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Firms’ Learning Capabilities under a New Economic Environment: A Case Study of Mexican Auto Parts Firms

Bertha Vallejo
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1 FIRMS’ LEARNING CAPABILITIES UNDER A NEW ECONOMIC ENVIRONMENT: A CASE STUDY OF MEXICAN AUTO PARTS FIRMS

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Abstract

The study presented in this paper describes preliminary findings on changes in the adoption of different learning mechanisms before and after the implementation of the North American Free Trade Agreement (NAFTA), based on a study of 193 Mexican automotive firms. The results obtained give us useful insights on the composition and capability levels of the sector as well as highlighting changes in the research and development (R&D) capacity of these firms under the new competitive market conditions.

The study is based on firm-level panel data from the automotive industry obtained from the National Survey on Employment, Salaries, Technology and Training (ENESTyC) carried out by the National Statistics Office and the Ministry of Labour for the years 1991, 1994, 1998 and 2000. It presents a descriptive analysis of quantitative measures taken by firms with regards to learning, and focuses on changes in learning trends owing to different market conditions brought about by NAFTA. The analysis is complemented by a multivariate probit model that tests the relationship between critical firm-level variables and a firm’s probability of conducting R&D activities, training staff, acquiring technological packages and/or receiving technology transfers from their headquarters, or procuring machinery and equipment.

The empirical analysis highlights important associations between different kinds of learning mechanisms adopted by firms and their own critical characteristics. The study shows that of all the learning mechanisms available to firms, training is the one most commonly used in the sector – and it is on the increase. However, the results also indicate that training is mainly given to those who operate specific machines or technologies, and does not go towards helping firms develop the absorptive capacity they need if they are to move towards newer and more complex technologies and market changes. This may imply that the automotive sector is moving towards a lower level of dynamic learning, concentrating on day-to-day operational activities with a tendency to import knowledge from foreign countries. On the other hand there may be more

1 ** The author expresses her gratitude to Wladimir Raymond (University of Maastricht) for his invaluable directions and comments on the econometric procedures followed in this analysis. The usual caveats apply.
competition since the implementation of NAFTA, which requires firms to conduct training simply in order to maintain their operational level rather than to upgrade their capabilities. The results obtained in this study provide useful insights and lessons that go beyond the Mexican context and that may be useful for other manufacturing sectors in developing countries.
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1. INTRODUCTION

As with other industrializing countries, old traditional manufacturing firms in Mexico were originally established to produce goods for a fraction of the domestic market. These firms operated in an environment protected by the government mainly under infant-industry arguments of the previous import substituting industrialization (ISI) strategy. Most of these firms were started-up with machinery and equipment that had been discarded from foreign countries when their production plants were upgraded.

During the 1980s, in order to make itself internationally competitive, Latin America underwent important macroeconomic transformations. The region implemented structural adjustment programmes recommended by the International Monetary Fund and the World Bank. This new economic paradigm is what the Economic Commission for Latin America and the Caribbean (ECLAC) has coined the New Economic Model (NEM).

The 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 2000,1703). The NEM could be seen as the Latin American version of the export-oriented industrialization strategy followed by East Asian countries, based on the Ricardian theory of comparative advantage.

In the case of the automotive sector in Mexico, a 1989 decree aimed to modernize the automotive industry and set it on a market liberalization course based on the new economic trend that the government favoured at that time. This decree proposed to integrate Mexico with the global auto industry through increasing exports and gradually reducing protection from external competition. In addition, it allowed passenger cars and trucks to be imported, reduced the local content input requirements to 36%, and lifted restrictions on foreign ownership. These were the first steps in opening the industry to external competition, not only from foreign firms located within Mexico but also from firms in foreign countries.

Mexico’s NEM pathway was reinforced in 1991 by the proposal to establish a North American Free Trade Agreement (NAFTA) between Mexico, the United States and Canada, which came

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

3 Under the Ricardian theory, if inputs are increased for the production of a commodity where the ratio of domestic input cost to foreign input cost is lower than average, then both domestic and foreign benefits increase.
into force in 1994. The new legal environment of the industry resulted in a more liberalized trade regime, in which domestic firms were exposed to greater external competition as the ownership and domestic integration requirements of the industry disappeared. One of the most important changes brought about by NAFTA was the focus of automotive production on the export market, which forced firms to adapt both their production plants and strategies to meet international requirements. Under these new conditions, domestic firms can be integrated into the automotive value chain based solely on their competitiveness and performance levels. The first step in becoming competitive is to ‘learn to learn’. By building learning capabilities, a firm can achieve a basic level of absorptive capacity and enhance its production chain while climbing the ladder towards more complex innovation and technical change.

The analysis conducted in this study attempts to show how firms have changed their learning mechanisms as a result of trade liberalization, while also shedding some light on their efforts to upgrade their knowledge competences to achieve a higher technological level. Although implementing NAFTA has to some extent created a divide between Mexican market liberalization and the economic structures of the rest of Latin America, there are important lessons to be learnt from its implementation that are applicable to other developing economies, especially those moving towards more free-market trade regimes. The empirical exercise in this paper tests the following hypotheses:

a) Automotive suppliers have changed the nature and direction of their learning processes under NAFTA compared to the previous economic regime.

b) Learning mechanisms of auto-parts firms are strongly associated with firm size, ownership structure and supplier tier level.

The first part of the analysis is based on descriptive statistics of the main learning mechanisms chosen by firms in the sector over time. The results provide preliminary insights into the sector’s efforts to acquire and upgrade its technological learning and they also illustrate the changes undergone in the sector’s preferences in the adoption of particular learning mechanisms. The analysis carried out by this study contributes to the scarce empirical literature on learning and technological efforts by manufacturing firms in developing economies. The second part of the analysis is based on a multivariate probit model that examines the association between critical firm-level variables and a firm’s likelihood of engaging in different learning mechanisms. The analysis is based on data from a panel of 193 firms in the automotive industry, obtained from the National Survey on Employment, Salaries, Technology and Training (ENESTyC) carried out before and after the implementation of NAFTA.

The paper is organized as follows: the following section provides a brief review of the literature related to the relevance of learning in strengthening and building firms' technological
capabilities. Section 3 presents the data, specifications and methodology used in the empirical analysis. Section 4 presents descriptive results of the learning proxies analyzed and provides preliminary insights on the technological efforts conducted by these firms. Section 5 presents the results obtained from the multivariate probit model and examines the degree of association between critical firm-level variables and choice of learning mechanisms or processes. Lastly, section 6 concludes with the main findings and implications of the analysis.
2. THEORETICAL FRAMEWORK

In order to survive and respond positively to new competitive and economic conditions, such as the ones brought about by free trade agreements (e.g. NAFTA), firms need to make explicit efforts to build up adequate 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 in a similar way to how firms operate at the technological frontier (Dahlman et al. 1987). By using these capabilities, firms can create new knowledge and integrate it with their existing knowledge base (Teece et al. 1997).

2.1 Learning mechanisms and their proxies

Firms learn through different processes or mechanisms, typically involving repetition and experimentation, which enable them to perform tasks more quickly and efficiently and to identify new production opportunities (Teese et al. 1994, 11). It is through these learning mechanisms that firms build, supplement and organize information about their activities and their own culture. They contribute to improving the skills of their workforce and to up-grading firms’ own technological capabilities (Arrow 1962; Benarroch and Gaisford 2001; Young 1991; 1993). These learning activities are an important part of firms’ technological efforts to move towards higher learning and capability building (Dahlman and Westphal 1981; Jonker et al. 2004; Romijn, 1999).

From the range of learning activities or mechanisms discussed in the literature, this analysis considers the following proxies; each of them represents a different type of learning process or effort that firms undertake.

Acquisition of machinery and equipment

This is a proxy variable that indicates learning by using, based on the assumption that firms learn by using the machinery and equipment acquired (Rosenberg 1976). Improving production plants by using existing technology is an important aspect of technological development particularly for developing countries (Dahlman et al. 1987). Authors such as Bell (1984) and Lall (1990; 1992) consider it an important part of firms’ investment capabilities in their technological capability taxonomies.
Learning by training

A more dynamic learning process is that associated with learning through training, which is also an important mechanism by which firms can acquire external knowledge (Dahlman and Fonseca 1987; Figueiredo 2001). Training upgrades the knowledge and abilities of the labour force, and prepares workers to more efficiently execute their tasks and duties. Training can also be seen to play an intermediate role between formal education and the acquisition and use of embodied technology.

Learning from changing

Mechanisms such as these create an upwards spiral of greater understanding and confidence that in turn promote further improvements (Figueiredo 2001). The most common forms are learning by research and development (Cohen and Levinthal 1989; Katz 1973) and learning by exploring (Teubal 1984). There is also learning by searching (Bell 1984; Dahlman and Fonseca 1978), which involves external upgrades to capabilities as firms establish technology contracts with foreign consultants or equipment suppliers, engage in technology transfers or acquire technological packages.

2.2 Firm-level critical factors

A large body of empirical work has examined the role of learning in firms’ capability building and performance and has shown that these are influenced by different firm-specific characteristics, such as size, age or ownership nature (Biggs et al. 1995; Cameron et al. 2005; Jonker et al 2004; Oyelaran-Oyeyinka 2004; Oyelaran-Oyeyinka and Lal 2004). Therefore this analysis includes the following critical factors to explain firms’ adoption of various learning mechanisms.

Size of the firm

This is an important variable in determining the type of learning mechanism used by the firm, as learning costs and processes differ between large firms and small- and medium-sized enterprises (SMEs). Furthermore, the cost of temporarily loosing an employee while they are being trained is proportionately higher for smaller firms. All this may be reflected in a lower percentage of small firms conducting training than larger sized firms (Oyelaran-Oyeyinka and Lal 2004; Shefer and Frenkel 2005).
Ownership structure

The nature of the firm’s ownership plays an important role as it leads to different structural alternatives and behaviours (Rasiah 2003). Foreign ownership facilitates the flow of knowledge and technical progress from outside the country. Furthermore, the participation of foreign-owned firms increases a sector’s sensibility to the structure, strategies and reactions of the global environment in addition to those followed by the domestic industry. In several of his empirical studies, Rasiah (2003; 2004) has found a positive relationship between foreign ownership and firms’ technological capabilities.

Age of the firm

Another factor believed to affect a firm’s technological capability is its age, although the relationship is not straightforward. On the one hand, firms with a longer operating history have more experience and generally have greater tacit knowledge. In this way, a firm’s age can be seen as a proxy of its accumulated experience – or learning-by-doing (Arrow 1962). On the other hand, firm’s ability to manufacture or produce certain goods is expected to increase with its experience as it masters the production of more complex products over time (Romijn 1999). On the other hand, studies in organizational theory argue that older firms have more inertia and tend to become increasingly at odds with their environment, leading to obsolescence and an increase in failure rates (Baum 1989).

Tier supplying level

Traditionally, the automotive industry in developed and industrializing countries has a supply chain that exhibits a pyramidal structure, where the second and third tier suppliers form the base and the assemblers the top of the pyramid, with first tier suppliers in the middle. Fourth tier suppliers are generally supporting firms or suppliers of raw materials -not necessarily specialized in the auto industry- and are generally located along the pyramid’s edge, as are competing imports (see figure 1). As firms climb the ladder of manufacturing complexity, the type of knowledge required and the nature of the organization become increasingly complex. It is important to remark that achieving manufacturing complexity is not necessarily associated to the closeness of firms to the terminal industry – the peak of the pyramid –. A third tier supplier can have productive processes as complexes as first tier suppliers.
Learning by operating

As previously discussed, firms learn by operating or using equipment in their everyday manufacturing processes; those operating more complex equipments (e.g. computerized machine tools or robots) are assumed to have stronger capabilities than those using simple tools. Therefore this kind of learning, closely related to Arrow’s learning by doing (Arrow 1962) and derived from performing production activities and tasks, contribute to learning through a more passive and automatic process based on experience and continuous repetition of manufacturing processes.

Learning by hiring

A common mechanism through which firms absorb and accumulate capabilities from their external environment is by hiring people with higher levels of formal education. Employing a labour force with a certain level of education is one way that firms can build and strengthen their technological capabilities. Authors such as Katz (1987), Romijn (1999) and Jonker et al. (2004) have found that this is an important contributor to the building of technological capabilities by firms, especially in developing countries.

Linkage capability

In his taxonomy of technological capabilities, Lall defines a firm’s linkage capability as “…the skills needed to transfer technology from one enterprise to another (suppliers, buyers or competitors), from service firms to manufacturers, and from the science-and-technology
infrastructure to industry” (Lall 1990, 23). In this study, linkage capabilities in firms in the automotive sector are measured by two dummy variables: one indicating whether the firm is a unit of a bigger corporation, and the other indicating if the firm has linkages with universities, R&D centres or technological institutes. Firms within these categories are thus assumed to have developed a set of skills that allows them to interact with other firms and institutions to facilitate knowledge flows.
3. EMPIRICAL ANALYSIS

The empirical analysis is divided into two parts. First is a descriptive analysis of the learning efforts conducted by the sampled firms that aims to explore in more detail their characteristics and trends over time. Second is a multivariate probit model examining the association between critical firm-level characteristics and a firm’s probability of conducting R&D activities, training, acquiring technological packages or receiving technology transfers from their headquarters, and procuring machinery and equipment.

3.1 The Data

The analysis is based on firm-level data on the automotive industry obtained from the National Survey on Employment, Salaries, Technology and Training (Encuesta Nacional de Empleo, Salarios, Tecnología y Capacitación en el Sector Manufacturero – ENESTyC). ENESTyC is implemented jointly by the National Institute for Statistics (Instituto Nacional de Estadística, Geografía e Informática – INEGI; http://www.inegi.gob.mx) and the Ministry of Labour (Secretaría del Trabajo y Previsión Social – STPS). The surveys were conducted for the years 1991, 1994, 1998 and 2000 and, although they present differences in their structure, their objectives and main methodology were maintained, which permits a comparative analysis. The ENESTyC surveys contain variables measuring firms’ technological characteristics and absorptive mechanisms from 52 different manufacturing activities. After extensive screening work, we selected a set of 193 firms belonging to different tier-levels of the auto parts sector, excluding assemblage or terminal sector firms (representing the peak of the pyramid in figure 1). The 193 firms selected constitute a panel data as the same firms were sampled from 1991 through to the year 2000. However, owing to the sampling methodology of the surveys, a few of these firms are randomly missing for 1994 and 1998. The analysis conducted is therefore based on an incomplete or unbalanced panel of firms.

Furthermore, in developing countries, surveys are generally conducted over unequally distributed time intervals. The collection of data of the ENESTyC survey follows this trend:

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4 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 in the sample. For these surveys, the sample of small and micro-sized firms was randomly selected.
from the first survey in 1991 to the survey in 1994 there is a three-year time interval; there is a four-year gap between the 1994 and the 1998 surveys; and then to the 2000 survey the interval is two years. Thus, our panel is not only unbalanced but it is also unequally spaced.

As a way to overcome these complications, we approached our research questions using a multivariate probit model based on a cross-sectional estimation for 1991, representing the period before the implementation of NAFTA, and a restricted model with pooled variables for the NAFTA period. The following sections present the methodological notes of analysis followed by preliminary results and findings.

3.2 Methodology

The descriptive analysis provides qualitative and quantitative comments on the sector’s learning trends, while the cross-sectional multivariate probit regression for 1991 examines the degree of association between certain critical firm-level variables and a firm's probability of employing different learning mechanisms; from 1994 onwards under NAFTA, the analysis used is a restricted multivariate probit regression.5 These results are complemented by the preliminary findings from the descriptive analysis, allowing a deeper overview of the differences over time in the mechanisms adopted by firms of different structure.

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5 Owing to the unequally spaced distribution of the panel, we divided the sample into two groups: before and after NAFTA, consisting of a cross-section multivariate probit regression for the year 1991 and a restricted pooled multivariate probit model for the period since (1994, 1998 and 2000). The results obtained are similar to those from independent cross-sectional regressions analysed for each year. However, under the assumption that the years under NAFTA also correlated with a firm’s probability of adopting these learning mechanisms from one year to the next, this methodology is more appropriate.
4 DESCRIPTIVE ANALYSIS OF LEARNING MECHANISMS AND EFFORTS

4.1. Methodology

Following empirical literature on capability building in developing countries (e.g. Jonker et al. 2004; Romijn 1999) the study starts by analyzing the learning mechanisms and efforts of the sampled firms in building, up-grading and strengthening their technological capabilities.

Learning by hiringFollowing the methodology of the ENESTyC surveys, this study classifies a firm’s labour force into three main groups: managers, white-collar workers (the professionals and administrators) and blue-collar employees (the manual/production workers). Managers are described as the group in charge of decision-making for the firm’s organizational and production activities; we consider that the education level of this group is the dominant factor in the capability building activities and processes undertaken by the firm. However, this is not the only important factor in assessing firms’ performance: the level of education of the other workforce groups also plays an important role in the execution of learning tasks.

Although white collar employees are not directly involved in decision-making of organizational and production processes, we assumed that the level of education of this group affects execution and adoption of the capability building efforts planned by the managerial group in the firm. White collar workers are generally either university graduates (e.g. lawyers, engineers and accountants) who work in process engineering, quality control, and information and communications technology (ICT), or they are technicians, supervisors and administrative staff with working experience, responsible for the management of important variables related to manufacturing and quality control of the production line.

The third main workforce group covered by the surveys is blue-collar employees. Although this group refers to production workers, we assumed that their operational performance is positively associated with their level of education. The analysis has divided this group into skilled and unskilled categories: the former refers to employees skilled in a specific area or task. Unskilled blue-collar workers have a minimum level of work experience and training and are primarily assigned to assist skilled workers. Unskilled workers undertake the physical movement of raw materials and components and also do general cleaning activities.

The indicators for this variable in the descriptive analysis refer to the proportion of firms reported to employ personnel with the following four levels of formal education:
• Graduate education – personal with at least one successfully completed year of masters or PhD-level studies.

• University or technological education – personnel with at least one successfully completed year of education at a university or technological institute.

• High school education – employees with at least one successfully completed year of high school education, in which the student may receive certain technical education.

• Basic education – personnel with a completed elementary school education, including those with a minimum of one completed year of junior high school degree.

Learning through training

Training is another important indicator of learning as it is assumed to play a mediating role between formal general education and the specific technologies used by the firm. Training in firms is divided into different subjects that range from motivational work to quality control issues. Considering that the degree of specificity of the training is closely related to the technologies used by the firm, this analysis only considers training related to the use and reparation of machinery and equipment and quality control. For the purposes of this study, constraining the definition of training in this way gives a better approximation of the efforts made by the firm in relation to production improvement. For this descriptive analysis the recipients of training were classified by the number of firms that reported to have provided these kinds of training by workforce group.

Learning by using

The acquisition of machinery and equipment is considered a proxy for learning by using technology embodied in machinery and equipment employed by the firm (Rosenberg 1976). In this study we consider equipment procurement to be an important aspect of the sector modernization after the implementation of NAFTA: it represents one of the several technological (and financial) efforts that firms need to make in order to be competitive.

In the descriptive analysis we assess the change in the nature of the equipment acquired by firms over time. The evaluation classifies the embodied technology acquired according to its physical nature for both new and used equipment, and also by its degree of technological complexity. This results in six categories: manual equipment, automatic equipment, machine tools, numeric control machine tools, computerized machine tools and robots.

6 This kind of training covers issues in the use of materials and tools, as well as basic and advanced courses on mechanics, electricity, hydraulics, electronics and related subjects.
Learning by R&D and learning by searching

R&D activities include the following processes: 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. In order to control the effects of the analysis conducted and to protect the confidentiality of firms in the sample, we gave R&D a binary value for the econometric analysis: 1 if the firm conducts any of these three activities, and 0 otherwise.

Learning by searching is represented by the acquisition of technological packages or technology transfers from firms’ headquarters. This variable has a binary value of 1 if the firm acquires technology in either of these forms, and 0 otherwise.

Linkage capabilities

Universities are considered to play an important role in a country’s innovation system. In developing countries as Mexico, these knowledge institutions are particularly important as they concentrate the scientific knowledge necessary for production activities and act as trainers of human capital – mainly professionals – who in turn transmit their knowledge into a firm to generate organizational learning.

This variable is measured with a binary value of 1 if the firm is reported to have a link with a university, technological institute or research centre, and 0 otherwise. It is expected that the existence of university–industry collaborations will have a positive effect on a firm’s likelihood of engaging in more advanced and complex learning processes.

4.2. Descriptive Results

This section presents an exploratory analysis on changes in the networking and distribution of firms adopting different learning mechanisms. It provides us with useful insights into the technological efforts of these firms by capturing qualitative elements and trends not reflected by the econometric results of the multivariate probit analysis.

Level of formal education of the workforce

Table 1 indicates the proportion of firms across time employing managers and white and blue collar workers according to their degree of education. The most remarkable finding of the
analysis is the increasing trend by firms in the sector to hire people with more years of formal education.

Regarding the level of education of managers, findings from table 1 indicate that although there are a few firms employing managers with only high school education, about 91% of firms in the sector employ managers with further education – at university or technological level. This is a significant qualitative improvement compared to the period prior to NAFTA, where the corresponding percentage was close to 85% of the firms.

<table>
<thead>
<tr>
<th>Table 1. Workforce groups by education level</th>
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<tbody>
<tr>
<td><strong>Level of employment</strong></td>
</tr>
<tr>
<td>Managers</td>
</tr>
<tr>
<td>White collars</td>
</tr>
<tr>
<td>Skilled blue collars</td>
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<tr>
<td>Unskilled blue collars</td>
</tr>
<tr>
<td>No. firms</td>
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</tbody>
</table>


Data on the level of education of white-collar employees show two important trends. First, the proportion of firms hiring personnel with university education for this workforce group decreased from almost 98% in 1991 to 93% in the period under NAFTA. Second, the analysis illustrates a shift in firms’ preferences towards hiring more white collars with graduate education under NAFTA. These two trends may be related to each other and they may be a consequence of an increasing division of labour within this workforce group under the NAFTA framework.

On the one hand, it may be that firms are hiring more professionals with postgraduate levels of specialization skills and abilities who are expected to help to up-grade production capabilities, needed 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 workforce group in the total labour force of the firm.

The level of education of blue collars employed by firms also shows an important evolution. While in 1991 only 4% of the firms employed skilled production workers with formal education from a technical institute or university, by 2000 this had more than trebled to 14%. As expected, the majority of this labour group consists of personnel with a medium level of education. Table
I also shows that the most significant change in recruitment strategies for all blue collar workers is in the requirement for a high school education for skilled employees, and at least a basic education for unskilled workers.

From this analysis we can conjecture that under NAFTA the level of education required by firms in personnel they recruit has significantly increased. This is backed up by results from Labarca (1999) that described how firms in Latin America have no incentive to invest in the formation of basic skills and knowledge in their labour force, instead preferring to benefit from the employees’ own past learning efforts. 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 now more focused on hiring well-educated personnel to rapidly build up and strengthen their capabilities.

**Training**

Table 2 shows changes in the proportion of firms that conduct training by size and across time. The table shows an important increase in the number of firms conducting quality control training in the period under NAFTA. It also shows that by 2000, differences in the incidence of either of these two forms of training by firms with more than 100 employees had reduced considerable in comparison with 1991. The notable increment in the number of firms training employees on quality control issues may be related to an increase in the capabilities of firms towards more production processes involving more elaborated organizational changes and technological up-dates.

We also found that training –as an aggregate activity in relation to these two forms- is the learning mechanism most commonly adopted by the firms in the sector under the NAFTA framework.

**Table 2. Ratio of automotive firms conducting training**

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</tr>
</thead>
<tbody>
<tr>
<td>11– 50</td>
<td>1.0%</td>
<td>0.6%</td>
<td>0.0%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.5%</td>
<td>0.0%</td>
<td>0.6%</td>
<td>0.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>51–100</td>
<td>3.1%</td>
<td>3.6%</td>
<td>1.1%</td>
<td>4.1%</td>
<td>3.1%</td>
<td>2.4%</td>
<td>0.6%</td>
<td>3.1%</td>
<td>0.5%</td>
<td>1.8%</td>
<td>1.1%</td>
<td>1.0%</td>
</tr>
<tr>
<td>101–250</td>
<td>20.2%</td>
<td>31.9%</td>
<td>23.2%</td>
<td>23.8%</td>
<td>17.6%</td>
<td>23.5%</td>
<td>17.7%</td>
<td>16.6%</td>
<td>6.7%</td>
<td>16.3%</td>
<td>12.2%</td>
<td>12.4%</td>
</tr>
<tr>
<td>251–500</td>
<td>22.8%</td>
<td>21.1%</td>
<td>26.0%</td>
<td>26.4%</td>
<td>19.2%</td>
<td>14.5%</td>
<td>20.4%</td>
<td>17.1%</td>
<td>8.8%</td>
<td>13.9%</td>
<td>11.6%</td>
<td>14.5%</td>
</tr>
<tr>
<td>≥500</td>
<td>21.2%</td>
<td>22.9%</td>
<td>32.0%</td>
<td>22.8%</td>
<td>17.1%</td>
<td>17.5%</td>
<td>26.0%</td>
<td>14.5%</td>
<td>6.2%</td>
<td>10.2%</td>
<td>14.4%</td>
<td>11.4%</td>
</tr>
<tr>
<td>Total(%)</td>
<td>68%</td>
<td>80%</td>
<td>82%</td>
<td>78%</td>
<td>58%</td>
<td>57.8%</td>
<td>64.6%</td>
<td>51.8%</td>
<td>22.3%</td>
<td>42.8%</td>
<td>39.2%</td>
<td>39.9%</td>
</tr>
<tr>
<td>N</td>
<td>132/193</td>
<td>133/166</td>
<td>149/181</td>
<td>151/193</td>
<td>112/193</td>
<td>96/166</td>
<td>117/181</td>
<td>100/193</td>
<td>43/193</td>
<td>71/166</td>
<td>71/181</td>
<td>77/193</td>
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</tbody>
</table>

Regarding the main recipients of each of these kinds of training, analysis of the data shown in table 3 indicates that firms providing training on use, repair and maintenance of machinery and equipment (operational training) oriented it strongly to skilled production workers. The proportion of firms providing this kind of training to this workforce group rose from 69% in 1991 to 76% by 2000. However, the percentage of firms providing this kind of training to unskilled production workers decreased under NAFTA from 81% in 1991 to around 76% in 2000. It is also noteworthy that more managers and less white collar employees received this kind of training since the start of NAFTA.

Table 3. Recipients of training by workforce group

<table>
<thead>
<tr>
<th>Workforce Group</th>
<th>Use, Repair and Maintenance of Machinery and Equipment</th>
<th>Quality Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managers</td>
<td>1.8% 0.0% 0.9% 5.0%</td>
<td>37.2% 26.8% 52.1% 44.2%</td>
</tr>
<tr>
<td>White Collar Employees</td>
<td>10.7% 9.4% 4.3% 5.0%</td>
<td>41.9% 36.6% 43.7% 54.5%</td>
</tr>
<tr>
<td>Skilled Blue Collar Workers</td>
<td>68.8% 65.6% 79.9% 76.0%</td>
<td>60.5% 56.3% 52.1% 50.8%</td>
</tr>
<tr>
<td>Unskilled Blue Collar Workers</td>
<td>81.3% 76.0% 69.2% 76.0%</td>
<td>39.5% 25.4% 29.6% 42.9%</td>
</tr>
<tr>
<td>No. Training Firms</td>
<td>112 133 117 100</td>
<td>43 71 71 77</td>
</tr>
</tbody>
</table>

Source: Elaborated by the author with data from the ENESTyC surveys.

Table 3 also shows an important increase in training on quality control issues for all groups of workers with the exception of skilled blue collars. As expected, most of the training given to managers and white collars focused on quality control issues rather than operational training. This is probably a reflection of the growing relevance of quality in production owing to the more stringent manufacturing requirements and stiffer competition under NAFTA.

Acquisition of machinery and equipment

As is the case with most other developing countries, Mexico’s manufacturers depend strongly on the acquisition of technology from foreign countries. For firms in this sample, the United States is unsurprisingly the main supplier of technology; Mexico has a long-standing technological dependence on the United States, it is geographically close, and the main automotive assembling firms operating in Mexico are US-owned.
Table 4 shows the distribution of firms of different sizes acquiring machinery and equipment through time. The table distinguishes the technology purchased by whether it is new or used equipment as these two categories have different effects on firms’ technological achievements. As illustrated in table 4, the procurement of both kinds of physical capital increased after NAFTA was introduced.

Table 4. Equipment procurement by auto parts firms

<table>
<thead>
<tr>
<th>No. Employees</th>
<th>Acquisition of New Machinery and Equipment</th>
<th>Acquisition of Used Machinery and Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>11–50</td>
<td>0.0%</td>
<td>0.6%</td>
</tr>
<tr>
<td>51–100</td>
<td>2.6%</td>
<td>1.8%</td>
</tr>
<tr>
<td>101–250</td>
<td>21.8%</td>
<td>20.5%</td>
</tr>
<tr>
<td>251–500</td>
<td>23.3%</td>
<td>13.9%</td>
</tr>
<tr>
<td>≥500</td>
<td>20.7%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Total</td>
<td>68.4%</td>
<td>54.8%</td>
</tr>
<tr>
<td>N</td>
<td>132/193</td>
<td>91/166</td>
</tr>
</tbody>
</table>


It can be observed from the data that slightly more than 12% of the sampled population of firms acquired used machinery in 1991. This proportion had increased to 16% by 2000, with medium-sized firms being responsible for almost half of this rise. In the same year, it is noticeable that this category of firms was the only one that significantly decreased its acquisition of new machinery and equipment. As expected, the acquisition of new equipment by large firms increased slightly under NAFTA, probably owing to the need to adjust their manufacturing standards to match those required by the export market – the main focus of the terminal industry under NAFTA.

As NAFTA brought about new automotive models and production requirements, Mexican producers of auto parts in turn felt the need to invest in the automatization and modernization of their plants. This falls into two categories: automatization of production lines, with the aim of improving speed and consistency; and robotization of key operations to improve product quality. It can also be illustrated from table 5 that the acquisition of numeric control machine tools – more sophisticated production machinery involving mechatronics – increased in the years following the introduction of NAFTA; the percentage of firms buying new equipment rose from

---

7 Around 80% of the sampled firms that did acquire technology reported an increase in the need to upgrade the knowledge and technical abilities of their labour force in order to efficiently operate the new machinery or equipment. This finding adds value to the use of this variable as a proxy for learning by using.
In the period prior to NAFTA, it is likely that a firm’s level of technological complexity was not perceived to be a major problem as competition came mainly from other traditional plants. However, under the new market conditions, the sector was exposed to strong competition from foreign firms with greater technological mastery, which in turn brought the implicit requirement for local firms to upgrade their machinery and automatization levels. The findings in table 5 show that although there has been an increase in efforts by firms in the sector to upgrade their technology, they are still very much concentrating on medium-level technological equipment; focusing on the automatization of a few production lines rather than undertaking a complete plant modernization. The data in table 5 illustrate a strongly increasing tendency for the sector to acquire new automatic machinery and equipment (up from 34% in 1991 to 52% by 2000). However, despite a marginal increase over time, only around 2% of firms purchase new technology for highly advanced manufacturing operations (i.e. robots).

According to the Mexican Trade Commission (Bancomext 1999), most Mexican automotive manufacturing is concentrated on producing components of medium and low technology, which lends weight to our findings. In other words: as firms do not produce very technologically advanced products, they do not require technologically complex equipment in their plants. However, this leads to a vicious circle: if firms do not have more technologically complex

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8 The degree of technological specialization achieved by firms will be relevant in our later productivity analysis, which explains how the acquisition of machinery and equipment influences a firm’s performance.
equipment, they cannot upgrade their production. Only conscious investments in learning and capability upgrades will break this cycle.

However, analysis of the data shows that introducing more machinery and equipment reduces the number of machine operators and unskilled production workers employed. Our data shows that reductions in these personnel categories have doubled in the period under NAFTA compared to 1991. This may suggest that as firms gradually move towards more complex technologies, their capacities increases (i.e. the level of formal education), and those employees with a low level of formal education do not have a place in the new production structure of the firm. This may explain the trends observable in table 1, where there is a strong movement to hire personnel with higher levels of education in the period under NAFTA. These findings also led us to skill-biased technical change hypothesis, which sustains that a adoption of new technology caused a rise in the demand for highly skilled workers.

Research and development activities and the acquisition of technological packages or technology transfers

Table 6 shows a significant reduction in the number of firms conducting R&D in the NAFTA period. Our results tally with those of Archibugi and Pietrobelli (2003) who found that in Latin America, in-house R&D activities are very low both for domestic and foreign firms.

<table>
<thead>
<tr>
<th>Table 6. Research and development activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Employees</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>11–50</td>
</tr>
<tr>
<td>51–100</td>
</tr>
<tr>
<td>101–250</td>
</tr>
<tr>
<td>251–500</td>
</tr>
<tr>
<td>&gt;500</td>
</tr>
</tbody>
</table>


From table 6 it can be observed that R&D activities are increasingly concentrated in larger firms. The same trend is seen for firms acquiring technological packages or receiving technology transfers from their headquarters. This is an expected finding since large firms generally have more structured capabilities that enable them to conduct these kinds of complex learning activities. These firms are also expected to be located in the frontier of their tier level of
the automotive supply chain and to have a closer association with the technological requirements of the terminal industry (the assemblers); and have possible a higher integration into the production chain and they will therefore be required to up-grade their capabilities in a more technologically complex trajectory.

*Linkages with universities, research centres and technological institutes*

Table 7 shows the proportion of firms that reported having either training or R&D activities in collaboration with a university or technological institute. As described by authors such as Casas et al. (2000) and Dominguez and Brown (2004), Mexican university–industry collaboration is very low; in the case of the auto parts sector it is progressively reducing over time.

Analysis of the data presented with more detail in table A in the appendix indicates that most of the industry’s collaborations with knowledge centres are for training purposes.

**Table 7. University–industry collaborations**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>11–50</td>
<td>0.5%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>51–100</td>
<td>0.0%</td>
<td>1.2%</td>
<td>0.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>101–250</td>
<td>3.6%</td>
<td>3.6%</td>
<td>2.8%</td>
<td>0.5%</td>
</tr>
<tr>
<td>251–500</td>
<td>4.1%</td>
<td>1.8%</td>
<td>2.8%</td>
<td>3.1%</td>
</tr>
<tr>
<td>≥500</td>
<td>2.6%</td>
<td>0.6%</td>
<td>6.6%</td>
<td>1.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10.9%</td>
<td>7.2%</td>
<td>12.2%</td>
<td>6.2%</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>21/193</td>
<td>12/166</td>
<td>22/181</td>
<td>12/193</td>
</tr>
</tbody>
</table>

*Source: Elaborated by the author with data from the ENESTyC surveys*

Table A also suggests that the choice of training actors has changed significantly under NAFTA. The role of the public sector, represented by the industrial chambers and public training centres, is declining, as is the participation of universities and technology centres as external training providers. The remaining participation of these institutions in 2000 can be explained as being agreements between terminal assembly firms and universities to train ‘potential labour’ to a more skilled level.\(^9\)

\(^9\) For more on the skill biased technical change hypothesis see Pianta (2004).

\(^10\) Universities, particularly private universities, are increasingly starting to run joint programmes with automotive assembly firms. Under these agreements the study plans of students in subjects such as mechanical engineering include training in the use of specialized automotive software and other training specific for the needs of these terminal firms. An example of this kind of programme is the Automotive Design Center in the ITESM-Campus Toluca, which is sponsored by Daimler-Chrysler. This highlights the debate about the role of universities: in developed countries they act as a creator of knowledge, while in developing countries their role is mainly as a trainer of skill.
As in the case of training, there are very few partnerships between firms and traditional knowledge centres concerning R&D activities. Arocena and Sutz (2001) found that R&D-based university–industry linkages in this sector in Latin America appear to be so weak and they are almost nonexistent. This highlights the disparity between the region’s low reliance on local knowledge institutions and high reliance on foreign science and technology (see also Arocena and Sutz 2002). Table A in the appendix indicates that there is a strong tendency for firms to undertake this activity in-house. The results show that in 1994 – the year of the introduction of NAFTA – 89% of the firms in the sector conducted R&D either in-house or at other sites within their national organization. However, it is in decline, particularly for foreign firms, which carried out about 30% of R&D activity in their overseas headquarters or branches in 1998, and nearly 50% of it in 2000.\footnote{11} The following sections presents the methodology and statistical results obtained from the econometric analysis concerning the effect those firm-level characteristics have on the adoption of learning mechanisms.

\footnote{11} Auto parts manufacturing in Mexico is mostly based on specifications and product-design requirements established by the assembly firms. Assuming that foreign firms operating in Mexico already have longstanding relationships with the terminal industry, it is not surprising that they would want to move their R&D activities closer to either the assembler’s headquarters or the strategic design-and-development centres in foreign countries, rather than in Mexico.
5. THE MULTIVARIATE PROBIT MODEL

Given that learning is considered to be a systematic process that occurs by different mechanisms, the econometric analysis estimates a firm’s probability of conducting learning through four different proxies, each of which reflects a different nature and area of investment in learning. The model is based on the assumption that learning mechanisms do not work in isolation from each other. It also assumes that if a firm is exposed to diverse mechanisms through which it can acquire knowledge, the adoption of one type of mechanism will have an influence on the probability of adoption of the others. Thus, variables related to training in a firm or the acquisition of machinery and equipment themselves contribute to the accumulation of capabilities for purchasing embodied technology, acquiring technological packages, receiving transferences from headquarters or for conducting R&D and vice versa. Therefore the multivariate probit model is the appropriate econometric tool to analyse correlated discrete dependent variables as it avoids efficiency losses that may be incurred if the correlation of dependent variables is not taken into account.

5.1 Methodology and variables

The analysis is based on a multivariate probit model for a binary outcome with the following form:

\[ y_{im}^* = \beta_m x_{im} + \varepsilon_{im}, \quad m = 1, 2, \ldots, M \]

\[ y_{im} = 1 \text{ if } y_{im}^* > 0, \text{ and } 0 \text{ otherwise} \]

The model supposes that:

\[ y_1^* = \beta_1 x_1 + \varepsilon_1, \quad y_1 = 1 \text{ if } y_1^* > 0, \text{ and } 0 \text{ otherwise} \]

\[ y_2^* = \beta_2 x_2 + \varepsilon_2, \quad y_2 = 1 \text{ if } y_2^* > 0, \text{ and } 0 \text{ otherwise} \]

\[ y_3^* = \beta_3 x_3 + \varepsilon_3, \quad y_3 = 1 \text{ if } y_3^* > 0, \text{ and } 0 \text{ otherwise} \]

\[ \overline{Owing to the binary nature of these variables, the model only observes a firm’s choice or not of these learning mechanisms, and does not investigate the ratio or intensity of which these mechanisms are adopted.} \]
\[ y_4^* = \beta_4 x_4 + \varepsilon_4, \quad y_4 = 1 \text{ if } y_4^* > 0, \text{ and } 0 \text{ otherwise} \]

Each individual equation is a standard probit model, where:

\[ y_{im}^* = \text{unobservable variable where } m = 1, 2, 3 \text{ or } 4 \]

\[ y_1^* = R&D \text{ activities} \] – dummy variable with values of 0 or 1 indicating whether the firm conducts R&D activities, or not.

\[ y_2^* = \text{Training activities} \] – binary variable, with values 0 and 1, indicating whether the firm conducted training or not in the use and reparation of machinery and equipment, and on quality control.

\[ y_3^* = \text{Acquisition of machinery and/or equipment} \] – dummy binary variable that indicates with 1 the purchase of machinery and/or equipment, and with 0 otherwise. It excludes the acquisition of manual tools.

\[ y_4^* = \text{Acquisition of technological packages or technology transfers from firms’ headquarters} \] – dummy variables with value 1 if the firm has acquired technology by any of these two mechanisms, and 0 otherwise.

\[ y_{im} = \text{observed outcome, } y_{im} = 1 \text{ if } y_{im}^* > 0, \text{ and } 0 \text{ otherwise}. \]

\[ N_t = 1, 2 \ldots, 193, \text{ where } t \text{ is the year. } N_t \leq N; N_{1991} = N_{2000} = 193; N_{1994} = 161, N_{1998} = 181. \]

\[ x_{im} = \text{observable vector of explanatory variables} \]

\[ \beta_m = \text{vector of parameter estimates associated with } x_{im} \]

with

\[ \varepsilon_{im} \sim N(0, 1) \]

NB: \( \varepsilon_{im} \) is distributed as a multivariate normal with mean vector 0 and covariance matrix R with diagonal elements equal to 1.0. For identification reasons, the variances of the epsilons must equal 1.

\[ \text{The same relationship applies to the time framework analyzed. The learning efforts carried out in one year are expected to have an effect on the efforts conducted in future years.} \]
\[ E [\varepsilon_1 \mid x_1, x_2, x_3, x_4] = E [\varepsilon_2 \mid x_1, x_2, x_3, x_4] = E [\varepsilon_3 \mid x_1, x_2, x_3, x_4] = E [\varepsilon_4 \mid x_1, x_2, x_3, x_4] = 0 \]

\[ \text{Var} [\varepsilon_1 \mid x_1, x_2, x_3, x_4] = \text{Var} [\varepsilon_2 \mid x_1, x_2, x_3, x_4] = \text{Var} [\varepsilon_3 \mid x_1, x_2, x_3, x_4] = \text{Var} [\varepsilon_4 \mid x_1, x_2, x_3, x_4] = 1 \]

Where the pair-wise correlation of the error terms is not equal to 0:

\[ \text{Cov} [\varepsilon_1, \varepsilon_2] = \rho_1 \]

\[ \text{Cov} [\varepsilon_1, \varepsilon_3] = \rho_2 \]

\[ \text{Cov} [\varepsilon_1, \varepsilon_4] = \rho_3 \]

\[ \text{Cov} [\varepsilon_2, \varepsilon_3] = \rho_4 \]

\[ \text{Cov} [\varepsilon_2, \varepsilon_4] = \rho_5 \]

\[ \text{Cov} [\varepsilon_3, \varepsilon_4] = \rho_6 \]

The model is solved using a maximum-likelihood procedure, which requires the computation of multivariate normal integrals:

\[ P = \int_{[0,1]^m} \cdots \int_{[0,1]^m} f(x_1, \ldots, x_M) d_{x_1} \cdots d_{x_m} \]

where:

\[ f(\cdot) \] is the \( M \)-variate normal probability density function for \( x \) with mean vector zero and \( M \times M \) positive definite covariance matrix, \( W \).

As numerical approximations perform poorly in computing high order integrals, we use the GHK (Geweke-Hajivassiliou-Keane) smooth recursive simulator to approximate these integrals\(^\text{14}\). The approximation is obtained by averaging a set of \( R \) replications obtained by transforming draws produced by a random number generator. The replications estimator of \( P \) is consistent in \( R \)\(^\text{15}\). Each observation has its own seed for the random number generator, so for identical parameter values and fixed \( R \), the draws are repeatable (estimated using Limdep, version 7; 1998).

\(^\text{14}\) Hajivassiliou et al. (1996) reviewed 11 simulators and found that for multivariate normal distributions the GHK was the most reliable method.

\(^\text{15}\) Further details in Greene (1997).
The log-likelihood of this model is calculated as the sum of the logs of the probabilities of the observed outcomes. These are computed using the following construction:

\[
\text{Prob} \left[ y_1, y_2, \ldots, y_M \mid x_1, x_2, \ldots, x_M \right] = \text{MVN} \left( Tz, TRT' \right)
\]

where

- \( z \) = vector of utilities
- \( z_m = \beta_m x_{im} \)
- \( R \) is the correlation matrix
- \( T \) is a diagonal matrix with \( t_{mm} = 2y_m - 1 \)

(i.e. \( t_{mm} = 1 \) if \( y_m = 1 \), \( t_{mm} = -1 \) if \( y_m = 0 \))

Because the model measures probabilities, the absolute scale of the coefficients obtained by 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 it is necessary, after obtaining the final results of the multivariate probit model, to obtain the marginal effects of the explanatory variable \( x_{im} \) in order to observe the proportional change in the dependent variable, \( y_{im} \). This procedure is done using the standard normal density function \( \phi \) 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:

\[
\delta E[y_{im} \mid x_{im}] / \delta x = f(\beta x_{im}) \beta = \phi (\beta x_{im}) \beta
\]

where \( f \phi (\beta x_{im}) \) follows a standard normal density function \( \phi \).

As \( \beta x_{im} \) gets increasingly positive, \( F(\beta x_{im}) \) approaches 1, \( f(\beta x_{im}) \) approaches 0, and the marginal effects therefore approach 0. Similarly, as \( \beta x_{im} \) becomes increasingly negative, \( F(\beta x_{im}) \) approaches 0, and \( f(\beta x_{im}) \) and the marginal effects again approach 0.

The discrete effect of the dummy variables included in the explanatory variables is found 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:

$$E[y_{im}|d = 1] - E[y_{im}|d = 0] = F(\beta x_{im}' + d) - F(\beta x_{im}')$$

where, $d$ is the estimated parameter for the dummy variable.

As $\beta x_{im}'$ becomes increasingly positive, both terms of this expression: $F(\beta x_{im}' + d) - F(\beta x_{im}')$, approach 1, so the net effect of the dummy variable approaches 0. As $\beta x_{im}'$ becomes increasingly negative, both terms approach 0 and, again, the net effect of the dummy variable approaches 0 (Anderson and Newell 2003).

The following critical firm-level variables are used as the explanatory variable $x_{im}$ in analyzing firms' probability of conducting the various learning mechanisms $y_{im}$.

**Firm size**

This study adopted the number of employees as a measure of size. This variable is expected to have a positive relationship on firms' probability of undertaking training, R&D activities, acquiring new machinery and equipment, acquiring technological packages or receiving technology transfers from their headquarters. As in preceding papers, the analysis adopted a natural logarithm for the number of employees (Biggs et al. 1995; Yasuda 2005).

**Ownership**

This variable is represented as the foreign equity participation in the firm (on a scale of 0–1) and is expected to have a positive relationship in explaining firms' probability of conducting learning.

**Tier supplier level**

A binary variable of technological specialization has been created with value 1 if the firm belongs to the first-tier supplier level and 0 otherwise. This variable is expected to have a positive relationship with respect to the probability of conducting learning activities as the degree of specialization required increases as firms close in on the top of the pyramid (figure 1).
**Age of the firm**

To measure a firm’s age, the analysis considers the natural logarithm of the number of years that have elapsed since the firm started to conduct its actual manufacturing activity. Assuming that firms keep a memory of the environment in which they were founded and operated for long time, it is expected that this variable has a negative correlation with the probability of conducting more complex learning activities.

**Being part of an industrial group or corporation**

This variable has value 1 if the firm belongs to an industrial group, and 0 otherwise. Firms that are part of a bigger corporation are considered to have different critical characteristics than firms that operate in isolation. Firms in a corporation receive administrative and financial support from their headquarters and are assumed to have a higher probability of engaging in more elaborate learning processes. The variable is expected to have a positive relationship with the dependent variables of the analysis.

**Level of education of the managers**

There is no doubt that the employment of a more skilled workforce facilitates firms’ efforts and investments to upgrade their capabilities. However, all decision-making taken by the firm is concentrated in the managerial position. Hence we include a variable measuring the number of managers with a postgraduate 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 conducting more complex learning mechanisms.

**Links with universities**

Interaction and linkages with external knowledge-actors are important elements when talking about interactive learning in firms. Such relationships are quantified by the number of firms that have conducted training or R&D activities with universities, research centres or technological institutes.

**Use of machinery and equipment**

This evaluation is done by dividing both the new and used equipment acquired by a firm according to its physical nature by its degree of technological complexity. The analysis divided embodied technology into six categories: manual equipment, automatic equipment, machine
tools, numeric control machine tools, computerized machine tools and robots. In the econometric analysis the procurement of machinery and equipment is given value 1 if the firm acquired machinery and equipment, regardless of whether it was used or new, and 0 otherwise. Firms acquiring manual equipment were not considered for this analysis.

*Free trade agreement*

The analysis aims to compare the learning mechanisms chosen by this group of firms before and after the introduction of NAFTA. Therefore we divided the sample into two periods, one representing the period previous to the agreement (1991) and the other for the period under NAFTA, represented by the years 1994, 1998 and 2000. Two dummy variables for the years 1994 and 1998 are incorporated in the analysis to compare results with the year 2000. We expect that by 2000, firms will have better adjusted to the structural changes brought about by NAFTA.

**5.2 Statistical Results and Findings**

*Correlation Analysis*

The set of correlations between the learning variables and explanatory variables used in the analysis is given in table B(1-2) in the appendix. It can be noted from this table that, in the unadjusted model, some of the explanatory variables are significantly correlated with each other, for instance the size of the firm is closely linked to both the age of the firm and the level of foreign equity participation.

Since these three variables represent critical firm-level characteristics, it is not surprising to find that they are highly correlated with whether the firm belongs to a group. This suggests that the number of years the firm has been in operation, foreign equity participation and the size of the firm are important factors that positively influence whether that firm is part of a bigger corporation or not. In addition, the variable that described whether a firm is highly competitive with imported goods was found to be significantly related to the age and size of the firm, and therefore with whether the firm is part of a group or not. In the empirical analysis, we performed regressions on four different models, each of them with a different combination of explanatory variables in order to include the above-mentioned firms-characteristics.
Multivariate Probit Results

Owing to the high correlation found between important explanatory variables, three regressions were run analyzing different combinations of independent factors. Tables C1–3 in the appendix report the marginal effects obtained from the four multivariate probit models analyzed for the four different learning mechanisms covered by this study.

Size of the firm

The results show major changes in the structural characteristics of firms adopting these learning mechanisms through time. As expected, size of the firm was found to be positively associated with the probability of undertaking one of these learning mechanisms. The results indicate that, in the NAFTA period, as a firm grows in size so does its likelihood of conducting any of these four learning mechanisms. This result is not surprising and could be anticipated from the raw data analyzed in the descriptive section, where we found that most of learning activities were concentrated in firms with more than 101 employees. In the period prior to NAFTA, firm size was a statistically significant predictor only of training.

Firm tier supplier level

The association of tier supplier level with the probability of learning has also changed since the introduction of NAFTA. In 1991, this variable had no association with firms’ probability of acquiring machinery and equipment. However, under the NAFTA environment first tier suppliers are much more likely to acquire technology compared to firms from other supplier levels. Being a first tier supplier was also found to be positively and significantly associated with the probability of learning by searching (i.e. to purchase a technological package or to receive technology transfers from headquarters).

Employee education level

The proportion of managers with postgraduate education also had a positive and significant association with a firm’s probability of conducting more complex types of learning, such as learning by searching or by conducting R&D. This finding supports arguments in the technological capability and organizational theory literature that higher levels of education in

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16 To validate the use of a restricted pooled regression in our multivariate Probit model, we followed the following steps to compare the likelihood scores of the two models: \( LR_{test} = 2 \times (\ln[L_u] - \ln[L_r]) \)

17 Multivariate probit coefficients for the unrestricted models can be found in table D in the appendix. The corresponding Wald tests are also presented in these tables.
the managerial positions allow for more complex processes of knowledge acquisition. And give some room for discussing the ‘skill-bias’ technical change proposition that firms tend to employ individuals with greater technical competence as firms move into activities involving sophisticated technical contexts.

**Linkage capability**

The existence of links between firms and universities is positively associated with a greater likelihood of conducting most learning activities. However there is one exception: in the period under NAFTA firms collaborating with universities are less likely to learn by searching in comparison with any other kind of learning activity. It might be that universities are a competing mode of knowledge acquisition to this alternative; this variable was found to be significantly associated only with firms’ probability of undertaking R&D. However, as illustrated in tables 7 and A, university–industry collaboration in Mexico is still very poor and constrained to just few firms in the sample, making full conclusions difficult to draw.

**Acquisition of machinery and equipment**

Employing more complex technologies embodied in machinery and equipment used in the production process was positively associated with firms’ likelihood of conducting any of the learning mechanisms analyzed. However, this proxy was only found to be significant in explaining the probability of undertaking R&D activities. It may be that as firms increasingly use more complex technologies, they attain higher technological and absorptive capabilities that allow them to engage in more difficult learning processes or mechanisms. The coupling of electronic functions with traditional mechanical engineering routines (mechatronics) results in relatively complex machinery with routines that tend to demand higher and some times specialized skills. The implications for firms are two-fold. First is the additional learning efforts to master new electronic functions that are embedded in mechatronics. Second is the often-required re-organization of the workplace function, because digital-based technologies are not stand-alone and tend to work within networks. Getting to master the resulting complementary and employing the innovation-inducing advantages is a challenge faced by adopting firms.

**Foreign equity participation**

This had a positive and significant association with the probability of acquiring technological packages or receiving technology transfers from headquarters. This was not a surprising finding as foreign firms are believed to have a stronger association with the global automotive industry,
better financial resources and better access to mechanisms for building and straightening their capabilities.

**Age of the firm**

As expected, a firm’s age was found to be negatively associated with its probability of adopting any of the learning mechanisms. Newer firms are more likely to procure equipment, acquire technological packages or receive technology transfers than older firms. This is probably because older firms have a ‘memory’ that was formed under the ISI period; which it is difficult to adapt to the recent changes and newer technological paradigms.

**Group structure**

Being part of an industrial group or corporation was found to be strongly associated with a firm’s age, size and ownership structure. For 1991 this variable was positively and significantly associated with the likelihood of conducting training and acquiring technological packages. In the period under NAFTA, this variable is a significant indicator of a firm’s chance of conducting R&D activities as well as acquiring technological packages.

The significance of these firm-level characteristics in explaining the probability of firms’ adoption of certain learning mechanisms has changed since the introduction of NAFTA. In addition, the type of learning mechanism(s) adopted by firms has also significantly changed in the period under NAFTA. Our findings indicate that firms are increasingly likely to purchase embedded technology, acquire technology packages or train their staff in the years leading up to 2000. Only the likelihood of conducting R&D reduces in the period under NAFTA, which can be observed from the raw data presented in tables 6 and A illustrating the increasing shift of foreign firms’ R&D activities to other countries.

Lastly, regarding the correlation within the learning mechanisms analyzed, the study found that in the period before NAFTA, R&D activities had a positive and significant association with training and the acquisition of machinery and equipment. However, since NAFTA came into force this association is only significant for the relationships between R&D activities and the acquisition of embodied technology, and between R&D activities and the acquisition of technology packages and technology transfers from headquarters. The fact that training is no longer significantly correlated with other learning activities may be explained by examining the quality and relevance of the training given, which may not be adequate for the new, higher
requirements of the original equipment manufacturing industry or the continual need for firms to modernize that NAFTA has brought. From the analysis of tables 2 and 3 we can conjecture that most of the training is concentrated in operational activities, such as the use, repair and maintenance of machinery, and not in more complex areas. More training on quality control issues may reflect the fact that the firm has already reached a certain level of manufacturing maturity. However, such training is still not widely adopted by firms in the sector.
6. SUMMARY AND DISCUSSION OF FINDINGS

This study set out to test two hypotheses. This first is that automotive suppliers have changed the nature and direction of their learning processes under NAFTA compared to the previous economic regime. We have shown this to be true; however, there is still much to do if they are to reach internationally competitive levels such as those required by the industry.

The analysis found that more firms conducted training in the period under NAFTA than before. This learning mechanism has been adopted by around 70% of firms in the sector, regardless of their size, ownership nature and tier of the supplier chain. Most of training is focused in the use, repair and maintenance of machinery and equipment. However, training on quality control issues is increasing, probably because firms need to improve the quality of goods to compete under the new trade agreement.

The acquisition of machinery and equipment also showed an increasing trend under NAFTA. As expected, about 50% of the embodied technology purchased is by large-sized firms. The results from the econometric analysis show that it is first tier suppliers who are most likely to acquire equipment than firms in other levels of the auto supply chain. Our analysis also discloses important differences in the kind of machinery and equipment acquired before and after NAFTA. Under the NAFTA framework, more firms acquire automatic machinery and equipment as shown by an increase in the adoption rate, which has almost doubled from 27% in 1994 to 52% by 2000. However, firms’ acquisition of more complex technologies, such as computerized machine tools, dropped by around the same proportion from 37% in 1994 to 18% in 2000. Purchase and use of robots, although showing a slight increase over the period, is still very poor and concentrated in only four firms. We may conjecture from these findings that the sector’s level of technical specialization is low to medium. This finding is supported by the report of the Mexican Trade Commission (Bancomext, 1999) on domestic manufacturing of auto parts, which says that automotive manufacturing in Mexico is concentrated in producing components of medium and low technologies.

With respect to more complex and dynamic learning, the analysis illustrates an intriguing reduction in foreign firms’ likelihood of conducting R&D activities in this period, coupled with a preference for transferring this activity to their headquarters or branches in foreign countries. At the same time, the number of domestic firms conducting R&D has dropped compared to the period before NAFTA.
Also to do with R&D, the larger the automotive firm the more likely it is to engage in R&D. Table 6 shows that about 70% of this activity is located in firms employing more than 250 people. This is an expected finding since empirical evidence has shown that large firms are more able to cover the substantial costs generated by this activity.

Furthermore, most of the R&D activity in the sector is concentrated in the design of new products and in quality improvement of both products and processes. This may be explained by a rise in the pressure exerted by the assemblers for suppliers to adapt their production to meet the new rigorous international standards. Only firms that already meet this level of specification can afford to widen their R&D efforts to look at the design and manufacture of machinery and equipment. This is shown by the low number of firms (around five) that conduct this more advanced activity.

We did not find robust evidence to support our second hypothesis – that learning mechanisms of auto-parts firms are strongly associated with firm size, ownership structure and supplier tier level. We did, however, find significant and positive associations between size, age and supplier tier. Also, in the period under NAFTA, we found a significant likelihood that firms conducting R&D also engage in the acquisition of embodied technology; yet firms acquiring technological packages or receiving technology transfers from their headquarters are significantly less likely to conduct R&D activities, as illustrated in the findings presented in tables C1–3.

The econometric analysis reveals that there is a positive and significant correlation between firms conducting R&D and those acquiring machinery and equipment, both before and after the start of NAFTA. This may be a dual process that results from firms upgrade towards more complex technological capabilities. In the period prior to NAFTA, the study also found a positive and significant correlation between R&D and training activities. The relationship does not hold under NAFTA, perhaps because the previous training regimes were no longer sufficient to meet higher level of technological requirements of the industry.

No statistically significant association was found between training and the acquisition of embodied technology in either of the two periods. This raises the idea that training given by firms in the sector is mainly 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. This may imply that the sector is moving towards a lower level of dynamic learning, concentrating on operational activities. Where, on the one hand, firms in the sector have an increasing tendency to import high-level knowledge from foreign countries, on the other hand they are conducting more training simply to maintain rather than upgrade their capabilities. It is likely that financial factors play an important role in this decision.
One notable discovery is the drop in the number of associations between firms in the sector and knowledge actors. Universities and public training centres play a negligible role in knowledge transfer in the sector. This finding agrees with results from other empirical studies on the manufacturing sector in Mexico, which revealed that the contact between firms and knowledge centres (including universities) is largely nonexistent (Casas et al. 2000; Dominguez and Brown, 2004).

In conclusion, our findings highlight how important it is to develop industrial policy that can direct industry efforts towards strengthening institutions that support R&D activities. Until now the public sector has focused on training; financed mainly by a combination of the terminal industry and the government to facilitate the import of machinery and equipment that is not always adequate to the capabilities of the acquiring firm. Special assistance programmes that are tailored to the needs of the sector and specific for the structure of the firms are urgently required, particularly those focused on SMEs and firms located in the lower tiers of the supply chain. After all, if firms in developing countries are not capable of mastering today’s technologies, how can they move into new or alternative technologies?
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