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A regional approach to study technology transfer through foreign direct investment: The electronics industry in two Mexican regions

Ramón Padilla-Pérez*

United Nations Economic Commission for Latin America and the Caribbean (ECLAC), Subregional Headquarters in Mexico and Science Policy Research Unit (SPRU), University of Sussex, Presidente Masaryk 29, Col. Polanco, 11570 Mexico City, Mexico

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ABSTRACT

This paper develops a conceptual framework and presents empirical evidence to examine technology transfer from foreign direct investment (FDI) to host regions, from a systemic perspective that integrates micro- (the firm) and meso (the region)-level analyses. This approach helps identify four different levels at which technology transfer may occur. Comprehensive fieldwork in Mexico was undertaken to collect evidence of an FDI-led, large industry (electronics) in two regions. The empirical evidence collected in this research shows that technology transfer derived from FDI may impact diverse actors of the host region (local firms, universities, research centres, industry associations), but also that its occurrence is neither automatic nor homogenous across regions.

1. Introduction

International technology transfer is central for developing countries, which traditionally lack indigenous capabilities to generate new technologies. Technology transfer occurs through several mechanisms such as foreign direct investment (FDI), joint ventures, licensing, import of goods, co-operative alliances, subcontracting, export of goods, mobility of personnel and development assistance (Radosevic, 1999). FDI in particular has played a central role in developing countries. Multinational enterprises (MNEs) have been a very important source of production and technological resources, including capital goods, new product and process technologies, and new knowledge and managerial skills, whose potential effects on the host economy are enormous (Cantwell, 1995; Dunning, 1993).

Technology transfer from MNEs to host countries has been studied from a micro-level perspective, i.e. a process that occurs at firm level (Alonso et al., 2000; Carrillo and Hualde, 1998; Hobday, 1995). Inter- and intra-firm processes have been analysed, but have rarely considered the role of interactions between firms and other agents within an institutional framework. Technology transfer from MNEs has been also studied at the macro-level, examining its impact on the whole country though macroeconomic data (Blomström and Person, 1983; Blomström and Kokko, 1998; Kokko, 1994; Kugler, 2006). Although the importance of local factors and efforts has been recognised, few efforts have been made to develop conceptual tools and methodologies to study the impact of MNEs on host regions.

This paper aims to study how MNEs, through their subsidiaries, transfer technology to host regions. Micro- and meso-level analyses are integrated, and the various levels at which technology transfer occur are studied: from parent companies to foreign subsidiaries; to local personnel within foreign subsidiaries; from foreign subsidiaries to local firms; and from foreign subsidiaries to local organisations (technical education schools, universities, public research centres and industry associations). The framework

* Tel.: +52 55 5263 9664; fax: +52 55 5531 1151.
E-mail address: ramon.padilla@cepal.org.

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here developed is applied to compare systematically technology transfer in two regions.

Technology transfer is one side of the story in the process of developing indigenous capabilities through global–local interactions. This research acknowledges the importance of local efforts and absorption capabilities to study the impact of FDI on host regions. However, it is not the aim of this paper to analyse the capability building process. As said, this research integrates micro- and meso-level factors to study technology transfer to host regions.

Comprehensive fieldwork in Mexico was undertaken between September 2004 and January 2005. Two regions within Mexico were selected and a survey of firms was conducted involving 80 foreign subsidiaries and locally owned firms, in addition to interviews with 30 local organisations.

Mexico is an interesting case to study given the large amount of FDI that has taken place there. Over the last two decades, Mexico has been outstanding among developing countries in terms of the amount of FDI it has attracted. Between 1985 and 2005, it received $US 211 billion of FDI, the fourth highest level of investment among developing countries, after China, Hong Kong and Brazil (UNCTAD, 2006). Considering that there are important differences between industrial sectors in terms of sources of technological knowledge, the actors involved in innovation processes and the links and relationships among actors, this research focuses on one industry: electronics. In Mexico, the electronics industry is an interesting case study given its size, participation in manufacturing exports, large number of firms, strong presence of MNEs and its geographical agglomeration in regions across Mexico. One region in northern Mexico – Baja California – and one in central Mexico – Jalisco – were selected for the fieldwork.

The paper is divided into four sections. The following section presents the conceptual framework and the methodology here developed to study the impact of FDI from a systemic perspective. Section 3 examines the empirical evidence collected in two regions in Mexico. Section 4 presents the conclusions.

2. The conceptual framework

This section develops a theoretical framework to study technology transfer from FDI to host regions (sub-national regions), drawing on the existing literature and findings from the empirical evidence collected in this research. First of all, technology transfer is understood as the reception and utilisation by one country of technology developed in another (Graham, 1982, p. 55). The forms that technology can take vary from the disembodied (patents, licences) to embodied technology, i.e. the technology embodied in machines or people (especially tacit knowledge). There are several different mechanisms that a MNE can use to transfer technology to the host country. These include arm's length sales of technology to independent purchasers (e.g. through technical service or licensing agreements), through a range of cooperative alliances to equity investments (Dunning, 1993, p. 311).

From an operational perspective, parent companies transfer technology to their subsidiaries in order to ensure the latter can perform their duties.[1] However, technology transfer mechanisms and the type of knowledge differ significantly among MNEs. Scott-Kemmis and Bell (1988) identify three different categories of technology transfer. The first category includes capital goods and technological services to expand the production capacity of the importing firm or industry. The second consists of operating and maintenance skills and know-how, which are transferred through information codified in manuals, formulae and blueprints and through training and instruction which may contribute to increasing the human capital of the recipient country. The third category encompasses the knowledge and expertise required to generate and manage technical change and takes place mainly through both codified information and specialized training.

The nature of the technology, and the technological capabilities and characteristics of the transferor and recipient are factors that influence the mechanisms used by MNEs to transfer technology, as well as the complexity of technological knowledge transferred. Radically new technologies and those where the perceived risk of loss of proprietary rights is the highest are less likely to be transferred to subsidiaries (Dunning, 1993). MNEs also differ in their willingness to transfer technology and the mechanisms to do it, according to their corporate strategy.[2] The capabilities of the host countries are also a factor that affects the type and complexity of technology transfer. If a MNE finds skilled workforce, high levels of managerially and technologically skilled employees and access to knowledge and research facilities, it will be more interested in investing in knowledge-intensive activities (such as R&D) and consequently in transferring technological knowledge related to those activities (Cantwell and Iammarino, 2003; Kuemmerle, 1999; O'Donnell and Blumentritt, 1999; UNCTAD, 2005).

Technology transfer from FDI to host economies has been widely studied in the literature on spillovers (Blomström and Kokko, 1998; Caves, 1974; Grossman and Helpman, 1991; Kokko, 1994; Kugler, 2006). However, the spillovers approach focuses on the interaction between foreign subsidiaries and local firms, and assumes that technology spills over freely to everybody and no clear distinction is made between information and knowledge (Padilla-Pérez, 2006).

Although the existing literature on technology transfer through MNEs (e.g. Dunning, 1993, 1994; Radosevic, 1999; Romo Murillo, 2005) has recognised the role of local actors, few efforts have been made to develop conceptual tools and methodologies to study the impact of MNEs at the meso level. The conceptual framework devel-

[1] The existing literature identifies several motivations for an MNE to transfer technology: economic, operational, strategic and social, among others. See, for instance, Kumar et al. (1996) and Reisman (2005).

[2] For instance, the literature recognises that technology transfer strategies differ according to whether firms from the US and Europe, or Asia are being considered. Empirical analyses show that Asian firms, in comparison with European and US firms, in general have a less internationalised R&D activities structure (Meyer-Krahmer and Reger, 1999; Molero and Heijs, 2002; Reger, 2001, 2002).

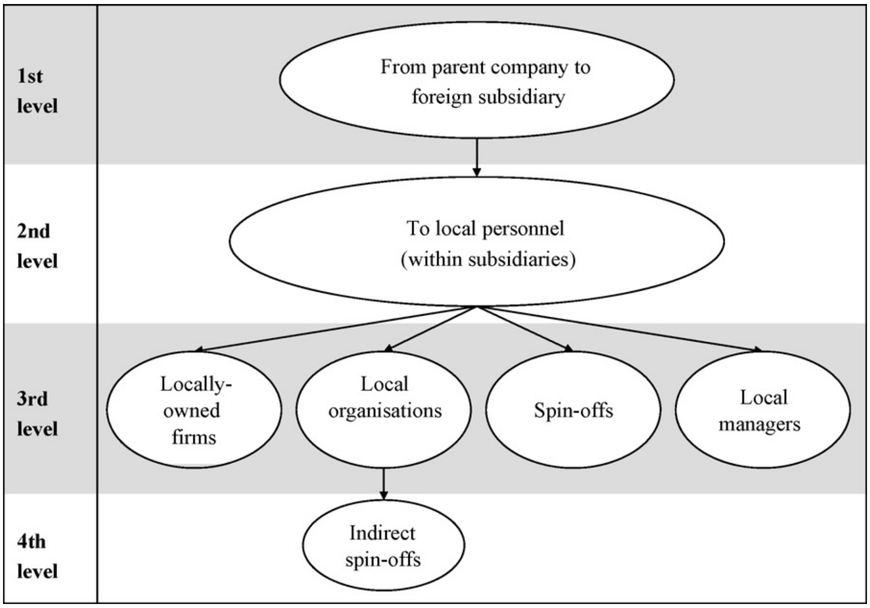

Fig. 1. Technological impact of FDI on host regions. *Source*: Own elaboration.

oped here adopts a systemic and evolutionary approach which is defined by two main features. On the one hand, it recognises that the impact of FDI on host countries is the result of the interactions of MNEs not only with locally owned firms, but also with innovation-oriented organisations such as universities, research centres and industry associations. On the other, it argues that in the search for higher competitiveness and profits, MNEs deliberately transfer technology and interact with local firms and other organisations, thus their technological impact on host regions cannot be reduced to unintended spillovers.

As said, the conceptual framework draws on the existing literature and findings from the empirical evidence collected in this research. First, the literature on technology transfer identifies different mechanisms by which FDI has positive effects on host countries, such as backward linkages with the host economy; imitation of technologies or organisational forms used by MNEs, and knowledge and skills acquisition for local human capital (Dunning, 1993, 1994; Hobday, 1995; Radosevic, 1999; Romo Murillo, 2005). This literature also recognises that the impact of technology transfer from MNEs on host country is determined by several factors including their activities, the existing production and technological capabilities of the host country (including absorption capabilities[3]), the quality and availability of local resources and the policies and attitudes of local governments (Cohen and Levinthal, 1990; Radosevic, 1999; UNCTAD, 2005; Young et al., 1994). Thus, it is a complex effect influenced by local, national and international factors, and conditions external and internal to the foreign affiliate.

Second, there is a large body of literature that studies the importance of regional dynamics for technical change (see, for instance, Braczyk et al., 1998; Evangelista et al., 2002; Howells, 1999; Iammarino, 2005). The subnational region, understood as "territories smaller than their state possessing significant supralocal governance capacity and cohesiveness differentiating them from their state and other regions" (Cooke et al., 1997, p. 480), is of special relevance for this research. The extent of interaction among innovation-oriented agents, including firms, tends to rise as geographical distance reduces (Cantwell and Molero, 2003). Therefore, the impact of MNEs is stronger and clearer in the region in which they are established.

Following a meso-level approach, four different levels at which technology transfer takes place are here identified (see Fig. 1). The first level of technology transfer depicted in Fig. 1 relates to knowledge and resources flows from the parent company or clients to the subsidiary established in the host region.[4] The parent company provides its subsidiaries with process, organisational and product-centred technologies. Technology transfer takes place through diverse mechanisms such as capital goods, blueprints and visits of foreign experts.[5] Local personnel

[3] See Cohen and Levinthal (1990) for further details on absorption capabilities.

[4] Along the same lines, Scott-Kennel (2004, p. 630) distinguishes two processes or levels of technology transfer through MNEs: "The transfer of a bundle of resources from the parent is expected to improve the affiliate's performance relative to local competitors. In addition it has the potential to raise the capabilities of local firms through diffusion and transfer via linkages of the affiliates with local firms".

[5] See, for instance, Carrillo et al. (1998) and Carrillo and Gomis (2004).

are not necessarily involved in this process, especially in very hierarchical and vertically integrated firms in which key decisions and technologically sophisticated activities are reserved to foreign personnel.[6]

The second level takes place within foreign subsidiaries when local employees are trained in new technologies. Training can be formal (e.g. induction programmes, taught courses, etc.) or informal (on-the-job training). The latter occurs when local employees become involved in the activities carried out by the foreign subsidiary, from simple assembly to more complex product design and development activities.[7] The distinction between first- and second-level technology transfer highlights the importance of the involvement of local personnel, which is crucial to absorb imported technologies.

The third level of technology transfer takes place when foreign subsidiaries interact with local agents. Foreign subsidiaries buy goods and services from locally owned firms (backward linkages) and provide technical assistance to ensure these are delivered according to the required specifications, costs, quality and time.[8] Foreign subsidiaries also interact with local innovation-oriented organisations such as universities, technical education schools and research centres.[9] There is an array of mechanisms used by foreign subsidiaries to transfer technology to local organisations: collaborative research projects, secondment or visiting programmes for professors (i.e. academics spending time in firms working on specific projects), in-firm training and advice to update the curricula of taught programmes.[10]

Third-level technology transfer also includes mobility of personnel from foreign subsidiaries to local organisations. Four main types are identified:

(i) Movement of highly skilled personnel from foreign subsidiaries to locally owned companies. Local personnel working for foreign subsidiaries acquire knowledge and skills – through day-to-day activities, and formal and informal training – which they bring with them when moving to a local company.[11]
(ii) Spin-offs. Local personnel – using knowledge, skills and contacts acquired while working for foreign subsidiaries – may set up their own companies to supply goods or services to their former employer or other companies.[12]
(iii) Local personnel working for foreign subsidiaries may move to local organisations, bringing with them knowledge, skills and contacts. Highly qualified workers may move to research centres and universities to engage in research activities or teaching. They may also move to public offices focused on promoting the development of the industry in which they previously worked. Their understanding of the needs of the industry and their personal contacts are very valuable for the design and implementation of public policies.[13]
(iv) Local personnel may participate in local private organisations such as industry associations. These organisations constitute an important mechanism to facilitate and foster the participation of local personnel in the dissemination of technology, to lobby for the improvement of the institutional framework, and to promote initiatives aimed at improving human resources and technological capabilities in the region.

The fourth level comprises indirect spin-offs, which here are defined as private enterprises set up by entrepreneurs who work for private or public organisations (but not private enterprises). These entrepreneurs gain skills and knowledge through interaction with MNEs during their employment in a public or private organisation. For instance, a researcher from a public research centre carrying out collaborative research projects with MNEs acquires knowledge through interactions with these foreign firms. Later this knowledge can be used by the researcher to set up his/her own company.

This section has described global–local interactions from the point of view of MNEs, that is, the activities that they are involved in and how they transfer technology to the host regions through diverse mechanisms. Yet, it is acknowledged that the development of indigenous technological capabilities is heavily conditioned on the features of the local system. The effects of FDI on local capabilities are conditioned on the existence of local components and their ability to internalise foreign technologies (Cantwell and Iammarino, 2003; Meyer-Krahmer and Reger, 1999; Narula, 2001). The absorptive capacity of the region, i.e. the ability and the speed with which its components can absorb technologies transferred through MNEs, and disseminate them among local firms, is central to explaining the impact of FDI (Criscuolo and Narula, 2001; Molero and Alvarez, 2003).

3. Technology transfer in two regions in Mexico

This section aims to present empirical evidence of the four levels of technology transfer from MNEs to host regions. Two regions with a strong presence of electronics

[6] See, for example, Buitelaar et al. (1999) and Gallagher and Zarsky (2007).

[7] In-firm training in foreign subsidiaries has been widely studied. See, for instance, Carrillo (1993), Contreras and Kenney (2002), Hualde (1995, 2001), Lara Rivero (1998), and Padilla-Pérez and Juárez-Torres (2007).

[8] For further details on technology transfer from foreign subsidiaries to local firms see Buitelaar et al. (1999), Carrillo and Zarate (2003), and Vera-Cruz et al. (2003).

[9] The literature on systems of innovation was a central input to map all the potential interactions of foreign subsidiaries with local innovation-oriented organisations. See, for instance, Lundvall (1992), Nelson (1993), and OECD (1999, 2002).

[10] See Cohen et al. (2002), Molas-Gallart et al. (2002), Mowery and Sampat (2005), Partida and Moreno (2003), and Rivera (2002) for further details on the interaction between firms, and universities and research centres.

[11] Contreras et al. (1997) highlight the role of local managers and engineers in foreign subsidiaries as a valuable resource to generate an endogenous process of domestic industrial and technological development.

[12] Görg and Strobl (2002) and Markusen and Venables (1999), for instance, discuss how multinationals can exert positive effects on the development of indigenous firms.

[13] The identification and description of the last two types of third-level technology transfer, as well as the fourth level, are based on the empirical work done for this research.

Fig. 2. Selected regions in Mexico.

firms were identified: the metropolitan area of Guadalajara in central Mexico and four cities in the state of Baja California (Ensenada, Mexicali, Rosarito and Tijuana) close to the border between Mexico and the United States (see Fig. 2). From the existing literature, it became evident these two regions had different characteristics relevant for this research: the integration of MNEs with the local industry, their interactions with universities and other local organisations, the complexity of process and product technologies, among other features.[14]

In 2004, there were 723 electronics firms in Mexico located across the country. These firms exported $US 42,908 million and employed 298,000 direct workers in 2004. The most important electronics firms in the world had at least one subsidiary in Mexico, for instance: Sony, Samsung, LG Electronics, HP, IBM, Siemens, Foxconn, Sanmina-SCI, Intel and Motorola. In Jalisco, the electronics industry comprised 44 firms and employed more than 33,000 direct workers at the end 2004, while in Baja California it comprised 187 firms and employed more than 91,000 direct workers (Padilla-Perez, 2005).

A representative sample of firms, in terms of type of firm[15] and origin of capital, were interviewed. The sample comprised 80 foreign firms and locally owned private enterprises: 36 established in the metropolitan area of Jalisco and 44 in Baja California, and in terms of origin of capital 53 foreign subsidiaries and 27 locally owned.[16] Information on local organisations was also gathered through semi-structured interviews. The organisations fell into four types: (a) universities and technical education schools; (b) public research centres; (c) local government; (d) industry associations and other private organisations.[17] The following sections describe the main findings.

3.1. First-level technology transfer: from the parent company to foreign subsidiaries

The first level of technology transfer relates to knowledge and resource flows from parent company or clients to the subsidiary. The firm-level survey showed that all foreign subsidiaries interviewed in the two regions had received technology from their parent company. But foreign subsidiaries also receive technology from their main clients, which in turn are foreign subsidiaries established in the same region, another region in Mexico or abroad.

Technology transfer from the parent company or clients to foreign-owned subsidiaries took place through various types of mechanisms. Some were related to the transfer of knowledge via short- or long-term visits of personnel from the parent company and temporary assignments of local personnel to other countries. Technology transfer also took place through mechanisms that do not involve face-to-face interactions, such as capital goods, blueprints and manuals. Finally, the level of technology transfer varied from year to year and throughout a year. When a new product, process or technology was introduced, technology transfer increased.[18]

Yet technology transfer was not a homogeneous process among foreign subsidiaries in the two regions studied. Eleven percentage of the foreign subsidiaries (all but one located in Jalisco) interviewed said they had received technology from the parent company, but more through an interactive two-way relationship than a passive and dependent process. These foreign subsidiaries possessed strong product-centred and process technological capabilities and carried out joint collaborative projects with the parent company or other subsidiaries of the MNEs. Thus, international transfer of technology was a two-way flow. If a process- or product-related problem arose, these foreign subsidiaries interacted with engineers abroad to solve it, rather that just waiting for assistance from the parent company.

In contrast to this two-way relationship, 10 foreign subsidiaries located in Baja California (27.8% of the sample in that region) had strong technological dependence on their parent company or clients. They were medium- or small-sized foreign firms with a small commercial office on the US side of the border (California). They had one or a few clients who provided them with equipment, machinery, raw mate-

[14] See, for instance, Buitelaar et al. (1999), Carrillo and Hualde (1998), Dussel (1999), Dussel et al. (2003), Gerber and Carrillo (2003), and Palacios (2003).

[15] Electronics firms were classified, according to international standards, into four types: original equipment manufacturers, contract manufacturers, suppliers and design houses. See Ernst (2004), Ernst and Kim (2001), and Sturgeon (2002).

[16] See Padilla-Pérez (2006) for more details on the methodology to define the relevant population and the sample.

[17] The sample of organisations included the four universities and four technical education schools most frequently mentioned by private enterprises during the survey in each region; two sector-specific industry associations in each region; two research centres in each region (in the regions studied only four research centres carry out research related to the electronics industry); and six local public offices in charge of supporting the manufacturing industry (two in Baja California and four in Jalisco).

[18] Carrillo and Gomis (2004) present the results of a survey carried out among electronics and automotive firms established in northern Mexico. One section of the survey studied technology transfer from the parent company or main clients. The results are largely consistent with the ones presented in this section.

Table 1
Activities carried out by foreign subsidiaries (percentage of firms that answered positively)

		Baja California (%)	Jalisco (%)
Process and production organisation technology	ISO accredited	81	86
	Complex techniques of production organisation	100	100
	Development of new machinery and equipment	28	52
Product-centred technology	Product R&D[a]	0	19
	Development of new products[a]	3	24

[a] Means between regions are significantly different at the 0.05 level.

Table 2
Technology transfer from parent company to foreign subsidiaries (percentage of firms that answered positively)

Type of technology transfer received from parent company	Baja California (%)	Jalisco (%)
Technical assistance related to product specifications	96.9	86.4
Technical assistance related to quality control[a]	87.5	63.6
Technical assistance related to process and organisation technology	75.0	63.6
Training of engineers and technicians	75.0	81.8
Purchase of machinery and equipment	81.3	63.6
Technical assistance related to procurement of components and raw materials	81.3	77.3

[a] Means between regions are significantly different at the 0.05 level.

rials and knowledge to carry out mostly labour-intensive assembly processes.

The survey of firms provided information also on the type of activities carried out by foreign subsidiaries established in Jalisco and Baja California. Since the complexity of the technology transferred is closely related to the technological complexity of the subsidiary activities, it is relevant to address this point briefly. As Table 1 shows, all interviewed foreign subsidiaries in both regions employed complex techniques of production organisation, such as just-in-time, quality control, six-sigma and lean manufacturing. They also had ISO-type certification (86% in Jalisco and 81% in Baja California). Development of new machinery and equipment and process-related software was less widespread in the two regions studied, but was more frequent in Jalisco than in Baja California. As for product-centred technology, 19% of foreign subsidiaries interviewed in Jalisco had conducted product R&D and 24% had developed new products. In contrast, in Baja California only 3% had developed new products and none had carried out product R&D.[19]

The most common type of technology transfer relates to product specifications in both regions: 97 and 86% of interviewed foreign subsidiaries in Baja California and Jalisco, respectively, had received this type of technology (see Table 2). This illustrates the high dependence that foreign subsidiaries located in the two regions studied have from product-centred technologies transferred from the parent company. Technical assistance related to procurement of components and raw materials (81% in Baja California and 77% in Jalisco), and training of engineers and technicians (75% in Baja California and 82% in Jalisco) were also important. The means between regions are not significantly different for any type of technology transfer (except for quality control).

The analysis of first-level technology transfer shows that, on the one hand, there are significant differences between regions in terms of the type of technology transferred to foreign subsidiaries, specifically in product-centred technologies where the means between regions are significantly different. On the other, technology transfer on the first level was mostly related to process and production organisation technologies, but limited knowledge and expertise related to product-centred technologies.

3.2. *Second-level technology transfer: to local personnel within foreign subsidiaries*

In terms of second level of technology transfer, i.e. technological knowledge transferred to local personnel working for foreign subsidiaries, all foreign firms interviewed offered formal and informal training to their employees. In general, on-the-job training was given by experienced internal personnel and was mostly directed to blue-collar workers. Some large foreign subsidiaries even had their own internal training unit. Seventy-four percentage of the foreign subsidiaries interviewed relied also on external sources of training on topics that were generally applicable to the industry, such as ISO certification and production organisation technologies. In many foreign subsidiaries computer-based training had become important.[20]

Foreign subsidiaries in the electronics industry in the two studied Mexican regions frequently receive highly qualified personnel from other parent company subsidiaries. These foreign experts transfer knowledge about process and product technologies, through formal and on-the-job training. Again, training of local personnel varied from year to year and throughout the year. When a new product, process or technology was introduced, training increased. Often, foreign personnel were seconded to sub-

[19] A non-parametric test for independent samples (Mann–Whitney) was used to compare the means, since the variables are not normally distributed. See Table 1.

[20] See Padilla-Pérez and Juárez-Torres (2007) for a detailed description of in-firm training in the electronics industry in Mexico.

Table 3
Technical assistance from foreign subsidiaries to locally owned companies (percentage of firms that answered positively)

Type of technical assistance provided to locally owned firms	Baja California (%)	Jalisco (%)
Technical assistance related to product specifications[a]	53.1	81.8
Technical assistance related to quality control	46.9	72.7
Technical assistance related to process and organisation technology	31.3	40.9
Training of engineers and technicians	25.0	40.9
Purchase of machinery and equipment	18.8	31.8
Technical assistance related to procurement of components and raw materials[a]	25.0	54.6

[a] Means between regions are significantly different at the 0.05 level.

sidiaries to train local human resources and set up new production processes, and local personnel were frequently sent abroad to learn from other subsidiaries.[21]

The amount and quality of training varied among the regions studied. In Jalisco the average length of training per employee was 47.3 h annually, whereas in Baja California was 37.5.[22] Firms that offer little training in general focus on on-the-job training to ensure that employees were capable of carrying out the tasks for which they had been hired. In contrast, firms with active training programmes provided the employees not only with firm-specific knowledge, but also with general and industry-related knowledge.

3.3. Third-level technology transfer

3.3.1. Technology transfer from foreign subsidiaries to locally owned firms

Backward linkages between foreign subsidiaries and locally owned firms are weak in both regions studied in Mexico. Almost all direct components are imported: local content is only 3%.[23] Although 98% of all interviewed foreign subsidiaries said they bought some kind of good or service from a local firm, only 13% of them bought direct goods, i.e. raw materials and components to be integrated into the final good, such as cables, harnesses, assemblies and sub-assemblies of electronic components, primary goods (copper, silver, etc.) and plastic components. Electronic components were imported or purchased from foreign-owned firms established in Mexico. Nevertheless, foreign subsidiaries bought a wide array of indirect goods from locally owned firms, such as packing and wrapping products, consumable goods, labels, fabrics, and paper board.[24] Again, there are significant differences between the two regions studied: 32% of foreign subsidiaries in Jalisco bough direct goods from local firms, but none in Baja California.[25] This illustrates the lower degree of backward linkages in the latter.

Global flagships – such as HP, Sony and Samsung – attract many foreign suppliers to Mexico, but few local firms had succeeded in supplying direct goods to foreign subsidiaries in the electronics industry. In order to comply with NAFTA rules of origin, foreign subsidiaries bought components from firms located in Mexico, independent of their nationality.[26]

The foreign subsidiaries questionnaire also enquired of firms that had bought local products and services from locally owned firms, whether they had provided technical assistance to their local suppliers. This question received a response from 98% of interviewed foreign subsidiaries (52 answers). Foreign subsidiaries transferred technology to suppliers of both direct and indirect goods. As Table 3 shows, technical assistance related to product specifications was the most important in both regions, and is related to the fact that the majority of locally owned firms carry out their activities following the specifications of foreign firms. The second most important kind of technical assistance was quality control, which was associated with the very high standards prevailing in the electronics industry. The percentage of positive responses was always higher in Jalisco, showing that in that region links between foreign subsidiaries and locally owned firms are stronger.

Suppliers of key components, such as Intel, Texas Instruments and Freescale have subsidiaries in Mexico and are very important sources of knowledge for both firms and local organisations, such as universities and research centres. These suppliers provide locally owned firms with detailed information on their products and give them technical assistance if they are interested in using their components to manufacture or design products.

3.3.2. Links between foreign subsidiaries and local organisations

Sources of technology of foreign subsidiaries differ importantly between the two regions studied (see Table 4). On average foreign subsidiaries in Jalisco were more open to external sources of knowledge (the percentage of positive responses was higher in this region for 8 out of 10 potential sources of knowledge). The percentage of firms that used universities and public research centres as a source of knowledge was significantly higher in Jalisco than in Baja California (however, the proportion was lower than 50% even in Jalisco). Similarly, the recruitment of highly quali-

[21] Training within foreign subsidiaries in Mexico has been studied in the literature. See Buitelaar et al. (1999), Carrillo (1993), Carrillo et al. (1998), Hualde (2001, 2003), and Lara Rivero (1998).

[22] Means between regions are significantly different at the 0.05 level.

[23] It corresponds to the total value of Mexican inputs purchased by firms active in the electronics industry divided by total value of sales. Own estimation based on INEGI, Industria Maquiladora de Exportación, on line, www.inegi.gob.mx. Similarly, Carrillo and Zarate (2004) state that local content is lower than 3% in the electronics industry of Baja California.

[24] Similarly, Carrillo and Zarate (2004) point out that there are no locally owned firms supplying direct goods to the electronics industry in Baja California. Domestic companies provide only indirect goods.

[25] Means between regions are significantly different at the 0.05 level.

[26] An interesting example is the strong agglomeration of firms in the TV sets sector in northern Mexico. See Carrillo and Zarate (2004), Contreras and Carrillo (2002, 2003), Koido (2003), and Mortimore et al. (2000).

Table 4
Sources of technology of foreign subsidiaries (percentage of firms that answered positively)

Source	Baja California (%)	Jalisco (%)
Suppliers of equipment and inputs	84	86
Public research centres[a]	13	36
Universities[a]	6	45
Recruitment of highly qualified personnel[a]	56	91
Licensing	9	18
Clients	53	73
Competitors	47	23
Consultancies	34	59
Fairs, exhibitions	53	41
Chambers of commerce and industry associations	25	45

[a] Means between regions are significantly different at the 0.05 level.

Table 5
Links of foreign subsidiaries with universities and technical education schools (percentage of firms that answered positively)

Type of link	Baja California (%)	Jalisco (%)
Training[a]	25	55
Student internships	66	73
Secondment programmes for professors	6	14
Collaborative research projects	6	18

[a] Means between regions are significantly different at the 0.05 level.

Table 6
University and technical education centres—industry links (percentage of positive answers)

	Baja California (%)	Jalisco (%)
Programmes and courses content updating	100	100
Student internships	100	100
Equipment donation	100	100
Technical assistance services	57	50
Secondment programmes for professors	14	66
Collaborative research projects[a]	0	33

[a] Means between regions are significantly different at the 0.05 level.

fied personnel, as a source of technology, was significantly higher in Jalisco. Suppliers of equipment and clients were an important source of knowledge in both regions, as said above.

Foreign subsidiaries were also asked whether they had linkages with local universities or technical education schools, and if so, what the nature of these relationships was. Table 5 summarises these responses. Again, foreign subsidiaries in Jalisco had on average more links with local universities and technical education schools (however, only training was statistically significant). The main link in both regions was through student internships, followed by training.

In summary, few foreign subsidiaries active in the electronics industry in Mexico, in the regions studied, had links with universities and research centres regarding research collaborative projects. They were mainly a source of human resources.[27] Suppliers of equipment and inputs and clients, most of them foreign firms, were an important source of technology. The comparison between Baja California and Jalisco shows that foreign subsidiaries in the former had less interaction with local sources of knowledge.

Interviews with local universities and technical education centres show that all had some kind of links with industry and all claimed the strongest relationships with foreign subsidiaries. The results presented in Table 6 are similar to the previous results: local universities and technical education schools in both regions interacted with foreign subsidiaries mainly through teaching-related activities, such as updating curricula for taught programmes, providing course content, student internships and donations of equipment for teaching purposes. Research-oriented activities, such as temporary secondment programmes for professors, and collaborative research projects, took place in Jalisco, but were very limited in Baja California.

Although a detailed assessment of regional capabilities is beyond the scope of this paper,[28] it is important to highlight some capabilities of local organisations in Jalisco that contrast those in Baja California. Universities and research centres in the former carried out basic and applied research related to the electronics industry. In Baja California, universities in general conducted little research related to the electronics industry, whereas public research centres were focused on basic research with no short-term commercial application and no link with the electronics industry. Moreover, in Jalisco there were a large number of universities and technical education schools that provided specialized and qualified personnel to firms in the electronics industry. These organisations had undergraduate and postgraduate programs clearly oriented to matching the needs of the industry. Baja California had a relatively smaller supply of universities and technical education schools, although its electronics industry was bigger than Jalisco's. In general, engineering departments were oriented to educating students to work for manufacturing industry, without a clear specialization in electronics.

3.3.3. Spin-offs

In 78% of the interviewed local firms in both regions, the founder or owner had prior work experience or business relationships with subsidiaries of MNEs, before setting up his/her own company (83% in Baja California and 73% in Jalisco[29]). It was possible to identify two main types of previous experience: 71% of the founders or owners worked for a foreign subsidiary and 29% provided services to foreign subsidiaries. The activities that local owners were involved in when employed by a foreign subsidiary were diverse: development of testing equipment, product

[27] Hualde (2003), based on the survey of firms operating under the maquiladora programme in northern Mexico, supports the finding that the main link between firms and the academic sector is student internships.

[28] See Padilla-Pérez (2006) for a detailed methodology to assess regional technological capabilities, as well as for an in-depth assessment of capabilities in Baja California and Jalisco.

[29] Means between regions are NOT significantly different at the 0.05 level.

design, product R&D, administrative activities (procurement, distribution, etc.), and so on. In many cases, these Mexican entrepreneurs had spent some time working in plants in other countries to gain further experience and eventually bring new knowledge to the Mexican subsidiary.

The studied regions also differ in terms of both the amount and type of spin-offs. Although the exact number of spin-offs in each region was not identified in this research,[30] there was a higher proportion of locally owned firms in Jalisco than in Baja California (45.5 and 15.5% of the relevant population, respectively). On the other hand, most locally owned firms in Baja California (91.6% of firms interviewed) were second-tier suppliers carrying out assembling or manufacturing activities. In Jalisco, in contrast, 73.3% of firms interviewed were design houses carrying out product and embedded software design, and even R&D activities.

If the owner or founder of the company had work experience in a foreign subsidiary, he/she was asked how this had contributed in terms of knowledge acquisition. The percentage of positive answer was similar in the two studied regions. Knowledge of markets was the most important (70% in Baja California and 100% in Jalisco), followed by knowledge of product technology (70% in Baja California and 73% in Jalisco) and knowledge of organisation technology (60% in Baja California and 64% in Jalisco).[31] Another type of knowledge that was mentioned frequently by interviewees was related to the needs of foreign subsidiaries active in the region. Their daily activities in the foreign subsidiaries provided local managers with knowledge about the kind of products and services required by the firm. Equally important was a good understanding of how foreign subsidiaries operate and their business culture, and the importance of meeting their specifications. Finally, previous experience with MNEs was helpful in developing business networks, which were very important for local entrepreneurs to identify suppliers, distribute their products and acquire new technologies.

The spin-offs described above manufactured, assembled or designed electronic goods or components. However, foreign subsidiaries active in the electronics industry may have positive impacts on other industries. As a result of the strong competition and high barriers to entry in the electronics industry, in the regions studied most of the spin-off firms were active in ancillary industries which supplied indirect goods and services to the electronics industry.[32] Two examples of local industries which have benefited from the presence of an FDI-led electronics industry are software, and tooling and moulding.[33]

[30] As said, the sample included only a representative number of firms, and it would have been necessary to interview all locally owned firms to find out whether they were spin-offs.

[31] Means between regions are NOT significantly different at the 0.05 level.

[32] Contreras et al. (1997) analyse the creation of local industries to supply goods and services to firms operating under the maquiladora programme and active in the electronics industry.

[33] See Carrera Riva Palacio (2005) and Hualde and Gomis (2004) for an analysis of the software industry Baja California and Jalisco; and Vera-Cruz et al. (2003) for the moulding industry.

3.3.4. Participation of managers in local public and private organisations

Mexican managers employed by foreign subsidiaries can have a positive influence on conditions in the host region through technology diffusion activities. This was clear in the case of Jalisco, but not in Baja California. In the former, highly qualified Mexican managers play an important role in the development of regional capabilities. In Jalisco, 86% of the foreign subsidiaries in the sample were managed by Mexican managers, who in general were interested in and committed to the development of the industry in the region. In contrast, in Baja California only 34% of the foreign subsidiaries in the sample were managed by Mexican managers.

A group of Mexican subsidiary managers had launched and implemented a set of initiatives to strengthen the competitiveness of the electronics industry in Jalisco through improved infrastructure, regulation, incentives and human resources. The group had set up a commission on human resources and technology to promote links with local universities and research centres, in order to strengthen the formation of human resources and foster the participation of local organisations in innovation-related activities. Also, through industry associations, Mexican managers working for foreign subsidiaries were providing technical assistance to small locally owned firms. In their spare time, these managers supported the industry association initiatives to help local firms engage in technology upgrading processes, improve product quality or obtain international certification.

Foreign subsidiaries have an impact on host regions through the mobility of their personnel to public and private organisations. As well as becoming involved in part-time teaching, highly qualified and experienced managers had left foreign subsidiaries and joined universities, research centres and public offices to contribute to the development of the industry. In Jalisco, there were several former general managers of large foreign subsidiaries who worked in local government, designing and implementing initiatives to foster growth and technological upgrading in the industry. Similarly, there were managers who led or worked for research groups within universities or research centres. These people applied the knowledge acquired during their employment with the foreign subsidiaries to the development of regional capabilities.

Section 3.3 has provided details of the mechanisms and activities through which MNEs, via their foreign subsidiaries, have transferred knowledge to local firms, universities, technical education schools and research centres in the studied regions. Backward linkages in the two regions studied were weak (mostly related to indirect goods), but when foreign subsidiaries bought goods to local firms, they transferred technology to ensure that products complied with high quality standards and that product specifications were met. On the other hand, foreign subsidiaries interacted with local universities and technical education schools mainly in the search for human resources. Therefore, technology transfer was mainly related to new knowledge to update the curricula of taught courses, but limited in terms of creating capabilities to generate and manage technical change.

The empirical evidence also shows that there was a low presence of locally owned firms in the electronics industry, especially in Baja California. Spin-offs to other industries, such as software and moulding, were more important. In turn, Mexican managers in Jalisco had an important role of disseminating to the rest of the local economy knowledge initially transferred through the first and second levels described above. Finally, similarly to first- and second-level technology transfer, there were significant differences between Baja California and Jalisco regarding third-level technology transfer.

3.4. Fourth-level technology transfer: indirect spin-offs

This subsection addresses indirect spin-offs, which were classified in Fig. 1 as fourth-level technology transfer from foreign subsidiaries to host regions. As mentioned, an indirect spin-off is defined as a private enterprise set up by an entrepreneur who previously worked for a private or public organisation (but not a private enterprise), which in turn benefited from interaction with MNEs.

In Jalisco, three former researchers from a public research centre had established their own electronics design houses in the region. When they worked for the research centre, they carried out collaborative research projects with foreign subsidiaries operating in the region. The knowledge and skills acquired through these projects were crucial when setting up their own companies. The sample in Baja California did not identify any indirect spin-off.

4. Conclusions

The framework here developed integrates micro- and meso-level analyses, identifying four levels at which technology transfer from MNEs to host regions takes place. It provides a tool to study systematically global–local interactions beyond inter-firm relationships or macroeconomic analysis, shedding light on the great potential of technology transfer and dissemination derived from FDI.

The framework was also helpful to compare technology transfer between regions. The same industry (electronics) was studied in two regions within the same country, thus controlling for sector and country-specific factors. The regional comparison shows that technology transfer is not an automatic, necessary and homogeneous result of the presence of MNEs. Higher local capabilities in Jalisco have been crucial to attract more complex types of technology (for instance related to product development) and to disseminate it to the rest of the local economy. Universities and research centres carrying out research related to the electronics industry and developing highly qualified and specialized human resources, and an active group of local managers are some crucial factors that explain the differences in technology transfer between Jalisco and Baja California.

As stated previously, MNEs may have different technology transfer strategies. Although it is beyond the scope of this research, it is important to note that the higher presence of Asian firms in Baja California, which tend to be more reluctant to transfer technology to host countries, as well as a lower integration to global production networks in comparison to Jalisco, may have had a negative impact on the willingness to transfer key technologies and interact with host regions.

The electronics industry in Mexico, dominated by MNEs, is a good example of economic and commercial integration of a developing country in Latin America into international markets. After several years in Mexico, and in some cases even decades, some foreign subsidiaries have built up close links with the local economy. However, the cases of Jalisco and Baja California show that this model of international integration has had significant limitations. First, backward linkages between MNEs and locally owned firms were limited. Foreign subsidiaries had attracted foreign suppliers to Mexico and local firms supplied mainly indirect goods, limiting the impact of the former on the host region. Second, although foreign subsidiaries had links with local universities and technical education schools, these were heavily concentrated on teaching-related activities, such as student internships, and very few research collaborative projects were identified. Third, since the activities of foreign electronics firms in Mexico are concentrated on the manufacture and assembly of components and goods, with reduced participation in knowledge-intensive activities such as product design and research and development, technology transfer is also constrained to activities with low knowledge content.

In terms of public policy, this paper shows that public initiatives aimed at attracting FDI and fostering technology transfer, must not be exclusively oriented to local private enterprises, but also to other local organisations that can be benefited by the presence of FDI—such as universities, research centres and industry associations. That is, public policies towards FDI must adopt a systemic approach.

On the other hand, since technology transfer from MNEs to host regions is not automatic and homogeneous, public policies towards FDI must go beyond fiscal incentives, and a stable macroeconomic and institutional framework. Additional policies aimed to develop qualified human resources, strengthen local universities and research centres, and foster links among MNEs and local organisations are crucial to encourage more knowledge-intensive technology transfer to the host region, and to absorb the technology transferred.

Finally, it must be noted that this paper examined the mechanisms by which foreign subsidiaries transfer technology to host regions. It is acknowledged that technology transfer is one side of the story in the process of developing indigenous capabilities through global–local interactions. However, the detailed study of technological capability building was beyond the scope of this paper. By the same token, this paper analysed only one-way technology transfer from foreign subsidiaries to the host region. Yet the foreign subsidiary may gain new knowledge as a result of its interaction with local actors. The study of this two-way relationship is open to future research. In addition, the empirical evidence collected for this research was a snapshot of two regions at a given point in point in time. As a line of future research, the same framework could be used to study the evolution of technology transfer, following a dynamic approach.

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