisingly the US is the main supplier of technology; Mexico's technological dependence on the US is longstanding, it is geographically close, and the main automotive assembly firms in Mexico are US-owned. The analysis identifies the technology purchased as new or used equipment as these categories have a bearing on firms' technological achievements. As Tables 2 and 3 showed, procurement of both kinds of physical capital increased after NAFTA was introduced¹².

It can be seen from the data that about 12% of the sampled population of firms acquired used machinery or equipment in 1991. This proportion increased slightly under the NAFTA environment to 13% of firms. The increase in the number of firms acquiring new equipment after NAFTA is higher, probably because of the need to upgrade their manufacturing standards to the requirements of the export market – the main destination of production from the automotive sector under NAFTA.

With regard to firm characteristics, the descriptive statistics show no significant changes between the two periods. Firm' size and experience remained unchanged, while the average number of first tier suppliers reduced slightly after NAFTA. Foreign equity participation increased to 29% under NAFTA from 23% in 1991. As NAFTA brought about new automotive models and production requirements, Mexican auto parts producers felt the need to invest in the automatization and modernization of their plants. This activity falls into two categories: automatization of production lines to achieve improved speed and consistency; and robotization of key operations to improve product quality. Innovation in production often refers to the incorporation in the manufacturing plant of more complex technologies. Tables 2 and 3 show that there was increasing automatization and computerization of the manufacturing processes of Mexican auto

parts suppliers under the NAFTA environment, which may be associated with the new market conditions brought by the trade agreement, involving new automotive models and production requirements. The tables show an increasing trend towards the adoption of more complex technologies under NAFTA. While in 1991 only about 5% of the manufacturing processes in the sampled firms involved computerized machine tools or robots, this increased to 12% under the agreement. It is assumed that firms introducing mechatronics into their production processes have better capabilities than those using more simple technologies. However, despite this significant increase, the use of mechatronics in production is still quite low. This may reflect the fact that although auto parts firms in Mexico are increasingly upgrading their production processes, and therefore the technological complexity of their products, automotive manufacturing in Mexico is concentrated mainly on low to medium technology components, which lends weight to our findings about the use and acquisition of machinery and equipment (Bancomext 1999). In other words, as firms do not produce technologically advanced products, they do not require technologically complex equipment in their plants. However, this produces a vicious circle: if firms do not have more technologically complex equipment, they cannot upgrade their production. Only conscious investments in learning and capability upgrades will break this cycle.

The tables also indicate the levels of education of managers, and white and blue-collar workers. The most remarkable finding from the analysis is the increasing trend for firms in the sector to hire people with more years of formal education.

Data on the level of education of employees show two important trends. First, the analysis illustrates a shift in firms' preferences under NAFTA towards employing more people with graduate education. Second, the proportion of employees with university or technical education increased from almost 9% in 1991 to 13% in the period under NAFTA. These trends may be related and they may be a consequence of an increasing division of labor within the workforce under the NAFTA framework. On the one hand, it may be that firms are recruiting more professionals with postgraduate levels of specialist skills and abilities, who are expected to help to up-grade production capabilities to meet the higher manufacturing requirements of firms in the upper tiers of the supply chain. On the other hand, firms may simply be incorporating more technicians and supervisors from technical institutes or universities into this workforce group, which may also explain the rise in the intensity of this group in the total labor force of the firm.

The data suggest a significant change in recruitment strategies under NAFTA, from which we can conjecture that since the agreement came into force the level of education required by firms in their employees has significantly increased¹³. This is backed up by (Labarca 1999) results which show that firms in Latin America have no incentive to invest in the formation of basic skills and knowledge in their labor force, preferring instead to benefit from their employees' prior learning. In addition, the rise in manufacturing and quality control requirements brought about by stiffer competition under the NAFTA framework have meant that firms' recruitment strategies are focused more on hiring well-educated personnel to rapidly build up and strengthen their capabilities and concentrate their training efforts in subjects more specific to the needs of the firm. Regarding managers, the findings indicate that although the number of managers with graduate level education is significant, there was a slight reduction in the period under NAFTA.

Another important change promoted by NAFTA was the incorporation of organizational structures in firms in the sector in line with those in the automotive industry worldwide. Based on 'flexible production' being the industry model, this study analyzes the adoption of the main features of this strategy, namely JIT and TQC¹⁴. In addition, the adoption of statistical process control exemplifies the use of advanced

manufacturing techniques involving the use of computerized systems such as CAPC (computerized-aided system of production control).

As Tables 2 and 3 show, although adoption of JIT and TQC increased significantly under NAFTA, flexible production was not fully adopted by the auto parts firms in this sample. While in the period prior to NAFTA only 8% of firms were using JIT and TQC techniques, this percentage increased greatly to 52% under NAFTA. The situation is similar for statistical process control, which increased from 18% in 1991 to 42% under NAFTA.

5. Empirical Results

5.1. Empirical Results for the pre NAFTA period (1991)

In a multivariate probit model with six dependent variables no significant associations were found between the acquisition of technological packages or TT from firms' headquarters and training in quality control, with other learning mechanisms. After conducting a Wald-test to measure the extent to which the equation estimates fail to satisfy the correlations hypothesized we ran two independent probit models and a multivariate probit model with only 4 dependent variables¹⁵. Table 5 presents the results for the marginal effects for the probability of conducting training in quality control (QC) and for the acquisition of technological packages/transfers from headquarters.

Table 5. Marginal effects of learning by searching and training in quality control (1991)

Independent Variable	Acquisition of Technological Packages// and TT from HQs		Training in Quality Control	
	dy/dx	Std. Err.	dy/dx	Std. Err.
<i>Number of firms=193</i>				
	y = Pr(Acquisition Techn. Packages/ TT) = 0.3049		Y = Pr(Training in QC) = 0.2048	
Size of the firm (number of employees in log)	0.031	0.042	0.082**	0.038
Foreign equity participation (%)	0.112	0.100	-0.111	0.092
Experience of the firm (in log)	-0.004	0.060	0.009	0.052
Tier supplier level*	0.009	0.096	-0.092	0.068
Adoption of mechatronics in production (%)	-0.237	0.289	-0.121	0.302
Participation of workforce with university studies (ratio)	0.267	0.450	1.336*	0.388
Participation of managers with graduate studies	0.109	0.102	-0.017	0.089
Adoption of JIT*	0.279	0.132	0.000	0.112
Adoption of statistical process control *	0.085	0.093	0.030	0.079

Notes: * dy/dx for dummy variables is a discrete change of from 0 to 1. * significant at 1%, ** significant at 5%, *** significant at 10%.

The results indicate that firms with JIT organizational management have a significantly higher probability of purchasing technological packages/transfers from their headquarters. In addition, the results indicate that firm size and participation of university graduates in the workforce have a positive and significant effect on training in QC. Coefficient estimates of the restricted model are presented in Table 6.

Table 6. Multivariate probit coefficient estimates (1991)

	Operational Training (1)	R&D (2)	Learning by using (new equipment) (3)	Learning by using (used equipment) (4)
	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
<i>Number of firms = 193</i>				
Independent Variables				
Constant	-1.180 (0.896)	1.401 (0.901)	1.450 (0.893)	-0.873 (0.974)
Size of the firm	0.155 (0.123)	-0.013 (0.122)	0.007 (0.120)	-0.076 (0.149)
Foreign Equity Participation	0.069 (0.297)	-0.251 (0.296)	0.395 (0.292)	0.026 (0.411)
Experience of the firm	-0.020 (0.171)	-0.361** (0.178)	-0.419** (0.171)	0.067 (0.248)
Tier Supplier Level	0.417 (0.282)	0.408 (0.294)	-0.224 (0.258)	-0.362 (0.486)
Adoption of mechatronics in production	-0.908 (0.821)	0.474 (0.907)	0.018 (0.804)	0.196 (0.953)
Participation of workforce with university studies	3.448** (1.416)	0.802 (1.370)	-0.701 (1.260)	-0.473 (1.879)
Participation of managers with graduate studies	0.612** (0.299)	-0.157 (0.300)	-0.091 (0.278)	0.090 (0.373)
Adoption of JIT	0.233 (0.365)	1.397* (0.535)	0.163 (0.350)	-0.376 (0.520)
Adoption of Statistical Process Control	0.323 (0.253)	0.840* (0.293)	-0.042 (0.242)	-0.208 (0.341)
Correlation coefficients				
Atrho 12	0.381*			
Atrho 13	-0.047			
Atrho 14	-0.013			
Atrho 23	0.032			
Atrho 24	-0.010			
Atrho 34	-2.069**			

Chi-square (6) = 54.563 p-value= 0.0000

Note: * significant at 1%, ** significant at 5%, *** significant at 10%. A hyperbolic arc-tangent transformation was used to retrieve the normal correlations.

From the analysis we found important correlations within the learning mechanisms analyzed in the period before NAFTA. There was a positive and significant association between R&D activities and operational training in firms. It is likely that pre NAFTA firms were conducting R&D that was related more to process and product quality improvements and to improvements in machinery; therefore there was a greater need for training in use, repair and maintenance of the equipment. In addition, the adoption of organizational structures of the flexible production model, namely JIT, is positively and significantly related to the probability of conducting R&D activities and to the probability of acquiring technological packages//transfers from headquarters. This result was to be expected since, in the late 1980s, the industry globally was starting to adopt this type of organizational management. It follows, therefore, that firms in Mexico that had adopted these organizational structures by 1991 are more competitive, and are closer to the industry worldwide. The adoption of statistically process control technologies was also found to be positive and significantly associated with the probability of conducting R&D activities during this period.

The results also illustrate that in this period, auto parts firms with more years of experience were significantly less likely to engage in R&D activities, to acquire new machinery or equipment or to give training in quality control. These results are not surprising, since older firms (more years of experience) have a 'memory' formed during the import substitution industrialization period, which makes it difficult for them to adapt their strategies to newer technological paradigms or more complex learning mechanisms. Furthermore, the results indicate that in this pre NAFTA period, firms whose labor forces include higher numbers of university graduates and managers with graduate degrees have a higher propensity to provide operational training.

The analysis showed a negative and significant association between the acquisition of new and used machinery and equipment. Firms acquiring new technologies are less likely to engage in the acquisition of used machinery, probably due to differences in the level of capabilities achieved.

5.2. Empirical results for the post NAFTA period

For this period, we ran a multivariate probit regression with five dependent variables. We initially ran a multivariate probit model with six dependent variables, but after testing their correlation with a Wald-test, we found that R&D was not significantly associated with other learning mechanisms (chi-square(5)=4.24; p-value=0.5152) Table 7 presents the marginal effects for a standard probit model for R&D.

Table 7. Marginal Effects in the period under NAFTA (R&D)

Variable	dy/dx	Std.Err.
Number of firms=537		
y = Pr(R&D) = 0.466		
<u>Independent Variables</u>		
Size of the firm (number of employees in log)	0.084*	0.029
Foreign Equity Participation (%)	-0.006	0.057
Experience of the firm (in log)	-0.022	0.039
Tier Supplier Level*	0.023	0.063
Adoption of mechatronics in production (%)	0.317*	0.116
Participation of workforce with graduate studies (ratio)	7.030***	3.646
Participation of workforce with university studies (ratio)	0.202	0.158
Participation of managers with graduate studies	0.128	0.089
Adoption of JIT or TCQ*	0.055	0.052
Adoption of Statistical Process Control*	-0.014	0.055
1998*	0.253*	0.067
2000*	0.155**	0.065

Note: * dy/dx for dummy variables is a discrete change of from 0 to 1. * Significant at 1%, **significant at 5%, ***significant at 10%.

As expected, *firm size* was found to be positively and significantly associated with the probability of conducting R&D. The results indicate that, during this period, as a firm grows in size so does its likelihood of conducting any of the three activities included in R&D. The use of computerized machine tools or robots in the production process was also found to be positive and statistically significant in explaining the probability of undertaking R&D activities during this period. It may be that as firms increasingly incorporate more complex technologies, they acquire higher technological and absorptive capabilities, which allow them to engage in more difficult learning processes or mechanisms. The use of mechatronics results in relatively complex machinery with routines that tend to demand higher and sometimes specialized skills. Mastering the resulting complementary and employing the innovation-inducing advantages of these kinds of technologies are the challenges faced by adopting firms. The proportion of the labor force with postgraduate qualifications also shows a positive and significant association with the firm's probability of using this learning mechanism. This finding supports the arguments proposed in the technological capability and organizational theory literature that higher levels of education in the workforce allow for more complex processes of knowledge acquisition. Again, this supports the 'skill-bias' technical change

proposition that as firms move into activities involving sophisticated technical contexts they tend to employ more technically competent people (Piva and Vivarelli 2004). Table 8 reports estimated coefficients obtained from the restricted multivariate probit with five dependent variables.

Table 8. Estimated coefficients of the restricted multivariate probit model (period under NAFTA)

	Dependent Variables				
	Operational Training (1)	Training in QC (2)	Learning by searching (3)	Learning by using (new equipment) (4)	Learning by using (used equipment) (5)
	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
<i>Number of firms = 537</i>					
Independent Variables					
Constant	0.163 (0.521)	1.141** (0.539)	-0.750 (0.527)	-0.248 (0.528)	-2.302* (0.649)
Size of the firm	0.063 (0.071)	-0.116 (0.073)	-0.045 (0.072)	0.042 (0.072)	0.144*** (0.085)
Foreign equity participation	0.189 (0.142)	0.158 (0.143)	0.024 (0.141)	0.096 (0.141)	0.022 (0.169)
Experience of the firm	-0.098 (0.097)	0.027 (0.100)	0.140 (0.988)	0.081 (0.099)	0.084 (0.124)
Tier Supplier Level	0.092 (0.156)	0.140 (0.160)	-0.062 (0.159)	-0.288*** (0.155)	0.272 (0.185)
Adoption of mechatronics in production	0.183 (0.290)	-0.107 (0.296)	-0.075 (0.298)	0.207 (0.292)	0.285 (0.335)
Participation of workforce with graduate studies	1.910 (8.249)	-6.386 (8.260)	-12.618 (8.807)	-8.110 (8.123)	-1.664 (9.573)
Participation of workforce with university studies	-0.623 (0.407)	0.002 (0.389)	0.499 (0.390)	0.023 (0.387)	-0.362 (0.585)
Participation of managers with graduate studies	-0.144 (0.210)	0.441** (0.215)	0.107 (0.213)	0.165 (0.217)	0.009 (0.263)
Adoption of JIT or TCO	0.121 (0.130)	-0.008 (0.133)	0.025 (0.132)	0.065 (0.130)	-0.210 (0.158)
Adoption of Statistical Process Control	0.001 (0.136)	0.084 (0.137)	0.022 (0.136)	0.047 (0.137)	-0.078 (0.167)
1998 (dummy)	0.083 (0.162)	-0.974* (0.167)	0.420** (0.162)	0.151 (0.163)	0.042 (0.207)
2000 (dummy)	-0.268*** (0.161)	-0.953* (0.166)	0.146 (0.165)	0.028 (0.162)	0.261 (0.196)
Correlation coefficients					
Atrho 12	-0.211*				
Atrho 13	0.025				
Atrho 14	0.063				
Atrho 15	-0.199**				
Atrho 23	-0.176**				
Atrho 24	0.009				
Atrho 25	-0.017				
Atrho 34	0.265*				
Atrho 35	-0.215**				
Atrho 45	-1.794*				

Chi-square (10) = 188.106 p-value=0.0000

Note: * significant at 1%, ** significant at 5%, *** significant at 10%. An hyperbolic arc-tangent transformation has been used to retrieve the normal correlations.

The results of the multivariate probit model for the years under NAFTA indicate a positive and significant association between the procurement of new equipment and the acquisition of technological packages/transfers from headquarters, an association that might be explained by the need to acquire the 'know-how' of a particular technology or process in operating the 'hardware' or equipment necessary to produce it. The results also indicate that first tier suppliers are significantly less likely to procure new equipment.

Although the percentage of firms acquiring used equipment is small relative to those acquiring new equipment, the analysis indicates that this activity, which is significantly associated with firm size, has a significantly negative association with probabilities of procuring new equipment, acquiring technological packages/transfers from headquarters, and receiving operational training.

The results indicate a strong and negative association between the probability of acquiring technological packages/transfers from headquarters and conducting training in quality control issues, which may suggest that firms' acquiring technology by these means have already achieved a certain level of manufacturing maturity and complexity, which includes the type of content in this kind of training, making additional training unnecessary. Our findings also indicate a negative and significant association between both kinds of training probably due to a significant substitution effect among the nature of the training that firms provide. Additionally, the probability of conducting training in quality control is positively and significantly associated with the level of education of managers. As the percentage of managers with university or postgraduate education increases, the probability of conducting this type of training -which is approaching flexible production requirements- increases. This sort of training significantly increased in the years under NAFTA, while operational training decreased significantly in 2000.

6. Discussion of Findings

The analysis in this paper was designed to test two hypotheses. This first is that the nature and direction of automotive suppliers' learning mechanisms changed under NAFTA compared to the pre-NAFTA economic regime. The second is that the learning mechanisms of auto parts firms are strongly associated with firm size, ownership structure and supplier tier level.

The descriptive statistics presented in Tables 2 and 3 provide evidence to support the first hypothesis. Although there was a significant increase in the number of firms giving QC training, increments in acquisition of technological packages, and equipment procurement are less marked. With respect to more complex and dynamic learning, the results illustrate an intriguing reduction in firms' likelihood of conducting R&D activities in this period. Table 4 couples this result with an increasing preference of foreign firms to transfer this activity to their headquarters or branches in foreign countries, and a drop in the number of domestic firms conducting this activity. Although the patterns widely seen in liberalizing economies indicate that it is not always productive or feasible for firms to engage in reverse engineering and designing their own product and process technologies for a limited protected domestic market, and that they have to compete in foreign markets with low prices and good quality products, obtaining the technology from available sources (e.g., headquarters) our econometric analysis does not present significant evidence that, in the period under NAFTA, firms in Mexico were using other learning mechanisms, such as the acquisition of readily-available new knowledge through TT and acquisitions to substitute for the own R&D activities.

The analysis shows that although the acquisition of new machinery and equipment was only the third most widely adopted learning mechanism in the sector in 1991, this activity became the most important means of learning for firms in the period under NAFTA. However, the types of machinery and equipment acquired by the sector are heavily concentrated in the low to medium specialization levels, as indicated by the poor acquisition of mechatronics –computerized machine tools and robots- for production. These results are in line with (Jonker, Romijn et al. 2006) who in their study on Indonesia found that the pulp and paper sector in West Java grew mainly through investments in embodied technologies. The Mexican Trade Commission report (Bancomext 1999) also supports our findings stating that in domestic manufacturing parts, automotive production in Mexico is concentrated in producing medium and low technology components.

Important changes in the structure and association of the learning mechanisms analyzed over time illustrate another change in the direction of the learning mechanisms that occurred under NAFTA. An interesting change in association in both periods is related to operational training. While in 1991 this learning mechanism was positively and

significantly associated with the likelihood of performing R&D activities, this association disappears under NAFTA. Furthermore, this activity has a significantly negative association with the probability of providing quality control training in firms. This suggests a strong substitution effect between the two types of training probably due to the higher technological and organizational requirements of the industry. It may also indicate that the level of adoption of operational training among firms did not change significantly between the two periods, while quality control training increased significantly under NAFTA. This suggests that training is focused on the operational knowledge needed to execute daily production activities and is not really part of the chain between formal education and the use and management of new technology – a function of training. This may also imply that firms concentrating only on this sort of training are moving towards a lower level of dynamic learning, and a concentration on operational activities. Furthermore, there is an increasing tendency to import high-level knowledge from foreign countries, while training seems simply to be focused on maintaining rather than upgrading capabilities. It is likely that financial factors play a role. This finding is in line with other studies (Blili and Raymond 1993; Oyelaran-Oyeyinka and Lal 2006).

Another association that emerged under NAFTA is that between the acquisition of technological packages/transfers from headquarters -or foreign subsidiaries- and procurement of new equipment. This suggested complementarity between these two mechanisms indicates that firms acquiring new embodied technologies have significantly more likelihood of acquiring the know-how through packages or transfers.

There was no robust evidence to support the second hypothesis. We did find significant and positive associations between size of the firm and the probability of training in quality control in the period prior to NAFTA, and between firm size and the likelihood of conducting R&D and procuring used equipment under NAFTA. This association was also found by (Oyelaran-Oyeyinka 2003) in his study on Nigerian firms and by (Rasiah 2003; Rasiah 2004) for East Asian manufacturing firms.

The results of our analysis indicate that in 1991 there was a negative and significant association between the experience or age of the firm and R&D and the acquisition of new equipment. For all the learning mechanisms analyzed, this variable did not play a significant role in the period under NAFTA. There was no significant association between learning mechanisms and tier supplier level apart from the negative relationship between this variable and the probability of acquiring new equipment in the period under NAFTA. Contrary to our expectations and to the findings in other empirical studies of manufacturing firms in developing countries (Oyelaran-Oyeyinka 2002; Oyelaran-Oyeyinka 2003), the nature of the ownership of firms did not play a significant role in either period.

Lastly, the econometric analysis revealed that under NAFTA there are positive and significant associations between firms with higher participation of university graduates in their labor force and superior use of mechatronics in the production process, and those firms conducting R&D. Managers with graduate level education had a significant effect on the probability of training focused on quality control activities.

The econometric model employed in this analysis does not tackle the quantitative effect of these learning mechanisms in firms' technological capability upgrading; it only provides insights into changes over time in the relationships among them, and explains the role of a number of firm-level factors in the likelihood of these activities being performed. The analysis only considers changes in the trends of this panel of 193 firms that were founded in the period prior to NAFTA and were operating in 2000. The exit or entry of new firms into the sector should be explored in further analysis.

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¹ By the mid-1980s the region was facing high inflation, balance of payments deficits, rising international debt, inefficiency and a lack of international competitiveness, which had plagued the ISI model in Latin America.

² The last ENESTyC survey conducted by INEGI was in 2001, and provided information for 2000.

³ Since the enforcement of the 1962 automotive decree, the automotive industry changed from an industry of 10 assemblers -with three wholly foreign-owned firms- to an industry of nine assemblers, six of which were majority foreign-owned (i.e., Ford, International Harvester, VW, Nissan, VAM). The auto parts sector was not explicitly considered in any automotive decrees before 1989.

⁴ Prior to NAFTA, automotive firms had two production regimes; one focused on the local market and the other on the export market. Under NAFTA, these regimes were merged to produce vehicles for both markets.

⁵ Owing to the binary nature of these variables, the model only observes a firm's choice or not of these learning mechanisms, and does not investigate the ratio or intensity of which these mechanisms are adopted.

⁶ The same relationship applies to the time framework analyzed. The learning efforts carried out in one year are expected to have an effect on the efforts conducted in future years.

⁷ Hajivassiliou et al. (1996) reviewed 11 simulators and found that for multivariate normal distributions the GHK was the most reliable method.

⁸ Firms surveyed in ENESTyC surveys are those that appeared in: i) the previous industrial census; ii) the monthly industrial survey; and iii) the Annual Industrial Survey (from 1994 onwards). In 1995, the ENESTyC survey was conducted as an annex of the Annual Industrial Survey and, following the structural characteristics of the later survey, did not include micro and small firms. For these surveys, the sample of small and micro-sized firms was randomly selected.

⁹ The slopes are assumed to be equal over time.

¹⁰ This kind of training covers the use of materials and tools, as well as basic and advanced courses on mechanics, electrics, hydraulics, electronics and related subjects.

¹¹ It is a necessary although insufficient condition for firms' upgrading and therefore learning.

¹² Around 80% of the sampled firms that acquired new machinery and equipment also reported an increased need to upgrade the knowledge and technical abilities of their labor force in order for the equipment acquired to be operated efficiently. This finding adds value to the use of this variable in our econometric analysis as a proxy for learning by using.

¹³ The author is aware that the rising education level of manufacturing workforce is not exclusively due to NAFTA, but is also an effect of the national educational policies in Mexico, which have raised the education level of the workforce generally. The causality of the NAFTA effect in this variable is rather tenuous and beyond the scope of this analysis.

¹⁴ Although automotive firms are already moving towards alternative-fuel vehicles, which implies different production models and organizational strategies, the author considers that it is important to assess the level of adoption of the basic 'lean production' model by firms in Mexico, rather than jumping to more advanced technologies not yet well established in the country.

¹⁵ Acquisition of technological packages or TT from headquarters was tested not to be significantly associated with other learning mechanisms (chi-square(5) =5.62, p-value=0.3453). The same applies for training in quality control (chi-square(5) =5.09, p-value=0.4056).