Towards an aerospace system of production in Mexico?

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Abstract: In recent years, some well-known aerospace companies have established manufacturing facilities in Mexico, a new comer to this industry. Based on the ILC-PLC theory, the objective of this work is to understand how these firms achieve the production of aircraft parts, which require specialised knowledge, in a country that has not yet developed a strong system of knowledge-producing organisations to support high technology activities. A survey applied to 30 aerospace firms in Mexico, interviews with regional development offices, and specialised magazines are the information sources of this work. The results reveal that these firms are mainly devoted to manufacturing processes, some of which are complex and require firm-external sources of knowledge. When this happens, these firms usually resort to their headquarters. Much investment is needed to create more knowledge-producing organisations targeted to the sector. For this investment to be more efficient, targeting some technical areas could be a good strategy.

Keywords: aerospace industry; emerging countries; Mexico; industry life cycle; product life cycle; internationalisation strategies; sectoral systems of production; technology transfer.

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1 Introduction

The world aerospace industry is experiencing important changes due to the ever rising technological demands to conceive and manufacture modern aircraft (Esposito, 2004) and to the desire of some countries to strengthen their local industry and/or to even compete at a global scale (MacPherson and Pritchard, 2007). Accordingly, we have a scenario in which firms in traditional leader countries like the USA, France, or Canada, are seeking to expand their activities in other countries in order to gain market shares, share risks/costs, tap new sources of knowledge, or to lower costs. The product life cycle/industry life cycle (PLC-ILC) theory (Vernon, 1966; Klepper, 1997) has been used among other things to analyse the way in which industries delocalise to new places. Some authors like Cantwell (1995) have dismissed the importance of the PLC-ILC theory in general, and Mowery and Rosenberg (1985) even argued that the PLC-ILC theory has not been able to predict the aerospace industry delocalisation moves. However, Niosi and Zhegu (2008) have shown that when coupled with the innovation system perspective (Lundvall, 1988; Nelson, 1993; Malerba, 2002), the PLC-ILC theory still yields good results.

Mexico is one of the places to which the aerospace industry is delocalising. Well-known names in the aerospace industry like the Americans Honeywell, Gulfstream, General Electric, Cessna, and the Canadian prime assembler Bombardier have recently established facilities in Mexico. The establishment of leader manufacturing firms from different industries is not new in Mexico. This has been the case for companies in the electronics, automobile, and auto parts industries too. However, the aerospace industry requires cumbersome and strict safety and quality standards compared to those industries. Our objective is to understand the technology transfer cycle of a high-technology industry, with substantial codified knowledge and scale economies, to a developing country with limited specific skills in the field, and that has not yet developed a strong system of knowledge-producing organisations to support high-technology activities.

The rest of this work is as follows: the second section explains the theoretical framework, research questions and methodology. The third section illustrates the evolution of the aerospace industry in Mexico. The fourth section analyses the activities of two actors of a potential aerospace production system in Mexico, namely, aerospace firms and government policy. Finally, some conclusions are given.

2 Theoretical framework

2.1 The PLC-ILC and aircraft manufacturing

One of the concerns of the PLC-ILC theory is to understand the location choice of the industry as it goes through its life cycle (Vernon, 1966). A turning point in the dynamics of the industry life cycle is the emergence of a dominant design (Abernathy and Utterback, 1978), which brings the standardisation of several dimensions of the industry's product architecture. The standardisation of some dimensions of the product's architecture increases the importance of scale economies, which put pressure on some firms, and finally some of them consolidate while other exit the industry (Klepper, 1997). It is at this point that delocalisation towards low-cost locations makes sense. Whether firms will delocalise the whole production, parts of it, or only some functions (manufacturing, R&D, testing, etc.) will depend greatly on the technical characteristics of the industry's products.

The aerospace industry's product, the aircraft, can be described as a modular product (Ulrich, 1995; Baldwin and Clark, 2000), in which different modules like engines, wings, and avionics, are connected through well defined interfaces to form the overall product or system (Frigant and Talbot, 2005; Niosi and Zhegu, 2005). This high degree of modularity implies some degree of standardisation. This is consistent with the fact that the current dominant design of the subsonic civil aircraft, the jet-engine, has been around some decades (Kehayas, 2007; Niosi and Zhegu, 2008). However, the fact that there is a dominant design at the level of the product does not impede that different modules exhibit ever-increasing technological change (Murmann and Frenken, 2006). The intense use of electronics and composites is a proof of this constant change (Esposito, 2004; Frigant and Talbot, 2005). Therefore, in the aerospace industry there are activities with a good deal of codification, but also activities at the cutting edge of technology. In terms of delocalisation an important question is what are the types of activities that have been delocalised?

2.2 Research questions and propositions

Research question 1 What are the types of activities transferred by aerospace firms to Mexico, and how these high technology firms overcome the infrastructure limitations of the local medium?

Proposition 1 The more likely activities to be transfer to a country like Mexico, a newcomer to the aerospace industry, which has a good manufacturing capacity but with a low development of its innovation system, should be related to low-cost manufacturing.

These manufacturing activities still require the high quality and safety standards that characterise the aerospace industry. Usually, when firms transfer complex activities overseas they experience certain level of uncertainty because they are not sure if the local medium will provide the resources needed to achieve those standards (Knickerbocker, 1973), this is more pronounced when the location is a newcomer as it is the case of Mexico in aerospace. It is important to note that aerospace is not a mass production industry (Hobday, 1998), and transport costs of parts represent a small fraction of the overall cost of an aircraft (Frigant and Talbot, 2005). This means that aerospace firms have relative freedom to seek for technical advice abroad, since there are lesser time and travel constraints compared to mass-production industries.

Proposition 2 The uncertainty about meeting the standards of aerospace manufacturing in Mexico is lowered in part by the ability to seek for technical advice abroad, and by the involvement of the Mexican government.

Since aerospace is a high technology industry, it requires a system of supporting organisations because no single firm posses all relevant knowledge. Building on the national innovation system (NIS) concept (Freeman, 1987; Lundvall, 1988; Nelson, 1993), the sectoral system of production and innovation (SSPI) concept (Malerba, 2002) goes beyond the traditional concept of industry and stresses that sectors are framed by institutions (policies, regulations, incentives and supporting organisations). In order to develop this type of system an innovation and technology policy (ITP) is needed (Teubal, 1996). This ITP should change according to the needs of the sector, and in its first stages needs to instil R&D in firms, incite collective learning among different agents, achieve a critical mass of projects, develop policy capabilities and define incentives [Teubal, (1996), p.452]. A positive sign in the case of Mexico is that the government has made public its support for the sector; however, it is important to know if this support is framed in an ITP able to create and nurture a production system.

Research question 2 Are there elements that can be considered as a part of a nascent aerospace production system in Mexico?

Proposition 3 Although the overall Mexican NIS is weak (OECD, 2009; Dutrénit et al., 2010), the Mexican context still provides some elements that may form an embryonic production system due to its industrial and educational infrastructure, few but important research centres, and the willingness of the current government to support the industry.

2.3 Data and methodology

Based in government reports, specialised magazines and newspaper articles we were able to identify and articulate the dynamics that the Mexican aerospace industry has followed so far. With the aid of Mexico states' lists of aerospace firms and with the aid of regional development offices we selected 30 aerospace firms to conduct a face-to-face survey upon 30 aerospace firms. These firms were distributed in four Mexican states, in five cities.

Since most of the questions included in the survey's questionnaire represent categorical statistical variables, descriptive statistical tools are used to illustrate the clusters characteristics. When using cross tabulation, the chi-square test for independence of two variables[1] is presented. Given the size of the sample, in some cases the expected count in some cells is lower than the recommended (usually five counts). For this reason, the Yates correction for continuity statistic[2], a non-parametric test, is also shown. This non-parametric test returns a p-value using a Monte Carlo simulation (Verzani, 2005).

3 The aerospace migration towards Mexico

3.1 The evolution of the Mexican aerospace industry

Back in the 1910s Mexico had an interesting attempt at building domestic aviation and aerospace sectors (Jáuregui, 2004). However, those efforts were abandoned in World War II, and Mexico redirect aerospace capacity to serve planes form the USA (Hernández Domínguez, 2007). Current activity is not dependent on those early efforts. Perhaps, the only way in which these first attempts influence future development was the continuity in maintenance, repair and overhaul (MRO) capabilities, that had to be kept and developed to service the planes bought outside the country. This tentatively explains the existence of an aerospace engineering degree since 1940 at the National Polytechnic Institute in Mexico City, where the major airport of the country is located.

It was in the late 1960s, when the first aerospace subsidiary manufacturing facility was established in Mexicali, the capital of the state of Baja California (Ornelas, 2010). One of the first documented cases was the facility opened in Mexicali, by Allied Signal, a US company that was a supplier of another US firm, Garrett aero-engines (Flight International, 1988). If we compare with the automakers and auto-parts companies that have moved into Mexico, the aerospace story has both similarities and contrast with the two. Contrary to aerospace, the automakers established facilities in Mexico to comply with regulations because that was the way to tap the local market (Bennett and Sharpe, 1979). Once the regulations were lifted, automakers took advantage of the already experienced subsidiaries and restructure them according to their new needs, which included not just the local market but also exporting (Carrillo, 1995). This is somehow similar to aerospace in the sense that global companies (both aircraft and automakers) try to rearrange their different units' operations in order to optimise; although, there are still strong commercial and political limitations. However, in Mexico, the aerospace firms resemble more the auto-parts than the automakers, for two reasons: almost all inputs come from abroad (Martínez-Romero, 2011) like in the case of the auto-part firms (Carrillo, 1995), and above all, most of the aerospace firms do not assembly complete sub-systems, let alone systems, which is contrary to the automakers.

It can be argued that there was not a purposeful attempt by the Mexican government to attract aerospace firms specifically in those years. The goal was to attract US manufacturing irrespective of their field, as long as those firms considered Mexico a place with the conditions to carry on their respective activities. The main advantage that Mexico provided was a low cost operations location. It was under these conditions that some aerospace firms (related with electronics like Allied Signal and Rockwell Collins) started to locate mainly in Baja California in the cities of Mexicali and Tijuana. Indeed, this state has the ancient firms established in the country and currently hosts almost half the aerospace companies in the country. An interesting point is that Mexicali and Tijuana are not the only industrial cities in the US-Mexico border. For instance, another important industrial border city is Ciudad Juárez in the state of Chihuahua, which hosts only few companies that barely touch aerospace activity. One possible explanation for this may be that in the beginning, aerospace companies were suspicious about the feasibility to transfer activities to Mexico, and wanted to close monitor these activities, and reduce transportation costs. California in the USA is a very important place in terms of aerospace activity, and most of the companies initially (and currently) located in Baja California have their counterparts in California. The states of Texas and New Mexico (adjacent to Ciudad Juárez) represent a lesser share of the US aerospace activity compared to California. Even if this explanation has some grounds, as the activity increases in Mexico, the feasibility is already proven, and as such the geographical distance surely diminishes in importance as the existence of important aerospace firms in the city of Chihuahua (which is not a border city) testify.

In year 2000, there were only 20 aerospace companies in Mexico, and they exported products worth 150 million USD to the USA (Ramírez, 2005). The downturn in the Mexican economy at the time urged the country to promote export sectors other than the ones already been promoted like automobile, electronics and auto parts. Thus, the idea took force in Mexico to promote a sector that had already some antecedents (though small), with good prospect of value added, and a prestige image associated. It was under the early presidency of Vicente Fox in year 2000 that aerospace was considered an important sector to promote (Ibid). However, it was until the next presidency that the main efforts in terms of policy support were materialised. This was signalled with the inauguration of the Bombardier plant in the state of Querétaro.

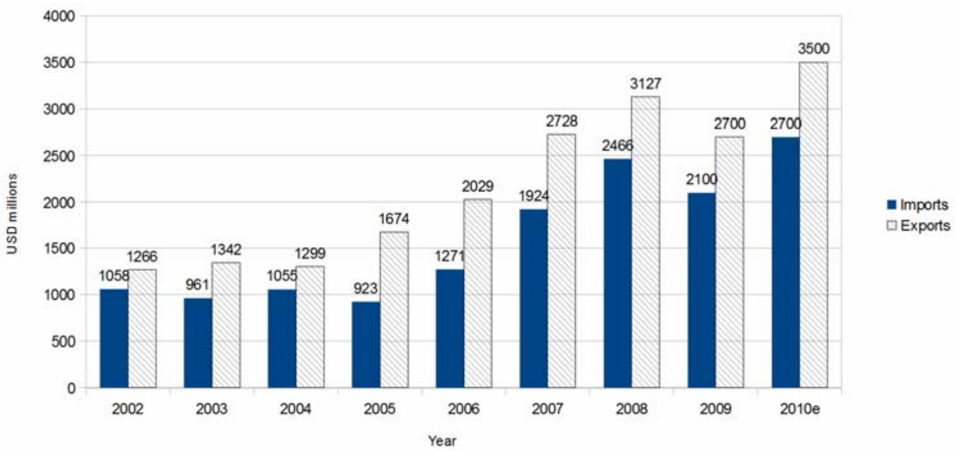
Therefore, from 2000 to date, Mexico has initiated an explicit campaign to attract aerospace companies to the country. The prior experience of the pioneering firms established in the country was taken as a sign that such a production, with high quality and safety standards, could indeed be done in the country. This situation, combined with the need to encourage other export sectors to help the troubled economy in the early 2000s, seems to be the detonator of this promotion. The experience in the automotive, auto parts, and electronics sectors represented the promise of a skilled labour force that could be relatively easily trained into aerospace activities. Additionally, the existence of an indigenous metal-mechanic sector meant the possibility to develop an important supplier base.

3.2 The Mexican aircraft industry in figures

According to the FEMIA[3], product exports of aerospace firms based in Mexico represented approximately 3.5 billion USD for the year 2010[4]. In Mexico, the exports value is a figure that represents production since almost all sales in this industry are exported, at least for the moment. Available data for year 2008 reveals that Brazil aerospace industry had an output of 7.55 billion USD from which 90% were exports [Maculan, (2010), p.1]. For year 2008, Mexico had exports for 3.127 billion USD, thus if we take the exports from Brazil, we have that the Mexican aerospace industry exports were about 46% compared to those of Brazil. In the case of India, exports amounted to 1.21 billion USD in 2008 [Mani, (2010), p.46], which represents 39% of the Mexican exports. Therefore, Mexican exports are almost half the exports of a country that has an original equipment manufacturer (OEM) like Brazil.

In terms of evolution it can be seen in Figure 1 that from year 2006 on, the industry started an upward trend in exports. It can be argued that the strong government promotion did coincide with the increase in the output. However, Figure 1 also shows how the sector is very sensible to international slowdowns like in year 2009 when negative impacts from the financial crisis of 2008 were felt. Indeed, previous projections had 2009 amount of exports equal to 4.050 billion USD (FEMIA, 2009).

Figure 1 International trade of the Mexican aerospace industry (years 2002–2010, USD millions) (see online version for colours)

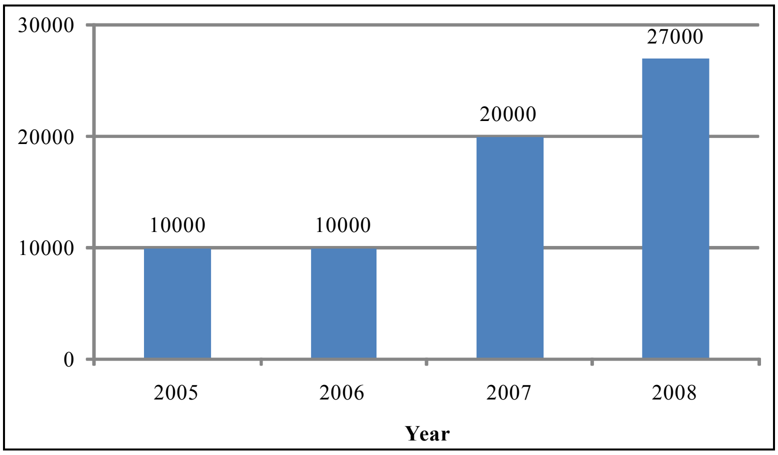


Note: Figures in USD millions.

Source: FEMIA (2010) webpage with data from the Ministry of Economy

In terms of employment, this indicator has also followed the upward trend beginning in year 2006.

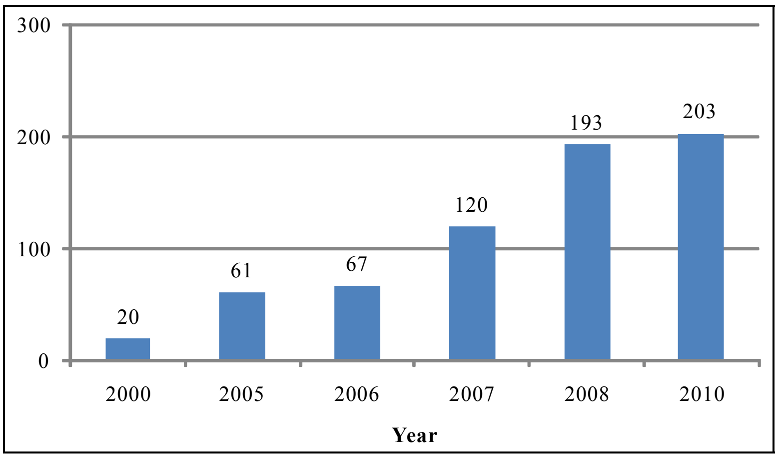
Figure 2 Employment in the aerospace industry in Mexico (see online version for colours)



Source: Data from Promexico[5] website: http://www.promexico.gob.mx/wb/Promexico/aeroespacial

Information for the year 2010[6] regarding the number of organisations related to aerospace reveals that there are 203 located in 16 Mexican states. In Figure 3, it can be seen how the number of organisations has grown rapidly since year 2006. Let us remember that in year 2000 there were only 20 firms in the country, thus, in one decade the increase has been of a great magnitude. Again, it is year 2006 where this trend took a notorious upward shift. Approximately 78% of these organisations are dedicated to manufacturing (M), 13% to maintenance, repair and overhaul (MRO), and 9% to engineering and design (E&D).[7]

Figure 3 Number of organisations related to the aerospace industry in Mexico (see online version for colours)



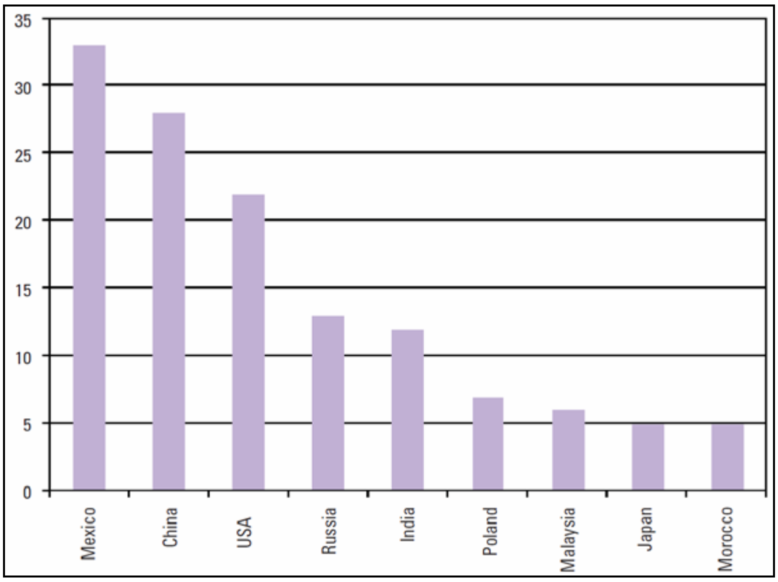
Source: Data from Promexico website, FEMIA website, and Ramírez (2005)

In addition to private productive firms, this list also contains organisations such as universities, research centres, airlines and sales representative offices. Thus, the actual figure for just the private productive firms is lower than 203, and should be close to the 152 firms that are classified as manufacturing (M).

If we compare the number of firms with a country like Brazil, we see that Mexico has more companies, even with the adjusted figure just described. The number of firms that made up the aerospace industry in Brazil is 40 (Maculan, 2010). One interesting fact is that from the entire aerospace output in Brazil, Embraer represents 80% of the activity (Maculan, 2010). Although that indicator is not available for Mexico, it is very unlikely that a single firm has such a big share of the national total.

According to the consulting group AeroStrategy (2009) (Figure 4), from 1990 to 2009, Mexico is the country that has received more manufacturing investments in aerospace.[8] Other countries that are pursuing aggressive strategies include China, second, Russia, fourth, and India in fifth place. It is important to note that the mentioned study takes into account the discrete number of investments and not the actual amounts invested. In fact, since China and India assembly complete planes, the invested amounts in those countries should be larger than the amounts of the investments located in Mexico. In any case, as shown in the previous paragraph, this information is consistent with the fact that Mexico has more aerospace firms than countries with local-owned companies like Brazil.

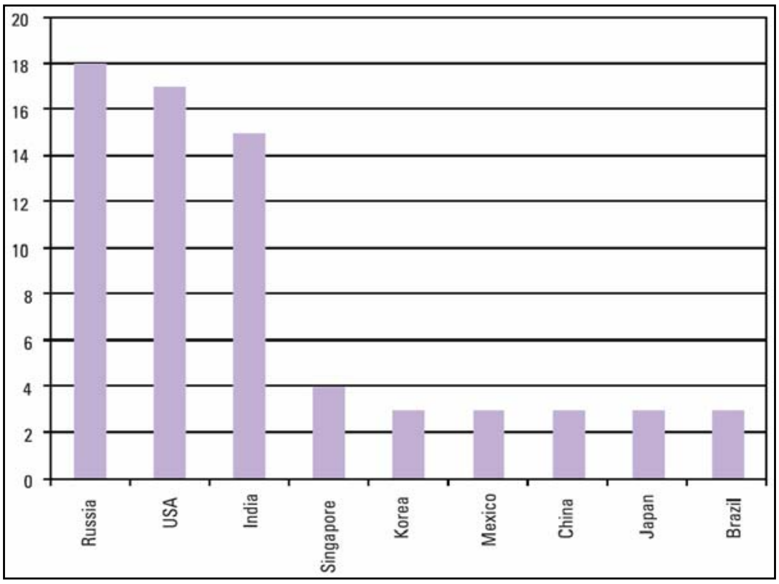
Figure 4 Number of manufacturing investments in aerospace, period 1990–2009 (see online version for colours)



Source: AeroStrategy (2009)

Even though the logical advantage of Mexico is low cost for manufacturing, the country also appears in sixth place in terms of investments in engineering and R&D, with China closely following in seventh place (Figure 5).

Figure 5 Number of engineering/R&D investments in aerospace, period 1990–2009 (see online version for colours)



Source: AeroStrategy (2009)

The AeroStrategy report mentions how most of the investments made in Mexico, whether for manufacturing or R&D, are made by means of wholly-owned subsidiaries instead of joint ventures. The principal reason is that there are no Mexican local firms to organise joint ventures to begin with.

We want to stress two related issues raised in this section. First, Brazil, China, and India, have at least one final assembler firm while Mexico does not. Although, for instance, Bombardier and Cessna are final assemblers in their home countries, they do not conduct final assembly in Mexico. That fact limits the accumulation of local capabilities in Mexico. Also, in other emerging countries, the final assembly is conducted either by a national-owned firm (like Embraer in Brazil) or by a joint-venture including a national-owned firm (like AVIC with Embraer and Airbus in China). There are no large nationally-owned firms in Mexico, and it seems unlikely that a foreign final assembler would decide to do that all by itself given the huge costs, capability restrictions and risks involved. The related second issue is that the government is backing those final assemblers in those other three emerging countries. Although today Embraer is a private firm, in its beginnings it was a government firm. AVIC and Comac in China and HAL in India are government-owned firms. The general economic orientation of the current Mexican Government is not well suited to government ownership of any firm. Therefore, given the lack of a final assembler, and the lack of local counterpart firms needed to form joint ventures (not just for final assembly), the main strengths of the aerospace sector in Mexico rely on the activities of foreign subsidiaries (with few exceptions of local firms), the subject of the next section.

4 Elements of an aerospace production system in Mexico

4.1 Firms' activities

In Table 1, we present (in no particular order) the kind of activities carried out by the aerospace firms established in Mexico. Here we report the activity considered principal by the firm. Some of the activities were reported by more than one firm, like for instance, electrical harnesses (5), metallic pieces (3), and engineering support (2).

Table 1 Activities carried out by aerospace firms in Mexico

Entertainment systems	*Radio modules (microwaves)*	*Carbon fibre pieces treatment and assembly*
Metallic and titanium rings	Wire and cable conductors	Seat covers
Engineering support	Sensors	Sub-assembly for helicopters
Communication racks	MRO of landing gears	Aerospace structure assembly
Interior furniture pieces	MRO of engines	Metallic pieces
Interior design	Turbine rings	Safety equipment
Electric coils	Turbine components	Electric switches
Electrical harnesses	Hydraulic components	

Source: Own survey

Although some of the activities are advanced in technical terms, as we are going to see next, most of them were not carried out for the very first time in the Mexican facility. In some way this is consistent with the PLC-ILC theory, at least with the information provided by the firms in the sample.

In Table 2, we can see that almost all firms produced at least one new product in the last three years. Manufacturing a new product does not imply that the firm designed the product. In fact, none of these firms were the designers of the new products they manufactured. Nevertheless, it is important to stress the manufacturing of new products because they represent adjustments to existing practices and as such it is a learning process that otherwise will not take place. Only 20% of the firms declared that the new product they manufactured was a world novelty. This means that these firms either figured out the manufacturing process and/or manufactured the product for the very first time. According to some personal communications with interviewees, this is the result of optimisation strategies followed by foreign firms, in which the subsidiary is in charge of not just manufacturing, but also of the design of the process, while the parent company gets more concentrated in designing, testing and prototyping the product. We have to wait to know if this trend consolidates or not. It is important to note that the design of the manufacturing process requires certain advanced skills.

Table 2 Novelty degree of new products

Degree of the novelty introduced	*Counts*	*%*
None	1	3.33%
Firm	21	70.00%
Country	2	6.67%
World	6	20.00%

Source: Own survey

Table 3 shows which departments of the firms were the most important to tackle the obstacles that new products represent. In the second column, importance is measured in a scale of 1 to 5, where 1 is low and 5 is high, firms were asked to evaluate the importance of these four firms' departments in their contribution to undertaking new products. Thus, the second column represents the average values of the whole sample. The engineering and management departments were considered by almost all firms as very important. This is consistent with the idea that most of these firms have to tackle engineering problems related to manufacturing processes for products designed elsewhere. It is important to note that the low values of R&D and marketing are due in great part to the fact that a lot of firms gave a value of zero to that question. If we take the average value for only the firms that gave a value between 1 and 5, most of which were Mexican-owned firms, the results are 3.5 and 3 respectively, still less than 4.79 and 4.17 for engineering and management. Thus, it can be argued that subsidiaries, by being part of the manufacturing department of a bigger firm, do not need to develop in-house R&D or marketing, whereas Mexican firms have to do it to a certain extent. That extent is limited though, as it is shown in the average values, in which even for national-owned firms values for engineering and management are bigger in their contribution to new products and processes.

Table 3 Internal sources of knowledge that had an impact in the new products and processes introduced

Firm's department	*Sample average*
Research and development	0.97
Marketing	0.62
Engineering	4.79
Management	4.17

Source: Own survey

Table 4 shows the agents to which Mexican aerospace firms resort when facing a technological problem[9]. The second column shows the number of firms that declared have used that particular external source of knowledge presented in column one. The third column simply presents the percentage that that number represents from the sample. Given that one firm could have used more than one external source, the count is more than the sample number and the percentage is more than 100%. It is clear that global headquarters and global clients are the more important external source of technical solutions. Practically all foreign-owned firms (which represent 70% of the sample) declared they received valuable information and training from their headquarters in order to put in place their manufacturing processes. Also, some firms (66.67%), among them foreign subsidiaries but not only, declared that clients located elsewhere were important contributors of ideas. That usually implied that clients made the trip to Mexico to advise the firms about their products' requirements and the best way to meet them. Global suppliers were also mentioned by 20% of the firms as important sources of knowledge. The only local source of knowledge with some relevance was the research institutes. However, it should be mentioned that the questionnaire asked for external sources of relevant knowledge, and to evaluate the importance of it on a scale from 1 to 5, being 1 low and 5 high. In this case, although six firms declared being helped in some way by a local research institute, the average value they assigned to that help was 2.7. On the other hand, the average value for knowledge coming from headquarters, global clients and global suppliers was valued with 5.0, 4.2 and 4.2 respectively.

Table 4 Sources of knowledge external to the firm

External source	*Counts*	*%*
Local research institute	6	20.00%
Local university	1	3.33%
Local consultant	1	3.33%
Local firms	0	0.00%
Local suppliers	3	10.00%
Country research institute	1	3.33%
Country clients	1	3.33%
Global headquarters	21	70.00%
Global clients	14	46.67%
Global research institute	0	0.00%
Global university	1	3.33%
Global consultant	3	10.00%
Global competitors	4	13.33%
Global firms	1	3.33%
Global suppliers	6	20.00%

Source: Own survey

4.2 Policy instruments

Although there are no incentives targeted specifically to the aerospace industry, firms in this industry can apply to different programmes. Regarding support for R&D activities, the country has changed its policy. From year 2001 to 2009, there was a fiscal stimulus programme[10] which consisted on tax credits in which firms were given 30% back of the spending and investing under R&D activities and in the training of specialised personnel essential for the attainment of the previously established objectives [Dutrénit, (2009), p.250]. This programme was changed in 2009 and now it is called fund for technological innovation[11]. This new programme started with a budget of approximately 210 USD million in 2009 (2,500 million Mexican pesos), and has three subdivisions: the technological innovation programme for high add-value business targeted to small and medium enterprises (24% of the fund); the development and innovation of precursor technologies programme targeted to firms with links with universities and research centres (28%); and the competitiveness programme targeted to big firms (48%) (Olivares Alonso, 2009). Starting in 2009, the new R&D programme does not reduce taxes; instead, it gives direct financial support prior to initiation of the project. Dutrénit (2010) reports that for year 2010 these three programmes amounted to 190 USD million, supporting 707 projects in 543 firms. Figures for aerospace are 5.3 USD million supporting 25 projects[12]. Even though, the sum is welcomed, this fund should eventually become much larger if it really wants to support high impact projects. For instance, the development of new turbines requires funds in the order of USD billions.

Besides R&D funds, in the survey we asked if firms received support for other activities. Labour training, promotion and subsidies were the categories in which at least more than one firm appeared. There were important regional differences in these responses, thus, we grouped the cities into either border cities or inland cites, coincidentally with 50% of the observation in each group[13]. Mexicali and Tijuana were considered border while Querétaro, Monterrey and Chihuahua were labelled inland. There are two reasons for this partitioning. The first is that Mexicali and Tijuana are literally border cities whose dynamics are extremely linked with their US counterparts. Although Chihuahua and Monterrey are located in states that border with the USA, their distance from the border prevents these localities to exhibit the amount of links usually found in border cities. The second reason has to do with the *maquiladora* programme. Although that programme is now extensive to the whole country, initially it was implemented in the border. For this reason, the border localities have a longer tradition in the *maquiladora* programme compared to inland cities.

Table 5 Differences between border and inland clusters regarding incentives received

Incentives	*Answer*	*Locality*			*Chi-square p-value*	*Yates correction for continuity p-value*
		Border %	*Inland %*	*Total*		
R&D fund support	No	73.3%	40.0%	56.7%	0.065[a, b]	0.14
	Yes	26.7%	60.0%	43.3%		
Labour training support	No	66.7%	20.0%	43.3%	0.010[a, b, *]	0.03
	Yes	33.3%	80.0%	56.7%		
Promotion	No	86.7%	93.3%	90.0%	0.543[a, b]	1.00
	Yes	13.3%	6.7%	10.0%		
Subsidies	No	93.3%	66.7%	80.0%	0.068[a, b]	0.17
	Yes	6.7%	33.3%	20.0%		

Notes: [a]More than 20% of cells have an expected count less than 5. Chi-square results may not be valid.
[b]Minimal expected count is inferior to one. Chi-square results may not be valid.
*Chi-square statistic is significant at 0.05.

Source: Own survey

Table 5 shows the specific incentives aerospace firms declared having been received. For the overall sample, the most mentioned incentives were labour training support and R&D fund support with 56.7% and 43.3% respectively. As it was corroborated with regional promotion offices, the labour training support consists on paying the salary of new employees for the first months, covering the expenses of specific training programmes and travel when this training took place elsewhere (sometimes in the country of origin of the firm). In some cases the firms obtained only one of those supports. When it comes to R&D fund support, a word of caution is needed. Although we do not have the detailed information about the projects aided under that programme, according to the interviews with the firms and to the type of innovation these firms declared, most of these projects were mainly technology transfer projects or projects related with novel manufacturing processes. In terms of promotion and subsidies, few firms declared being aided in that way, 10% and 20% respectively. Promotion was related with aid to attend international aerospace fairs, and subsidies consisted on considerable savings on land and energy. In Martínez-Romero (2011) we showed that inland firms felt more supported by being in a cluster than border firms; Table 5 shows that in fact the former firms receive more R&D fund supports and more labour training support.

It is too early to know if those support programmes will instil R&D and learning routines in the firms; however, at least with the data from R&D support, it seems insufficient for an industry with high financial needs. Furthermore, as shown in Table 4, local collective learning, another of the objectives of an ITP, is almost absent since most of the knowledge links occur with agents located abroad. This might be the result of a lack of research centres able to fulfil the needs of these aerospace firms[14]. Indeed, the development of a research infrastructure completely devoted to the sector seems mandatory, which will require time and big money sums. For these investments to be more efficient, targeting a specific aeronautics area would be a good strategy. The report named 'Plan de Vuelo Nacional' (Secretaría de Economía, 2009)[15] mentions the following specialisations for the different clusters: Baja California, electrical-electronics; Chihuahua, electrical-electronics and engine components; Querétaro, engine components and sub-assembly, and heat and superficial treatment; Nuevo León, overhaul and maintenance. These profiles seem to be based on the type of products currently manufactured by the more important firms in the respective clusters. However, apparently there are not signs that a technological platform (like dedicated research laboratories, or the attraction of specialised suppliers) is in place to support those specialisations.

5 Conclusions

In general terms, low cost manufacturing is the main reason for aerospace activity in Mexico, although there are few cases of firms in MRO and R&D. Almost all firms in the survey declared to have introduced new products or processes at the level of the firm. With few exceptions, innovation at the level of the firm meant that the product was designed elsewhere and then the firm was in charge of its production. When faced with technical problems these firms resorted to sources located abroad, mainly their headquarters. This is not new, and apparently, the aerospace industry may follow the steps of other foreign firms dominated industries like the automotive, in which Mexico plays the role of a good manufacturer. These facts fit the delocalisation logic predicted in the PLC-ILC theory in which the more standardised activities are the more likely to be transferred. On the other hand, the notion of Niosi and Zhegu (2008) is also valid and complement the PLC-ILC, in the sense that this delocalisation has been possible in great part to the previous infrastructure conditions that Mexico presents. Moreover, government involvement seems also a crucial factor to lower the uncertainty.

However, this does not mean that integration of whole planes or important modules is the next logical step to be expected in the Mexican case, as it is the case for automobiles. We argue that the particular characteristics of the aircraft as a product, which we illustrated with the aid of the modularity concept, will make different the life cycle transfer of aerospace activities compared to other industries. The proposition in this work is that this is not an automatic effect, because that posture downsides both the technological and market requirements of aircraft. Regarding the former, there are many modules, and mastering the technology just to manufacture and integrate one of them requires learning time, huge investments, and government backing. On the market perspective, we should bear in mind that assembling an aircraft in one location usually is done at the expense of other locations in the world. Countries with growing big civilian markets (and in some instances military markets provided by governments) like China, can afford to lure leading firms to assembly whole planes in their soils (and learn how to do it themselves thereafter). However, a relatively captive market like Mexico seems to provide no incentive to assembly locally. In this sense, local assembly of a complete module or sub-system would be feasible only in the medium run if Mexico is able to develop not just a cost-efficient aerospace manufacturing infrastructure but also a system of knowledge-producing organisations to which firms can resort to. In theoretical terms, it can be said that the technical characteristics of the product greatly affects the chances of a complete delocalisation of an industry.

As the evolution of the Mexican aerospace industry suggests, government involvement in the promotion of the sector was and is a strong signal that lowers uncertainty. This has allowed the attraction of an important number of firms, which has placed Mexico in the aerospace industry map worldwide. National and regional governments have provided different support measures to the sector, mainly in the education and training of the labour force, but also in R&D support. However, the amount of funds should grow in the future if the programme wants to really support high impact projects. Also, the development of research infrastructure seems mandatory to promote collective learning, which is rather limited so far. This infrastructure will be more efficient if targeted to specific aeronautics technologies. The profile of the different Mexican locations should be considered when planning this specialisation.

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Notes

1 The statistical software used to obtain this statistic was SPSS.

2 The statistical software used to obtain this statistic was PSPP and verified with the R programme (both free programmes).

3 FEMIA is a non-profit association that group most of aerospace firms in Mexico (Federación Mexicana de la Industria Aeroespacial).

4 FEMIA website: http://www.femia.com.mx/

5 Promexico is an office dependent from the Ministry of Economy in charge of attracting foreign firms to the country.

6 FEMIA website: http://www.femia.com.mx/

7 The actual percentages for M, MRO and E&D may vary slightly for year 2010; the percentages used were from previous information for year 2009 when there were 193 organisations.

8 The study consists of publicly announced 497 major investments (283 joint ventures and 214 organic investments) made by leading aerospace OEMs and service companies in the period 1990–2009, from which 178 pertain to manufacturing, 97 to engineering/R&D, and 222 to MRO (Ibid, pp.2–3).

9 This information regarding knowledge links is taken from Martínez-Romero (2011).

10 In Spanish, Programa de estímulos fiscales (PEF).

11 In Spanish, Fondo de innovación tecnológica (FIT)

12 The number of firms and the specific fund that was applied were not available.

13 This information regarding differences in support among different localities in Mexico is taken from Martínez-Romero (2011).

14 A success (and exceptional) case in this regard, is the turbine research centre of General Electric in the city of Querétaro. This centre was created thanks to a partnership with a public research centre (CIATEQ) located in that same city (*Negocios*, 2011).

15 In English National Flight Plan by the Ministry of Economy.