UNIVERSITÉ DU QUÉBEC À MONTRÉAL

THE DEVELOPMENT OF AEROSPACE CLUSTERS IN MEXICO

DISSERTATION

PRESENTED

AS PARTIEL REQUIREMENT OF

THE DOCTORATE OF ADMINISTRATION

BY

JAVIER MARTÍNEZ ROMERO

SEPTEMBER 2011

UNIVERSITÉ DU QUÉBEC À MONTRÉAL

LE DÉVELOPPEMENT DE GRAPPES AÉROSPATIALES AU MEXIQUE

THÈSE

PRESENTÉE

COMME EXIGENCE PARTIELLE

DU DOCTORAT EN ADMINISTRATION

PAR

JAVIER MARTÍNEZ ROMERO

SEPTEMBRE 2011

ACKNOWLEDGEMENTS

First of all, I would like to thank my parents, María Guadalupe and Francisco Javier. Since I was a child they have been constantly instilling in me the desire to learn and go beyond conventional wisdom.

Special thanks for my advisor, Professor Jorge Niosi, whose guidance taught me how to identify the relevance of a given phenomenon, and how to approach it with the pertinent concepts. His passion for the subject, but above all his desire to form new people, created the necessary trust for a fluid communication, for which I am very grateful.

I also want to thank Professors Patrick Cohendet and Majlinda Zhegu that were part of the committees for the comprehensive exam and research proposal, and Professors Catherine Beaudry, Isabelle Dostaler and Serghei Floricel which were part of the final dissertation committee. All of them made important comments on this research which helped me to improve it.

Last but not least, I want to say thank you to my loving companion, Julieta, who has been on my side in the entire doctoral journey. Her suggestions on parts of my work have been of great help.

Finally, I want to thank two institutions for the financial aid necessary for the completion of this doctoral program. The Mexican Council for Science and Technology (CONACYT in Spanish) provided me with a scholarship that covered a great part of the doctoral time. When other sources of financial aid were needed, the Canada Research Chair on the Management of Technology provided the resources.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RÉSUMÉ

Les entreprises de haute technologie ont tendance à se regrouper autour des institutions productrices des connaissances. L'industrie aérospatiale n'échappe pas à ce phénomène, et il y a des exemples bien connus des grappes aérospatiales autour des avionneurs d'ordre mondial. Récemment, des entreprises renommées dans cette industrie ont établi des usines de production au Mexique. Les objectifs de cette thèse sont de distinguer les types d'activités menées au sein de ces entreprises au Mexique, ainsi que d'analyser les forces qui attirent ce mêmes entreprises à des villes mexicaines, et d'examiner si les mesures de politique publique mises en place par le gouvernement mexicain sont adéquates pour encourager la réalisation d'activités à fort contenu de connaissances. Pour comprendre quelles seraient les activités les plus probables d'être transférées dans un pays en voie de développement comme le Mexique, nous utilisons des concepts tels que la modularité du produit, la théorie du cycle de vie du produit et de la industrie, et les grappes industrielles le tout dans une approche évolutive. Nous comptons trouver des entreprises dédiées notamment à des activités de manufacture, et du côté institutionnel peu d'incitatifs de politique publique.

Les sources d'information de cette thèse sont une enquête menée auprès d'une trentaine d'entreprises aérospatiales distribuées dans cinq villes mexicaines, et des entrevues avec des bureaux de promotion économique de quatre états du Mexique. Les résultats montrent que les forces d'agglomérations au Mexique sont reliées à des avantages de coût de manufacture, et les mesures de politique publique semblent être insuffisantes pour encourager les entreprises à se doter d'activités avec un plus grand contenu technologique. Nous pensons que les autorités mexicaines devraient reconnaître que la production d'avions représente un défi tout nouveau et pour cela les mesures devraient être plus ambitieuses et concentrées dans un petit nombre de villes. Même si des avantages autres que l'innovation sont les responsables de la présence des entreprises aérospatiales dans les grappes mexicaines, leur installation au Mexique représente un mérite étant donné les hauts standards de qualité qui caractérisent l'industrie. Une gestion adéquate de ces avantages peut représenter la base d'un futur développement dans le secteur.

Mots clés : industrie aérospatiale, grappes industrielles, pays émergents, transfert de technologie, politique d'innovation et de technologie.

ABSTRACT

High technology companies tend to cluster around knowledge-producing institutions. Aerospace follows this pattern, and there are well-known examples of aerospace clusters located around large prime contracting aerospace producers. A recent trend that is taking momentum is the setting up of manufacturing facilities by leading aerospace companies in Mexico. The goals of this thesis are to investigate the type of activities these firms are conducting, as well as the factors that attracted them to the specific Mexican cities where they are located, and to examine if national or regional policy measures are framed in a strategy to encourage those firms to carry on knowledge-intensive activities. To understand what types of activities were more likely to be transferred to a developing country like Mexico, we use the concept of modularity, the PLC-ILC theory, and the cluster concept, all of these framed in an evolutionary approach. We expected to find agglomerations of firms carrying out manufacturing activities with little support from public policy.

The main sources of information of this thesis are a survey applied to 30 aerospace firms in Mexico distributed in five Mexican cities, and interviews with four state economic development offices. The results of this thesis show that agglomeration forces in Mexican aerospace clusters are strongly related with cost-reducing manufacturing advantages and policy measures seem insufficient to encourage firms to undertake more complex activities. Mexican authorities should acknowledge that aircraft production presents new challenges due to their particular modular characteristics, and therefore, policy measures should be more ambitious and concentrate public resources in just a few locations. Even though advantages not related with innovation may explain the presence of firms in Mexico's aerospace clusters, these advantages should not be minimized given the high quality standards of the industry and, if properly managed, they may form the base for future development.

Key words: aerospace industry, industrial clusters, emerging countries, technology transfer, innovation and technology policy.

INTRODUCTION

High technology industries are often associated with economic success. Particularly, a common claim is that high-technology sectors are the main driving force of industrial growth in an advanced economy. These are thought to be economic engines, able to positively impact other more traditional technology sectors. Thus, the importance of a high technology sector is not just its own contribution to GDP (Gross Domestic Product), employment, revenue or exports, but the way it impacts other industries in the economy. These industries attract specialized suppliers thanks to their sophisticated demands, they also are a magnet for skilled personnel that may eventually work in related industries, and they may create new ideas and solutions with potential applications in other industries. Given the importance of high-technology sectors, scholars are interested in uncovering the economic, institutional and social dynamics that characterize their functioning, while policy makers are eager to obtain practical knowledge related to these dynamics in order to set policy measures able to foster the creation and growth of this kind of activity.

The opening of a manufacturing plant by the Canadian aerospace firm Bombardier at Querétaro, Mexico, was a highly publicized event by Mexican government officials. National and regional politicians announced the entry of Mexico into the world aircraft manufacturing industry. The fact is that Bombardier took a step that had already been taken by some other foreign aerospace firms: namely, transferring part of their activities to Mexican soil. It seems that this delocalization trend is gaining momentum. Apparently, Mexico can take advantage of this trend by developing a high technology industry and enjoy the benefits of that kind of sector. To adopt policy measures that could encourage this trend is important to know the requirements of the aerospace industry. In this sense, ***the first objective of this thesis is to understand the technology transfer cycle of a high technology industry, with a***

substantial codified knowledge and scale economies, to a developing country with limited specific skills in that field.

One key phenomenon related to high technology sectors is that some of them tend to agglomerate in more or less clearly circumscribed geographical areas; in other words, they tend to cluster. This has lead to the conclusion that some places provide regional advantages for the functioning of high technology sectors. The aerospace industry is no exception to the high-tech agglomeration trend. There are well-known examples of aerospace clusters like Montreal in Canada, Toulouse in France, and Everett (WA) in the US. Aerospace agglomerations in particular exhibit a very particular set of economic, social and technological conditions. These conditions have a great effect on the way knowledge is created, diffused and exploited. Accordingly, is important to know the type of clustering that is taking place in Mexico. Therefore, ***the second objective of this thesis is to understand why this industry tends to clusters in a host country, as it is the case in their home countries, even if the activities carried out in the host country are expected to be less knowledge intensive than in their home countries.***

From the Wright brothers' landmark flight in 1903 to present-day jet-powered airliners, and from the complete dominance of the American manufacturer Boeing not so long ago to fierce oligopoly competition today, the aircraft industry has experimented important changes. The evolution of the technology knowledge base of the industry, and the political and economic conditions that surround the industry are crucial elements to understand possible future venues. For this reason, an illustration of the main techno-economic dimensions of the products of this industry is presented.

All countries that have developed a successful aerospace industry have put in place costly and permanent policy measures to support its development. These measures are needed to nurture the set of relevant regional (and national) organizations that participate in this high technology industry, as well as to put in place the necessary institutions for their well functioning. The ability for a country to develop these organizations and institutions will strongly depend on the degree of development of the overall innovation system, and the maturity of its public administration to design, implement, evaluate and fine-tune technology and innovation policies. ***The third objective of this thesis is to point out policy measures that can encourage the transfer of more complex activities and the trigger of local learning processes in a country that starts almost from scratch in the aerospace industry.***

The rest of this thesis is structured as follows. **PART I** of this work comprises the theoretical framework and context: **Chapter I** is the theoretical framework. The first section is a revision of concepts like industrial districts, growth poles, anchor tenants and innovation systems, which aims at explaining why economic and/or innovative activity concentrate only in some places. An assessment of these concepts will reveal which of them are more pertinent to explain aerospace agglomerations. The second section of this chapter presents the main tenets of the industry life cycle and the product life cycle (ILC-PLC), and the technological dimensions of the aircraft as a modular product. Then, these two approaches are integrated to understand likely ways in which leading aerospace firms may delocalize their activities to new-comer countries. The last section of this chapter discusses the bases of a technology and innovation policy in evolutionary terms. **Chapter II** puts in context the aerospace sector in Mexico in particular and its innovation system in general. The first section is an overview of the aerospace industry in Mexico, and presents information about main indicators and the type of products produced in the country. The second section illustrates the Mexican context in terms of the economic policy followed by the government on recent decades and its effects on the development of the institutions that are supposed to support technology and innovation. **Chapter III** presents the hypotheses of this work. On **PART II** the empirical research is presented: **Chapter IV** contains the data and methodology. **Chapter V** details the results of this research. **Chapter VI** is a return to theory, in which conceptual contributions are laid out.

Then, the overall conclusions of the study, limits and further research, and a general policy proposal are presented. Bibliographical references and annexes are at the end of this document.

PART I: THEORY AND CONTEXT

CHAPTER I
THEORETICAL FRAMEWORK

1.1 Agglomeration forces in aerospace

Introduction

In places where aerospace firms establish, it is common to find out that regional development offices promote the growth of these firms. On the academic side, some authors like Beaudry (2001), Niosi et al (2005), and Smith and Ibrahim (2006) also make explicit use of the term aerospace cluster, to refer to aerospace firms located in a specific geographic region. Given those commonalities, it may appear that an aerospace cluster is easily identifiable in practice and has a more or less uniform set of analytical dimensions that makes it a clear concept. However, the *aerospace cluster* concept is far from being unambiguous, and thus the practical identification of clusters is not a straightforward exercise. This conceptual ambiguity may prove to be misleading in policy terms when it comes to foster and support so-called aerospace clusters. This is particularly important in the case of newcomer countries like Mexico, which are allegedly developing aerospace clusters.

Some authors mentioned above have not accepted the cluster concept uncritically; on the contrary, some of them use the cluster label while providing other analytical dimensions more appropriate to the understanding of the aerospace sector. Others, like Niosi et al (2005), explicitly challenge the concept and instead use terms like productive cluster and regional innovation system to better describe aerospace agglomerations. By the same token, Cooke and Ehret (2009) openly prefer the terms aerospace agglomerations or regions, and only use the word cluster when making reference to studies that do so. Although the studies mentioned so far analyse aerospace clusters in a meaningful way, they do it with different purposes and using different analytical frameworks. Given the central importance of knowledge creation, use, and diffusion in the economy in general and in aerospace in particular as a high technology activity, an aerospace cluster concept will be better served by the inclusion of categories that examine the role of technological knowledge and innovation in the development of such clusters. In this sense, the works of Niosi et al (2005), Niosi and Zhegu (2005) and Cooke and Ehret (2009) are an adequate starting point for such a quest, since knowledge and innovation are the central concern in those works.

As stated in the previous paragraph, the main objective of section 1.1 is to examine the concepts that describe industrial agglomerations, and to propose relevant analytical dimensions for assessing the technological strengths and weaknesses of aerospace clusters or agglomerations. In order to do that, section 1.1.1 is a theoretical discussion of the main concepts: agglomeration economies, industrial district, growth pole, anchor tenant, innovation system and cluster, which have been central in the analysis of the agglomeration of economic activity in general. With the aid of works that have studied aerospace clusters, section 1.1.2 analyses the relevance of these agglomeration concepts to the study of the aerospace sector. Ultimately, section 1.1 will lay the conceptual foundation that will allow us to identify what kind of aerospace agglomerations (if any) exist in Mexico. This is the first step towards the assessment of the potential of Mexico's aerospace sector to become a serious player in the world aerospace industry.

1.1.1 Clusters, industrial districts, innovation system and other agglomerations of innovative firms

In recent years the work of Michael Porter has popularized the cluster concept in reference to the agglomeration of economic activity. The word cluster has been used extensively even if some authors depart in significant ways from Porter's formulation. It can be said that the word cluster has been chosen as a fancy replacement for agglomeration, but there is not an intrinsic set of analytical dimensions shared by all authors or regional development offices for using the word. Given the ubiquity of the word cluster, the approach taken here is to use it to make reference to any kind of economic agglomeration, while using the term "Porter cluster" to make reference to the concept introduced by Michael Porter. Thus, later in section 1.2, when referring to aerospace clusters we will refer to agglomerations of firms dedicated to aerospace, but not in the sense of Porter's formulation.

The idea that some economic activities derive a number of benefits from being geographically concentrated is not new. A pioneering formulation of the phenomenon was made by the British economist Alfred Marshall. According to Marshall (1890), there are three main agglomeration economies that firms operating in one sector achieve by locating together: the first is the pull of specialized suppliers; the second is the attraction of specialized workers; and the third is the creation of an "industrial atmosphere" in which innovative ideas are easily transmitted among local agents. Implicit in the argument is that these economies would not be attained if firms were geographically scattered.

Marshall (1890) based his explanation on what he called "industrial districts" located in England, dedicated mainly to the textile industry. After the work of Marshall, other influential concepts relating economy and geography have appeared. Among the most influential are the "growth pole" developed by François Perroux; Marshall's "industrial district" as adopted and developed by Italian academics; Michael Porter's "innovative cluster"; and the "national innovation system" (put forward by

Christopher Freeman, B-A. Lundvall and Richard R. Nelson), in its "regional" variety pioneered by Cooke and Morgan (1998) and its "sectoral" approach developed by Malerba (2002); and the "anchor tenant" put forward by Agrawal and Cockburn (2003), as well as Feldman (2003).

In their deconstruction of the cluster concept, Martin and Sunley (2003) argue that any concept that attempts to understand the agglomeration of economic activity should include at least three relevant dimensions: industrial boundaries, geographical scope, and the socio-economic dynamics that takes place in the agglomeration. The first dimension is important because it clarifies what kinds of industries are more likely to benefit from being concentrated in one place. The second dimension, simply put, examines the geographical extension of the cluster effect: cities, metropolitan areas, provinces, states, or even less precisely defined geographical areas such as Silicon Valley or Route 128. The third dimension is critical because it seeks to uncover the series of relationships and economic effects that ultimately give clustered firms an advantage over non clustered firms, such as knowledge externalities. Given the pertinence of these three dimensions, the approach taken here is to evaluate the agglomeration concepts previously mentioned using the framework proposed by Martin and Sunley.

Industrial District

There is not a single definition for the 'industrial district' concept or a comprehensive one among Italian scholars, and even scholars like Rabellotti (1995) question the analytical quality of the concept, emphasizing instead that it is more like a set of stylized facts than a theoretical model. To appreciate this, we present three definitions of the 'industrial district' based on the Italian experience:

> "The districts are geographically defined productive systems, characterised by a large number of firms that are involved at various stages, and in various ways, in the production of a homogeneous product.

> A significant feature is that a very high proportion of these firms are small or very small."(Pyke and Sengenberger, 1990: 2)

> "Thus an industrial district is a small area in which, (if we include both dependent and independent workers), there are perhaps 10,000 to 20,000 workers, and around 1,000 to 3,000 firms with fewer than 20 employees. Many of these firms have a direct connection with the final market, others are "stage firms" and, still others, firms of the vertically integrated sector. A district comprises a cluster of firms producing something which is homogeneous in one way or another, positioning themselves differently on the market. Thus, the district could be defined as being a cluster, plus a peculiar relationship amongst firms. One thing that must, of course, be stressed is that this cluster does not have a centre for strategic decision-making. The fact that the firms connected to the final markets are numerous, and independent of one another, prevents the district from having one single head. The market is clearly national and international although the "stage-firms" work only indirectly for the international market."(Brusco, 1990: 14-15)

> "From the ideal type arising from the Italian experience four key factors characterizing industrial districts emerge:
> -clusters of mainly small and medium-sized enterprises spatially concentrated and sectorally specialized;
> -a set of forward and backward linkages, based both on market and nonmarket exchanges of goods, information and people;
> -a common cultural and social background linking economic agents and creating a behavioural code, sometimes explicit but often implicit;
> -a network of public and private local institutions supporting the economic agents acting within the cluster." (Rabellotti, 1995: 29-30)

Paradoxically, in terms of its activity's boundaries, the 'industrial district' concept is not defined in terms of an industry, as classified by its Standard Industrial Classification (SIC) codes. Instead, the unifying economic dimension of the district is a "homogeneous product" as the two first definitions point out. This means that in the districts there are firms from different industries, as long as they contribute to a particular stage of production of a specific product. Implicit in all, but explicit in the second definition, is the fact that all manufacturing stages leading to that "homogeneous product" are actually carried out within the district. In fact, Brusco (1990) acknowledges Becattini's contribution of redirecting the unit of analysis from traditional industry boundaries to all relevant activities leading to the final product. Regarding the links between the firms, the last two definitions among those presented in the previous paragraph stress the informal ties among these firms, as an extra component, in addition to formal ties; however, they do not explain exactly how these informal ties work. An aspect on which all authors agree is that the districts are made up of small, highly specialized firms. Therefore, in terms of industrial boundaries, the 'industrial district' is defined around a "homogeneous product", in which numerous small, highly specialized firms carry on all the relevant activities pertaining to different industries, but leading to the final product. This decentralized network of small firms is possible thanks to the collaboration between them, which is based on informal ties among participants.

The spatial scale of the district is not much developed in the definitions presented above. The first definition talks about geographically productive systems, the second about small area, while the third talks about spatially concentrated enterprises. Although not explicitly, it seems that the 'industrial district' is confined to a city-like region, on the model of the districts identified by Marshall, or to metropolitan areas, or even to larger areas such as Mexican or US states, German länder or Canadian provinces.

Regarding the socio-economic dynamics that characterize the 'industrial district', Becattini (1990) stresses the existence of a shared system of values, institutions and rules. In this sense, this author claims that "community and firms tends to merge". Summarizing the view of some authors about the Italian districts, Asheim (2000) mentions the district is usually portrayed as a shared system of values that allows for creating an industrial atmosphere that facilitates the flow of tacit knowledge between firms, and that trust was a crucial factor that allowed that flow. Nevertheless, authors like Lissoni and Pagani (2003) stress that even if networking is indeed important to share knowledge; there are often several networks in each district, each network with its own codes and epistemic community. Moreover, these authors found that in the Brescia (Italy) district of hosiery machinery, the knowledge exchanges were based more on stable user-producer relationships than in an allegedly trust shared by the whole community [1].

With the decline of the fordist mass-production organization era, that was characterized by the existence of big vertically integrated firms internalizing economies of scale, and long life-cycle products, new ways of organizing production were put in place in the economic landscape. The work of Piore and Sabel (1984) advocated that small specialized-flexible organizations were to take a more prominent role in the economic landscape, given the decline of mass-production. One of the cases of flexible specialization these authors use as an illustration is precisely the Italian industrial districts. This revival by Piore and Sabel (1984) led other authors, like the ones already seen, to focus their attention on the Italian industrial districts. However, it should be said that the industrial district was just one of the several flexible specialization organization types that Piore and Sabel (1984: 265-268) identified, and indeed a very peculiar one. The account of Piore and Sabel and the other authors reviewed so far shows that the districts are very dependent on context specific circumstances. First, the Italian experience is particular in that there were strong links between the productive sectors and the socialist party in Emilia Romagna (Piore and Sabel, 1984: 266). Second, as we have seen, the products are mainly traditional craft-type, with a high tacit component. Third, some authors question the ability of the industrial district to generate radical innovation. This assertion is based

[1] Other authors challenge this idea of trust as the only way in which cooperation can take place. For instance, Semlinger (2008) argues that if cooperation is confined to relationships based on trust it would be rather restrictive, because generally trust is limited to close social partners; thus, this will limit cooperation with strangers, which may lead to lock-in situations in which firms are unable to find new routines and ways to compete in a changing world (p. 552). Instead of considering trust as the only element which brings cooperation, Semlinger (2008) stresses out that symmetric mutual dependency can warrant a reliable collaboration, which makes the management of this symmetric dependency an important asset that firms involved in network arrangements should constantly maintain (p. 557).

in the tight co-operative customer-buyer relationship characteristic of the district. Critics say that this kind of relationship can lead to incremental innovation, but radical innovation often requires finding other sources of ideas, suppliers (Asheim, 2000), universities, research laboratories, and fine tuned innovation policy (Cooke and Morgan, 1998). Fourth, another critique points out that the industrial district is just a temporary arrangement of firms, that eventually will have to evolve into a different arrangement with more hierarchical features (Rabelloti, 1995; Asheim, 2000). In fact, Boschma and Lamboy (2002) find that markets in the Italian districts have became more concentrated with fewer firms and fewer local inter-firm relationships; moreover, powerful leader firms and business groups have emerged (p. 301). These authors explain that firms in Italian districts have evolved in a way in which some have acquired predominance over others and which external agents have emerged. Thus, there is a knowledge-asymmetry situation in which now large firms are reluctant to share their core competences (Boschma and Lamboy 2002: 301). The view in which districts are a collection of homogeneous firms that collaborate based on trust has been put in question for its recent departures of that homogeneity (Rabelloti, 1995; Asheim, 2000; Boschma and Lamboy, 2002) and because trust is not the only (perhaps not even necessary) element to allow collaboration in these networks. All these characteristics make difficult both the transferability of the model to other places, and the capacity of the industrial district organization to nurture more high technology activities.

Growth Pole

The 'growth pole' is the only one based completely on an explicit industrial terminology. Perroux asserts that for a region to qualify as an "engine region" (it seems that he equates this term with 'growth pole'), it has to exert driving (*entraînement*) or blocking (*stoppage*) effects over industries located in other regions (Perroux, 1955). Perroux (1982) mentions three main ways in which this engine region exerts the so-called driving effect over others: urban agglomerations, engine industries, and new industries (p. 200).

Following the above assertion, the industrial boundaries of the growth pole are determined by the engine company and the new industry. Nevertheless, even if these terms are based on industrial terminology, the industry boundaries are not well defined. For an engine industry to be qualified as such, it should also have driving or blocking effects over other industries, in the same way as the engine region. For this reason, it is not clear how Perroux differentiates an engine region from an engine industry. It seems that he treats them as different levels of the same phenomenon. This vision is reinforced by his treatment of big (usually multinational) firm that for Perroux (1982) is the economic agent with greater capacity to influence the economic landscape (p. 134-152). Therefore, it can be argued that the big firm is the lower level of analysis, while the engine industry is in the middle level, and the engine region is at the upper level. Thus, as long as a big firm, industry or region is capable of having driving effects over others, it is an engine firm, industry or region. The issue of new industries poses another difficulty because Perroux (1982) does not make any claim about the nature of firms that usually make up the dynamic industries. Therefore, drawing the industrial boundaries of the growth pole has to take into account the relationships between different industries and the capacity of the engine industry to influence others.

When Perroux (1982: 201) speaks of urban agglomerations effects that are manifested in the imitation of the city way of life by other regions, thus creating a flow of goods, services and investment, he seems to suggest that a city is the spatial scope for the growth pole. However, he also recognizes that concentration of engine industries (the main cause of growth) can occur in places with not too much urban development. Thus, it is not clear what the spatial boundaries for the growth pole are. Nevertheless, given that Perroux pays attention to the driving effects of big multinational firms, and that usually these multinationals are located in urban city-like areas, it can be argued that a city-like region is the spatial scope of the 'growth pole' concept.

The growth pole does not explain the effects of geographical economic concentrations in terms of explicit socio-economic terminology. Instead, Perroux uses the terminology that we have already seen. The engine industries and the new industries are the main drivers of growth in the economy as a whole. The engine industry exerts its effects mainly by means of its buying of inputs, selling of outputs, and investment, while the new industry exerts its driving effects by means of its initial high growth, with its consequent perturbing effects on existing industries (Perroux, 1982: 201). Thomas (1975: 22) adds to the new industry effects, explaining that new products or processes can enhance the efficiency of their respective industries, while at the same time, depending on the specific applicability of such new products to other industries, can also affect the efficiency of other industries' inputs or outputs. Thus, in Perroux there is the notion of technological innovation in the Schumpeterian sense, nevertheless as Thomas (1975) mentions, Perroux does not go into the micro perspective of innovation. Therefore, the internal socio-economic dynamics that create the concentration of economic growth in the growth pole is explained by Perroux from a macro perspective.

In the 'growth pole' current, what matters most is the existence of an engine industry and engine firm, and the channels by which this firm and industry affect other industries. The way in which these engines affect the rest of the economy is modeled in an input-output fashion. Thus, the strength of the linkages between propeller and propelled industries is a matter of degree. The question of specialization is not addressed by Perroux, perhaps because he treats the issue from a meso-economic perspective. Nevertheless, he clearly sees the big firm (sometimes multinational) as the one with the capacity to exert this engine quality. Thus, it can be argued that Perroux was thinking in terms of large vertical-integrated firm, whose activity will attract several others seeking complementarities. These ideas were very popular in the 1960s and 1970s in Europe, Latin America, and even North America, were governments tried to create agglomerations by attracting or establishing large firms (e.g. automobile pole in the Southern Italy; Brazil petrochemical poles; Quebec steal pole) (Niosi, 2002b: 40). In this sense, it is important to stress that the growth pole makes reference to a strategic decision of a big corporation motivated by the intention of public policy to develop a specific region, while the industrial district makes reference to a more or less spontaneous gathering of several small firms in which policy was not much involved. This last scenario was perhaps more pertinent to early stages of an industry, while the latter is more pertinent to a developed stage of an industry. This means that the growth pole idea has more modern elements than the marshallian industrial districts.

Anchor Tenant

Markusen (1996) makes the claim that the Marshallian industrial districts, like the ones described above, are just but one form of industrial organization among others. In fact, this author asserts that that industrial organization form is not as prevalent as others had suggested. Moreover, contrary to some claims in the sense that "flexible specialization" with its decentralization features will become ubiquitous with the fall of vertically integrated companies (Piore and Sabel, 1984), Markusen (1996) does not predict the replacement of all hierarchical forms of regional industrial organization in the future. Quite the contrary, Markusen (1996) recognizes the power of certain actors, like large firms and state laboratories, to shape the regions in which they are established. Among the types of industrial organizations described by Markusen (1996), the hub-and-spoke and the state-anchored districts are characterized by having key firms or laboratories that act as anchor tenants. In a sense, Markusen and other authors in this current rediscover and develop Perroux ideas about the magnetic effect of large firms. However, while Perroux was thinking in supply effects from the large corporation, Markusen and others in the anchor tenant concept put forward knowledge externalities emanating from the large firm, although there is also the recognition that in some cases, the anchor tenant can be research labs and not big firms, like in the case of the state-anchored model put forward by Markusen. Usually this last model makes reference to important state run research laboratories able to exert influence in the region they are established.

Recognizing the role that anchor tenants play in shaping the economic landscape, other authors have sought to explain why these anchors exert such an agglomeration force. Feldman (2003) recognizes the importance of technological innovation for economic growth and seeks to understand how anchor tenants affect the knowledge generation and specialization patterns of certain regions. Thus, research interest is now centered on how anchor tenants affect innovation in particular. It is important to note that Feldman (2003) studies the anchor tenant in the context of biotechnology activities, and as such this author proposes that universities research units may be the ones that act as anchor in this sector. Thus, in the same line as Markusen, Feldman, also recognizes that sometimes the anchor tenant could be a research laboratory and not just a big firm, but different from Markusen, Feldman points out that the laboratory does not necessarily have to be state-owned (Markusen is thinking mainly in military examples), but instead it could belong to a university.

The anchor tenant idea was first developed in the context of shopping malls (Agrawal and Cockburn, 2002). In more organizational and technology approaches, authors like Lowe (1997) adopted the anchor tenant notion to explain the way in which an eco-industrial park should be designed. Briefly stated, the eco-industrial park seeks to better manage and utilize common inputs and slack resources that are common to a determined group of business (p. 58). Defining the anchor tenant of the park will influence the rest of the membership because the rest should benefit from inputs, customers, and slack resources generated by the anchor. Thus, the anchor in this context is a firm that generates an important volume of inputs and outputs, and at the same time these by-products should be practical for the development of other firms. Thus, the anchor tenant notion of the eco-industrial park (Lowe, 1997) is similar to the growth pole of Perroux in which the anchor tenant affects other firms by means of inputs and outputs. However, the engine firm of Perroux generates agglomeration through its provision of either demand for products (i.e. components) or supply of key materials (i.e. special steel). The anchor tenant, instead, generates ideas that spill over the frontiers of the firm or research institution.

Agrawal and Cockburn (2003) define the anchor tenant as "a large, locally present firm that is: (1) heavily engaged in R&D in general and (2) has at least minor absorptive capacity in a particular technological area" (p. 1229). The hypothesis the authors advance is that "the presence of an anchor tenant firm enhances the regional innovation system such that local university research is more likely to be absorbed by and to stimulate local industrial R&D."(p. 1229). In the same vein, Feldman (2003) argues that the presence of an anchor tenant organization may provide a means to further the translation of general-purpose technologies developed at universities and research institutes into commercial products (p. 324). Philips (2002) also puts the accent on the technology transfer issue when discussing anchor tenants. In the context of technology business incubators, this author stresses the role of incubators in transferring research and technology created in universities.

Instead of defining the anchor tenant on the basis of industrial boundaries, Agrawal and Cockburn (2003) focus on technological areas. What matters is the technological area in which the anchor tenant firm manifests an important R&D competence. Therefore, the knowledge externalities this anchor tenant firm creates can benefit only those universities and firms that are involved in the technological area in which the anchor tenant has R&D competence. For Philips (2002), the anchor tenant of a technology business incubator is precisely the firm that by means of its technology characteristics can attract other firms to the incubator (p. 305). Therefore, the boundaries of the anchor tenant concept are set in terms of technological area, and the concept tries to explain concentration of university research and industrial R&D activities and not so much the concentration of production. In a more dynamic context, Feldman (2003) explains that the anchor tenant may generate various veins of possible research and commercial applications. This will determine to a great extent the technological specialization of start-up firms that develop around the anchor. Thus, even if Philips (2002) and Agrawal and Cockburn (2003) set the boundaries according to the R&D competence of the anchor tenant, it should be kept in mind that further development of technology can lead to different specialization paths on the part of start-ups.

With the aim of setting the geographical scope boundaries of the anchor tenant, Agrawal and Cockburn (2003) argue that the anchor tenant must have local presence. The main reason for this is the tacit nature of much of the knowledge involved in university research and industrial R&D. The geographical scope of the agglomeration is not well defined. Following the condition that the transfer of tacit knowledge requires recurrent face to face contact (as argued by Agrawal and Cockburn, 2003), it means that human daily transportation time sets up the geographical influence of the anchor tenant firm.

The condition that the anchor tenant firm be large and competent in R&D has several implications for the socio-economic dynamics that characterize the knowledge flow in the influence area of the anchor tenant. Two main implications are the volume of transactions, and the sophisticated demand in terms of university research and industrial R&D inputs, as well as the industrial R&D outputs it deploys. For instance, absent the concentration of volume, it would be difficult for universities to set up big laboratories and technology transfer offices. These university facilities will serve not just to satisfy the demand of the anchor tenant firm, but also the demand of smaller

R&D-oriented firms in the area. The small volume of transactions of even a handful of small R&D firms is needed; it is not enough for universities to set up big facilities. Indeed, authors like Hanel and St-Pierre (2006) in the context of a developed country like Canada, found that large firms are more likely to collaborate with universities than small firms do. The more developed absorptive capacity (see below) due to their own internal R&D activity (which is a very complex and resource-consuming activity not suitable for some small firms) is among the factors that explain why large firms tend to collaborate with universities more intensely than small firms do (Hanel and St-Pierre, 2006).

Three main socio-economic processes characterize the anchor tenant hypothesis: absorptive capacity, geographical localization of knowledge spillovers, and the role of tacit knowledge in knowledge transfer (Agrawal and Cockburn, 2003: 1231). Regarding the first process, the authors use the definition given by Cohen and Levinthal (1990) in which absorptive capacity is a condition that allows a firm to benefit from external sources of knowledge. The main input for developing that absorptive capacity is the firm's own R&D activity, because it implies a learning process that eventually can help the firm to decipher the R&D advances of other firms (Cohen and Levinthal, 1989). This absorptive capacity is crucial to absorb much of the technological knowledge that competitors and related firms possess, but also the knowledge spillovers generated by the anchor. Even if much of that knowledge is codified in patents, there remain important aspects that are difficult to codify and remain tacit[2]. Since that "tacit knowledge" requires recurrent face to face contact, the most viable beneficiaries from that knowledge are the firms and people who work nearby the anchor tenant firm (in the case that this firm generates

---

[2] Breschi and Lissoni (2001) criticize the sharp distinction of knowledge into codified and tacit. They argue that tacitness is a matter of degree, and even if certain knowledge has a high degree of tacitness, it does not mean that it will lead to geographical concentration per se. These authors observe that most research agreements and license sales are made in a market framework that does not have much to do with spatial proximity. In some way, this idea weakens the 'anchor tenant' argument.

spillovers) if the latter has the knowledge-generating capacity required. For this reason there are "localized spillovers".

The anchor tenant concept is formulated in terms of technological areas, and not so much in terms of traditional industry boundaries. When the anchor is a big firm, it stimulates those firms and universities that could eventually benefit from the specific technological areas in which the anchor is competent (Agrawal and Cockburn, 2003). When the anchor tenant is a research laboratory, as Markusen (1996) and Feldman (2003) point out, new start-ups may be in fact related to the anchor's technological field, but they can depart in significant ways once they evolve. Moreover, start-ups are not the only firms that can grow up out of the anchor, established firms can seek the expertise of the research lab and establish close to it, like the example of the Strathclyde University tells. In the same line, it is very revealing that Feldman (2003) studies biotechnology, which is a group of different technologies that can be applied to several industries. Also, as Pavitt et al (1997) have shown, large firms are multi-technology organizations. Thus, the anchor tenant organization favours the local concentration of technologically-related firms and research, and eventually other organizations that could take advantage of the anchor's diversified technology knowledge.

Innovation System

The concept of innovation system has been put forward more or less simultaneously by Christopher Freeman (1987), Bengt-A. Lundvall (1988) and Richard R. Nelson (1993). Derived from the concept of National System of Innovation (NSI), other approaches have emerged like the Regional Innovation System and the Sectoral Innovation System. In some way these three approaches are useful to understand the aerospace sector. They go beyond the traditional definition of industry and consider not only firms, but also other organizations like universities, research centres, and government agencies. The national character of the NSI is crucial for different reasons. First, military aerospace is an obvious national concern for security reasons, and since civil and military aerospace technologies are closely related, national governments have always been vigilant about the way technology evolves and about avoiding leakages to potential enemy countries. Second, the ever increasing and huge costs involved in the design and production of aircraft makes imperative the involvement of government financial support. These financial needs are so big that regional governments cannot fulfill them alone and should resort to national governments. Third, in terms of industrial development, the aircraft sector is seen as a high technology sector able to generate high revenues and technological externalities, thus it becomes a symbol of economic pride. Although this last situation can also be applied to the regional level, in general terms the techno-economic significance is so high that usually goes beyond the regions. Also, countries active in the aircraft industry usually involve more than one region on it, even if the level of activity is not levelled among them.

The tendency of aerospace activity to cluster is the main reason the regional dimension is important. Given this geographic concentration of the activity, national and regional governments usually deploy all relevant institutional support (like national research labs, universities, and incentives) in those specific areas. This creates a positive feedback effect because specialized workers gather in those areas creating a labour pool, which is one of the main attractor to aerospace clusters. Thus, even if national-created institutions are relevant, the concentration in specific areas and their subsequent reinforcement makes the regional dimension a pertinent analysis level.

The sectoral approach is relevant in the sense that different sectors exhibit differences in the way in which organizations interact. This is because these organizations have to master different technologies and face different market needs.

Given that the RIS and the SIS capture most of the insights of the NIS, we are going to concentrate in the first two. It is important to stress that these innovation system perspectives can be better understood by adding that actual ones can be either x-efficient or x-inefficient (Niosi, 2002a). First we are going to present the concepts of Regional Innovation System and Sectoral Innovation System and at the end a note about x-efficiency.

Regional Innovation System (RIS)

Cooke and Morgan (1998) assert that:

> "Regions which possess the full panoply of innovation organizations set in an institutional milieu where systemic linkage and interactive communication among the innovation actors is normal, approach the designation of regional innovation systems. These organizations can be expected to consist of universities, basic research laboratories, applied research laboratories, technology transfer agencies, regional public and private (e.g. trade associations, chambers of commerce) governance organizations, vocational training organizations, banks, venture capitalists, and interacting large and small firms. Moreover, they should demonstrate systemic linkages through concertation programmes, research partnerships, value-adding information flows, and policy action lines from the governance organizations. These systems combine learning with upstream and downstream innovation capability, and thus warrant the designation regional innovation systems."(p. 71)

This definition is much in the line of the National Innovation System concept developed by Freeman, Lundvall, and Nelson; and it stresses the process of learning, innovation, networks, and interaction among institutions. The emphasis is put in how those processes can affect the regional dimension.

The RIS is not defined in terms of industrial boundaries, in part because the concept itself does not explicitly explain concentration of certain activities, as the other concepts do. Thus, instead of looking at the aggregation industry level or associated industries, the question should be what kind of economic agents are included in the

RIS. As the definition suggests, there are clearly identified organizations (e.g. universities) that play a precise role in the innovation process (basic research in the case of universities). This absence of any element related to industrial boundaries deserves examination. For instance, is it possible for a RIS to foster innovation in several technological areas or just in one? Should these areas be related? Can the RIS specialize only in research and development activities and leave production to other regions? Some empirical evidence sheds light on these questions. Cooke et al (2004) use examples such as Catalonia in Spain, and Ontario in Canada. In these regional innovation systems, there are innovation institutions supporting several unrelated industries. In the same line, Niosi and Bourassa (2008) show how the larger metropolitan areas in Canada, Toronto and Montreal, were more industrially diversified than smaller ones, and were hosts to industries as diverse as pharmaceuticals, semiconductors, and software, in the former and aerospace, pharmaceuticals, health sector, and architecture services in the latter (p. 65). Thus, it seems that an RIS can nurture more than one industry, and that these industries do not have to be necessarily related. This view is reinforced by the assertion (Cooke et al, 2004: 8) that "regional, *sectoral* innovation systems are powerful forces in the new economic geography." The sectoral adjective is what makes the quote important. Other authors who reinforce this sectoral view are Niosi et al (2005), when they talk about Montreal as having regional systems of innovation in the aerospace industry as well as in the biotechnology sector.

Nevertheless one question arises from that sectoral perspective: can the RIS nurture different unrelated sectors? Or does each sector represent an independent RIS that coexists geographically with others? Trying to answer this question in a broad form is beyond the scope of this work, however, it seems that the latter is more plausible since, as we are going to see next, the supporting organizations and the learning that takes place in one sector are very specific to that sector. In this sense it is important to introduce the concept of sectoral system of innovation proposed by Malerba (2002).

Sectoral System of Innovation (SSI)

The concept of sectoral system goes beyond the traditional concept of industry and builds upon other industry-based approaches such as product life cycle and industry life cycle. A key difference is that sectors are framed by institutions (policies, regulations, incentives and supporting organizations).

Malerba (2002) defines:

> "A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. [It] has a knowledge base, technologies, inputs and an existing, emergent and potential demand. The agents composing the system the sectoral system are organizations and individuals...Agents are characterized by specific learning processes, competencies, beliefs, objectives, organizational structures and behaviours. They interact through processes of communications, exchange, co-operation, competition and command, and their interactions are shaped by institutions..."(p. 250)

Similar to the RIS, the SSI stresses the role of firms but also the role of other non-firm organizations like universities, as well as the policy environment. The importance of this sectoral approach is that all these firm and non-firm organizations are collaborating to nurture a specific product or family of products. How these products are defined, is not much developed in Malerba (2002). He asserts that interdependencies and complementarities define the real boundaries of a sectoral system, and that these may be present at the input, technology or demand (p. 250-251). He does not go in depth about how strong these interdependencies and complementarities should be in order to structure a system. This is in part because he recognizes that the system may evolve and with that, the different actors may also change. Indeed, Malerba (2002) talks about a sectoral system of innovation and production. Implicit is the idea that a production system may eventually become an innovation system, or a situation in which research organizations may give rise to production.

Regarding the geographical limits of an innovation system, the RIS is the one that puts more emphasis in this issue. Indeed, defining the "region" in the RIS context is a crucial issue in order for this concept to differentiate itself from the NIS, and to be considered more than just a lower analytical level. Cooke et al (1997) and Cooke and Morgan (1998) talk about two dynamic forces that shape the region: regionalisation and regionalism. The first "is the delimitation of a supralocal territory by a super-ordinate politico-administrative body, normally the state... [while the second] involves some form of devolved administration through, for example, a prefecture or delegated authority,... [it] involves political demands, 'from below', for often culturally defined territorial autonomy."(p. 64). Therefore, the spatial boundaries of the RIS are constantly developing, since these two forces are continuous socio-political processes. However it is to be noted that in Cooke the region is a province or a similarly large geographical and administrative area, while in Niosi et al (2005) the region is a metropolitan area. This may be explained by the fact that Europe has a bigger population density compared to the United States or Canada; moreover, in these last two countries people tend to concentrate in big metropolitan areas. Since the Mexican reality in terms of population density and human agglomeration is closer to that of the United States and Canada, the metropolitan area is going to be taken as the geographical unit of analysis.

In terms of the socio-economic dynamics characterizing the innovation system, Malerba (2002) stresses the fact that heterogeneous agents usually form communication networks precisely because by being different they can be complementary in terms of knowledge (p. 256). These interactions are shaped by institutions. A major point is that these institutions can be the result of both, the specific dynamics of the knowledge base of the sector, and/or the specific national institutions that apply for all type of activity (Malerba, 2002: 257). In more regional terms, both regionalisation and regionalism create a negotiated collective social order; which is the base for an institutional regulation framework that sets the routines, norms, and values that governs the relations between the different organizations involved in the RIS (Cooke and Morgan, 1998: 64)

Henceforth we are going to use the term innovation system (IS) when referring to one of these two concepts, and when specific reference to one of the concepts is needed we will indicate if we are talking about the RIS or the SSI.

It was Leibenstein (1966) who first put forward the idea that x-efficiency was a much greater responsible of output growth than allocative efficiency. This author mentions that "the simple fact is that neither individuals nor firms work as hard, nor do they search for information as effectively, as they could."(p. 407). Thus, this author explains that even if the firm (or for that matter a country) has the "right" resources (human and capital), it is not a guarantee that it will attain an "optimal" level of output. Among other elements, this is explained by the fact that not all factors of production are marketed, the production function is not completely specified of known (which eliminates the notion of "optimal"), and interdependence and uncertainty lead competing firms to cooperate tacitly with each other in some respects, and to imitate each other with respect to technique (Leibenstein, 1966: 407). In this sense, Leibenstein explains that x-efficiency has to do with improvements due to intra-plant motivation, external pressures and the capacity to trade inputs in imperfect markets. As examples of x-efficiency gains, Leibenstein stresses two main typical examples: first, the existence of similar firms in terms of resources and inputs, but with a great gap in terms of output production, and second, a firm that changes management (a resource not perfectively traded in markets) and has a sudden increase in productivity with the same resources in place. Therefore, comparison is a methodological way to apply and understand the notion of x-efficiency, which Niosi

(2002a) applies to the realm of innovation systems by means of benchmarking. In the same way that similar inputs can yield very different results in firms, Niosi (2002a) proposes that different innovation systems have different results due to the different level of development of their institutions. This author proposes that institutions can exhibit inefficiencies due to organizational inertia, badly designed contracts and information asymmetries (among organizations and employees), and lack of appropriate learning routines (p. 295). Moreover, sometimes the problem is not about getting efficient performance, but about getting the results that those institutions are supposed to pursue by mandate. When institutions do not reach the goals set by their mandate, they are x-ineffective (Niosi, 2002a). This study mentions how the development of R&D routines (a crucial activity in an innovation system) is underdeveloped in Mexico. In general terms, it can be said that Mexico is a slow learner innovation system because it already has in place some institutional measures that are supposed to support innovation, but overall output metrics reveal poor results in this area (see Section 2.7).

Porter's 'cluster'

Porter's (2000) definition of a cluster is:

> "A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities. The geographic scope of a cluster can range from a single city or state to a country or even a group of neighboring countries. Clusters take varying forms depending on their depth and sophistication, but most include end-product or service companies; suppliers of specialized inputs, components, machinery, and services; financial institutions; and firms in related industries. Clusters also often include firms in downstream industries (i.e. channels or customers); producers of complementary products; and specialized infrastructure providers. Clusters also often involve a number of institutions, governmental and otherwise, that provide specialized training, education, information, research, and technical support (such as universities, think tanks, vocational training providers); and

> standards-setting agencies. Government departments and regulatory agencies that significantly influence a cluster can be considered part of it. Finally, many clusters include trade associations and other collective private sector bodies that support cluster members."(p. 254)

The industrial boundaries of Porter's 'cluster' are not defined. In terms of industrial aggregation, Porter talks about companies and institutions in a particular field. At first glance, this cluster seems similar to the RIS, in the sense that both concepts include not just firms but also supporting institutions. The RIS pinpoints the "whole panoply of innovation organizations". Thus, the RIS focuses on organizations that can have a role in the generation of knowledge (such as universities and public research laboratories). Porter does not clarify what role these institutions play, except to say they are linked to companies by commonalities and complementarities. Therefore it is not clear what the role of these institutions is. Also, the words commonalities and complementarities seem to evoke either links among firms along the chain value of a given product, or cooperation of similar competing firms. Again, Porter does not clarify which is the case.

The spatial scope of the 'cluster' is completely open. As Porter admits, the cluster can be as big as a country. Setting geographical boundaries for innovative or productive economic agglomerations can be a very difficult task, and Porter foregoes tackling that issue.

Porter does not develop the analysis of regional externalities. Instead Porter (2000) argues for some economic spillovers somewhat similar to traditional Marshallian agglomeration advantages. He mentions the access of specialized inputs and employees, access to information and knowledge, complementarities (i.e. product complementarities), and access to institutions and public goods. It seems that Porter (2000) assumes that spatial proximity is the main ingredient for obtaining these advantages, because he does not develop any concept related to learning. A socio-economic factor that Porter advocates is that clusters tend to reduce opportunism problems, much in the line of the transaction cost school. The argument is made mainly for the vertical integrated firm in the sense that by locating most of its operations in one place, information about the different units will be more readily available and this could prevent some kinds of opportunism, such as principal-agent problems.

According to Porter (2000), another benefit of the cluster is innovation and new business formation. The main reason for this is that firms in the cluster can perceive more rapidly new opportunities due to proximity to leading firms. Porter's cluster explanation is an extension of his diamond of competitive forces that determines the competitive advantage of nations (Porter, 1990). The diamond is composed of firm strategy, structure and rivalry; factor conditions; demand conditions; and related and supporting industries. Porter (1990) argues that if these forces are closely located they can bring competitiveness to their members. Porter assumes that these forces are equally important for all industries.

Martin and Sunley (2003) strongly criticize Porter's cluster concept. Regarding industrial boundaries, these authors stress the ambiguity of the limits based on a "particular field". They argue that Porter does not explain if the firms in the cluster are big or small, or their degree of specialization. As for the relation between the firms in that "particular field", Porter includes downstream and upstream industries, and the way to set boundaries depends on the strength of the spillovers these industries have with the firms in the "particular field". Martin and Sunley highlight that Porter does not provide any explanation about how to measure the strength of these spillovers. The geographical boundaries issue is another aspect of which Martin and Sunley are very critical. Assuming that the advantages of clustering can be gained no matter how far away the participants are located from one another is a serious weakness of the concept, and we should say that this is also a weak issue in the other concept we have seen. Regarding the socio-economic advantages of the cluster, Martin and Sunley argue that Porter places more emphasis on the kind of institutions that made the cluster and not too much on the way in which they actually interact. As Cooke (2001) explains, in some real cases there is a whole set of organizations present in a cluster, but the cluster is not as successful as others with a more reduced set of supporting institutions.

1.1.2. The agglomeration concepts and aerospace clusters

The objective of this section is to assess the relevance of the reviewed concepts for the aerospace industry. The first question is why aerospace industries agglomerate. Since aerospace is a high-technology sector, it requires very complex and specialized inputs and resources. Therefore, it is expected that the scarcity of these resources makes them agglomerate in just certain geographical areas. However, although aerospace shares some characteristics with other high-technology sectors, it has very specific features. Moreover, the agglomeration forces may not be the same for all aerospace clusters. As Martin and Sunley (2003) suggest, a good starting point is to evaluate industrial boundaries, geographic scope and socio-economic dynamics in the cluster.

Industrial Boundaries

As it was shown, not all the concepts are well defined in terms of their industrial boundaries. The concepts that have a clearer definition are the 'industrial district' with its "homogeneous product", the 'anchor tenant' with a "technological area", and the IS with "products for specific uses", and the 'growth pole'. Conversely, the 'cluster' is the least defined concept in terms of industrial boundaries. The 'growth pole' claims that the ability for an industry, or for that matter a firm, to drive others is what makes that entity an engine, and therefore the place where the engine is located becomes a growth pole. How much force is needed for an industry or a firm to be considered an engine is not a well-developed issue in Perroux. Porter 'clusters' are defined by the even less clear term of "particular field", and the limits of that particular field are set by the strength of the spillovers between the participants industries and organizations; assessing that strength is what makes the industrial boundaries of the concept a blurred issue.

The type of firms and range of related or associated industries that should be included in the concepts are also different. The 'industrial district' is supposed to be composed of small firms, highly specialized in one productive stage of the final homogeneous product. Therefore, the very nature of the firm in the district makes it dependent and/or complementary to the others. Such a high specialization would not be feasible if the firm was isolated. Nevertheless, the mere condition of high specialization does not necessarily imply cooperation and co-location with others. It seems that the tacit component of the craft-like traditional products made in the paradigmatic Italian industrial districts, is what allows this kind of arrangement. However, when more large and bulky products are involved, the "growth pole" is better suited to explain agglomeration. By the volume of its inputs and outputs, a big firm serves as a pole of attraction for several smaller supplier and client firms. Moreover, the engine firm or industry can even create the seedbed for new industries dependent on the operations of the former. As it was shown, Perroux did not develop this issue in depth, but his contribution was to highlight the power of the big firm to shape its landscape by means of its inputs and outputs and by innovation. In a more innovation-focused approach, the regional RIS concept tries to uncover how firms and organizations form networks to collaborate in innovation projects. These networks can be formed by a different set of arrangements ranging from the existence of a big firm dominating small ones to the existence of multiple small firms without any hierarchical relationship. Also, the way in which the government interacts with these networks can vary greatly from direct intervention to only providing support. Therefore, what matters is that local networks do foster learning among participants. The anchor tenant concept is developed in more detail and more clearly explains how the big R&D firm is able to create the necessary conditions for suppliers, universities and related R&D organizations to establish a capacity that would not be possible without this anchor tenant. The main difference with respect to the growth pole is that the anchor tenant attracts others by means of the knowledge it generates or requires, and not mainly by the physical inputs and outputs it spawns. For instance, the anchor tenant can be a university. This is more likely in the early phases of a technology that heavily depends on university research, like biotechnology (Feldman, 2003) or renewable energies in which an interesting example is Strathclyde university in Glasgow, Scotland, where important firms around the world involved in wind and tidal turbines have set up research centres and manufacturing facilities to benefit from the high impact research done at that university[3]. In general, it can be said that some IS arrangements can include an anchor tenant as an actor that significantly determines the dynamics of the system. Indeed, anchor tenant proponents claim that such a firm enhances IS productivity by increasing the local university research/industrial R&D productivity. Both, the anchor tenant and the IS are defined in a learning context, although the former is explicitly addressed to high technology, while the latter is somehow open, and even some of the empirical works address industries that are not characterized by a high-tech context. Porter's 'cluster' specifies neither the degree of specialization of the firms that integrate the cluster, nor the size of the firms involved. It seems that the 'cluster' is open to any type of firm and productive arrangement. In table 1.1 we summarize all the agglomeration concepts.

---

[3] The Economist. 2011. "R&D in Scotland: Green rush", *The Economist*, February 17. Retrieved from: < http://www.economist.com/node/18178477>

Table 1.1

Agglomeration concepts

Concept	Industrial Boundaries	Geographical Scope	Dynamics	Authors
Industrial Districts	- large number of small firms - homogeneous product	- Small area - 10,000 – 20,000 workers - 1,000 – 3,000 firms	Market and non-market exchange of: - goods - information - people	Brusco (1990) Becattini (1990)
Growth Pole	- Engine firm (big multinational)	- Urban area	- input-output links - investment	Perroux (1982)
Anchor Tenant	Large firm: - R&D engaged - absorptive capacity in a particular area	- Metropolitan area (that allows face-to-face contact; tacit knowledge)	- absorptive capacity - tacit knowledge - knowledge spillovers	Agrawal and Cockburn (2003) Feldman (2003)
Regional and Sectoral Innovation System	- knowledge-producing organizations - Big and small firms - Technology support agencies	-From below: cultural identity -Form top: administrative authority	- A consistent pattern of communication between the parties should be promoted	Cooke and Morgan (1998) Malerba (2002)
Cluster	-companies and institutions in a particular field	Can be as big as a country	Access to: specialized inputs, employees and information Reduction of opportunistic behavior	Porter (1990, 2000)

In terms of industrial boundaries for aerospace, the first step is more or less clear: every firm that makes some component for the aircraft [IS: products for specific uses] or that helps build it can be considered an aerospace firm.[4] The aerospace pyramid classifies all these aerospace firms[5] in layers, the highest of which consist of the systems integrator, the most important firms in the industry [Growth Pole: Engine firm]. On the contrary, when firms are low on the pyramid, such as parts suppliers, their aerospace activities tend to be combined with participation in other industries[6]. For practical reasons, in this thesis every firm that produces aircraft parts is going to be considered as an aerospace firm. Also, as it is explained in section 4.2, regional promotion offices in Mexico have updated lists of aerospace firms.

---

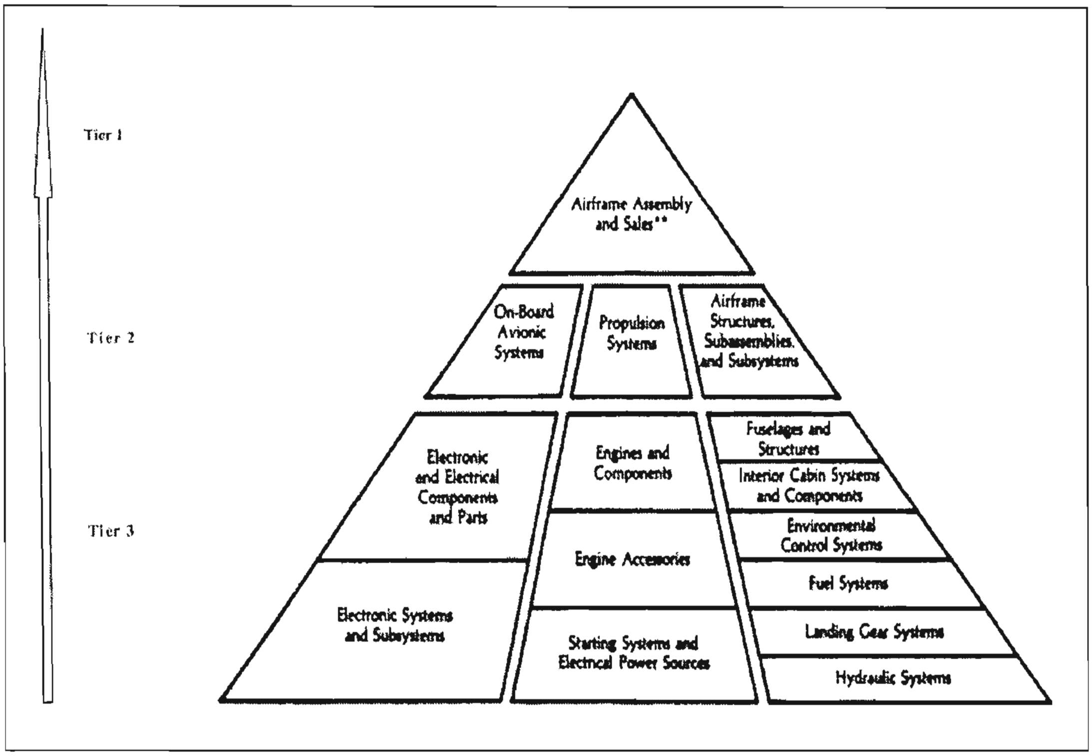
[4] The difficulty comes when a firm's activities pertain to sectors in addition to aerospace. This situation is common to metal shop firms that are usually suppliers to a range of industries.

[5] It is important to note that not just small suppliers, but also Tier 1 and Tier 2 firms are involved in other sectors besides aerospace. For instance, Bombardier is involved in other transportation markets like trains, while General Electric has a wide range of products outside of turbines, like electro domestics. However, most of these firms have clear aerospace divisions.

[6] For statistical reasons firms are classified everywhere every year according of the most important product or services (in terms of sales) SIC or NAICS codes, thus, smaller firms may be reclassified regularly depending on the sector they produce components for.

Figure 1.1

The producers' pyramid



Source: Niosi and Zhegu (2005: 8)

The second step is not as clear. There are at least two ways to classify aerospace firms: by their tier position (see figure 1.1); and by the type of aircraft to which their activity is targeted. In this sense, both Toulouse and São José dos Campos have a system integrator which is in the top tier – Airbus and Embraer respectively; but, Toulouse and Everett have system integrators for more than 100-seat aircraft, while Montreal and São José dos Campos have system integrators for regional and business jets, and Wichita is the home of several business jets system integrators. Moreover, some clusters like the Montreal one, have system integrators in different segments, thus additionally to Bombardier, Montreal has Bell Helicopter.

There are two additional aspects that must be considered when characterizing clusters according to the nature of firms located within them. The first is that the existence of a system integrator is not a predictor of a specific set of other tier or complementary firms in the cluster. In Montreal there are more firms dedicated to different parts of the business and regional jets than in São José dos Campos, even if both clusters are specialized in such smaller jets (Goldstein, 2005). Moreover, the existence of different firms dedicated to different parts in the same cluster does not strictly translate into collaboration between them. The decision to collaborate depends on technological or business strategic issues and not so much on geographical proximity. According to Goldstein (2005), Bombardier executives declared that if necessary, they could seek complementary firms elsewhere in the world. Thus they do not feel constrained by "local availability". This view is reinforced by the assertion made by Niosi and Zhegu (2005) that international spillovers are commonplace in the aerospace industry. Furthermore, Niosi and Zhegu (2010) provide examples in which some system integrator firms are more likely than others to act as anchor tenants of their respective clusters. The intensity on R&D activities seems to be the element that set apart system integrator firms that act as anchor tenants. For instance, Niosi and Zhegu (2010) show how the acquisition of Learjet (located in Wichita, Kansas, US) by Bombardier, meant the transfer of R&D activities to Montreal; deprived from

R&D-intensive activities the system integrator is no longer able to exert the function of anchor tenant as it used to (p. 272).

The second aspect is the fact that there are clusters in which tier 2 companies, such as engine manufacturers and not tier 1 aircraft integrators, are the prominent firm in the cluster or the anchor tenant, as is the case with General Electric in Cincinnati. As it is going to be explained in section 1.2.2, it is important to highlight that the different modules that made up the aircraft can be produced in different parts of the world, because aircraft – conversely with automobiles – are produced in shorter numbers

According to the above explanations, the aerospace cluster structure exhibits characteristics that make them akin to the growth pole, anchor tenant and, in some instances, the IS. First, the big firms that tower above aerospace clusters are indeed engines in the place where they are established, as the growth pole suggests. The huge investment in facilities and personnel, and the high added value of the activities have a huge impact in the zone. The presence of that large firm also represents the possibility for specialized suppliers to emerge. Second, like the anchor tenant concept suggests, these specialized suppliers may be the result of employee (and as a consequence, knowledge) mobility from the anchor to other firms in the area. In this sense, not only may specialized suppliers benefit, but competitors and other subsystem integrators benefit from the recruitment of former workers of the anchor tenant firm. Therefore, the structure of aerospace clusters seems to be heavily influenced by the presence of an anchor tenant. Third, government support is crucial to this industry, thus, as the IS concept highlights, institutional patterns of communications and collaboration are present in aerospace clusters. Nevertheless, the financial and political support that this industry needs is so vast that institutional support usually comes from the national and not just from the regional level.

Spatial Scope

In terms of geographical scope, the 'industrial district', but specially the 'growth pole', and 'anchor tenant' include at their core a city-like region, but this area can also cover its outskirts, what is called in North America the metropolitan area, usually containing several neighbouring cities. This will depend on the connectivity of the outskirts of the metropolitan region with the central city. The existence of efficient transportation systems and infrastructure that allow the movement of people (and with them their ideas) in relatively short periods of travel is what delimitates the influence area of an engine firm or an anchor tenant. The 'cluster' does not specify its geographic limits, although sometimes these seem to be either metropolitan or provincial. The RIS is the more ambitious in its conceptualization of "region", by identifying regionalization and regionalism forces as the driving forces that shape the region. In this sense, both the RIS and the 'industrial district' consider socio-cultural and historical factors that shape the region. Nevertheless, in the empirical works on regional innovation systems (perhaps for practical reasons like available statistics), the regions always match certain existing administrative demarcations such as metropolitan areas (regionalization).[7] This is somewhat problematic since these administrative regions can vary greatly, from country to country, in size and in their degrees of integration with the so-called national economy and international economy.

In terms of geographic scope, limits are also a difficult issue in aerospace. The works of Beaudry (2001), Smith and Ibrahim (2006) and Cooke and Ehert (2009) are very revealing of this respect. According to the second authors, there are five aerospace

---

[7] It seems that Cooke and Morgan (1998) develop a dichotomy between regionalization and regionalism inspired by the European experience, in which historical regional identities have developed and preserved themselves over centuries. Even if this phenomenon can have some parallels in other parts of the world, as it surely does, I am not sure that it can be applied to all regional economic phenomena in the world.

clusters in the UK (they cite as a source a 2001 report from the Department of Trade and Industry): North West, South West, East Midlands, North Ireland, and Wales (pp. 362-363); yet Cooke and Ehret (2009) argue that there are two aerospace agglomerations in Wales alone, one in the north and one in the south (pp. 554-555). To make matters more complex, Beaudry (2001) in her study of cluster effects on aerospace firms' growth, proposes counties as the relevant regional dimension. [8] This author identifies 5 counties in Wales –Clwyd, Powys, Mid Glamorgan, South Glamorgan, and West Glamorgan- with aerospace activities (p. 434), from which only three –Clwyd, Mid Glamorgan, and South Glamorgan- were identified as having a strong fixed effect (pp. 417, 436), thus, presumably considered as clusters.

None of the authors mentioned, made completely clear why they chose a particular geographic unit. It seems that the criterion followed by Smith and Ibrahim (2006) is based on broad regional political administrative divisions[9] (Wales is in itself a country) that ultimately may have the political and economic resources to support clusters. In the case of Cooke and Ehert (2009) it seems that their choice is based on mere geographical proximity[10]. Since these authors are concerned with learning and local systems, it may be that they consider proximity as a condition to interact. For Beaudry (2001) the approach is different. This author does not assume clusters as given. On the contrary, she explored which of the counties do have a positive impact on firms' growth. Once that exercise done, just some of the counties were identified as having a fixed effect. In the description about how Montreal came to be an

---

[8] Beaudry (2001) uses the European NUTS (Nomenclature des Unités Territoriales Statistiques) as the geographical unit. According to this author the UK had 65 NUTS at level 3 (the maximum disaggregation level), and for Wales alone, the number is of 8, from which 5 had aerospace firms.

[9] Smith and Ibrahim (2006) explain that if "[a] region had more people employed in that industry [in this case aerospace] that one would expect given the size of the region in terms of its labor force" it can be considered a cluster in that industry (p. 362). Nevertheless, how the regions are pre-defined has an impact on final results. In this case it seems that the whole of Wales was taken as a region, and as such it prevented further divisions within Wales itself.

[10] Cooke and Ehret (2009) do not give an extensive explanation for their claim of two agglomerations. Instead, they show a map of Wales in which the agglomerations are visually identified.

aerospace cluster and later an aerospace regional innovation system, Niosi et al (2005) adopt the metropolitan region as a unit of analysis. At the same time, he recognizes both national and provincial government (outside the metropolitan area) intervention to foster innovation in Montreal.

As Niosi et al (2005) stress, one of the main agglomeration forces at play in the case of aerospace is specialized labour. Thus, it seems that the scope of the cluster has to be delimited in some way by the possible mobility (or absence of mobility) of this specialized work force. In this sense, the metropolitan area may provide an adequate geographical scope for clusters in aerospace. Therefore, an important question in the case of Mexico is to understand what the most important agglomeration forces at play are, and see if they are strong enough to claim that a cluster even exists. Perhaps a mere collection of firms within a state or a metropolitan area, operating in the aerospace industry is not a sufficient condition for a region to be called a "cluster".

Socio-economic dynamics

All these concepts claim that spatial proximity is a necessary condition to develop socio-economic dynamics that gives regions an advantage. It is important to remark that knowledge generation lies beneath sustainable advantages. Therefore, it is important to know who generates the knowledge; what kind of knowledge is generated; and how knowledge is generated and transferred to others. The industrial district is not completely clear in this respect. It seems that the firms connected with the final international markets are the ones in a better position to be knowledge generators and disseminators. In this sense, the cultivation of craft-like tacit capabilities coupled with marketing tendencies are the type of knowledge that is important for this industrial arrangement based on traditional products. This implies both cooperation and competition, since firms are dependent on each other in order to bring the final product to the market. Some say that a social network locally rooted underlies that kind of arrangement. In some ways, this situation resembles the

Marshallian labour pool and the "atmosphere" in which the secrets of the trade are in the air. The industrial district concept is mainly concerned with relationships between firms. This is because firms are the main actors in traditional products. However, when it comes to more complex and high tech products, other actors are important as well. For this reason, the IS approach puts the accent on relations not just between firms but also with other organizations. Different sectors exhibit different characteristics in terms of innovation, but in general it can be said that organizations like universities and research laboratories are agents with a central role in the generation of knowledge. Also, government agencies are responsible to encourage innovation activities by means of fine tuned policies and measures. There can be several ways in which firms and other relevant agents interact to generate knowledge. The important point of the IS approach is that firms do not innovate in isolation; there are other agents that participate in the innovation process, whether by directly creating knowledge or by supporting innovation-lead activities of firms. Therefore, the IS perspective analyzes the institutional pattern of communication between relevant organizations. As it was mentioned, the IS theory recognizes several ways in which actors communicate and transfer knowledge. However, in the case of high-technology sectors, there are usually critical agents involved in the generation of this knowledge. Big firms like the ones described in the growth pole are the ones that dominate some of these sectors and generate most of the knowledge in the cluster. While Perroux does not make an in-depth exam of how knowledge is created by these firms, he certainly recognized that these engine firms can create the conditions for new industries to emerge.

The anchor tenant concept – that in Agrawal and Cockburn also makes reference to a big firm - goes into more detail about how that firm creates and affects the flow of knowledge in its surroundings. Agrawal and Cockburn (2003) argue that the anchor tenant firm is able to raise the level of the RIS by means of localized knowledge spillovers. The mere fact that a firm – or a research university or public laboratory in some cases such as biotechnology, according to Markusen and Feldman - has R&D capacity opens the possibility that former employees can move out of the firm and apply elsewhere some of the knowledge acquired in the anchor tenant firm. This is in line with the labour pool agglomeration proposed by Marshall. Of course, here there is the assumption that specialized people tend to be attracted to and remain in the same geographic place. Another advantage of the anchor is that it attracts specialized suppliers by means of its sophisticated demand and large volume. Since technology-intensive supplies and products have tacit knowledge characteristics, being located nearby can help to facilitate interaction. This argument is not without problems. According to Breschi and Lissoni (2001), much of the allegedly localized knowledge spillovers are in fact market transactions that do not depend too much on spatial proximity. These authors criticize the quasi automatic localized knowledge spillovers version which is usually expressed in studies that address the impact of external R&D (especially public and/or academic) on private firms' innovative capabilities. The 'anchor tenant' approach does not make the localized knowledge spillovers assumption, instead it shows the way in which university research is collocated with industrial R&D, but without making a claim in the causality. Also, Agrawal and Cockburn (2003), do not portray external university/public research as a substitute of industrial R&D. Indeed, one of the tenets of the concept is that the anchor tenant may be able to influence public research by means of its own research ability. For Porter, spatial proximity is the main driver of information and knowledge sharing. He advocates agglomeration economies and the reduction of opportunistic behaviour as the main advantages of proximity. Thus, this author suggests the traditional transaction-costs explanation in which the frequency of transactions and dependency on each-other will diminish the opportunistic behaviour of the parties, and this situation will lead to cooperation and competition. Martin and Sunley (2003) criticize this explanation as overly simplistic. While it is true that in some cases co-operation is a plausible behaviour, there are cases in which it is not necessary and can be even be detrimental to firms. Therefore, locating next to a competitor or a supplier is a matter that should be analyzed as a strategic issue instead of deciding *de facto* that collocation involves cooperation. Sometimes collocation could serve to imitate or to steal ideas and workers. It seems that in many instances closeness is not a decisive factor in diminishing opportunistic behaviour.

Marshallian agglomeration forces, the growth pole, the anchor tenant and the RIS contain elements that help to explain knowledge dynamics in aerospace clusters. In this industry, big firms are the ones that generate critical knowledge, and often demand for specialised parts, components and services. Like the growth pole perspective suggests, these firms have the power to influence the way in which knowledge is created, and are giant magnets of other firms. Indeed, in the aerospace sector, big leading firms are the major repositories of crucial knowledge. Moreover, like the anchor tenant suggests, these firms are able to influence suppliers and research laboratories by means of their sophisticated demands. According to Niosi et al (2005), Bombardier was a crucial factor for the introduction of aeronautics engineering degrees in local universities. The same seems to be true in Washington State where universities are under the influence of Boeing. The pool of specialized labour is another characteristic of the aerospace sector, pretty much in line with Marshall. On the other hand, contrary to collocation for cooperation (as is suggested in the industrial district and Porter's cluster), it seems that cooperation in the aerospace sector is not limited to proximity. As we have seen, a great deal of the interactions takes place outside of the cluster (Niosi and Zhegu, 2005). Smith and Ibrahim (2006) and Cooke and Ehret (2009) also stress the fact that a good deal of the interactions of cluster firms occur with out-of-cluster firms. The way in which these interactions occur has a lot to do with the corporate strategies of leading firms. One major feature of Niosi et al (2005) is that they pay attention to interaction not just between firms, but also between other organizations like universities and research centers. Thus, the RIS has some elements that help to explain how other organizations support the creation of knowledge in the firms. In particular, Niosi et al

(2005) explain how the national and the provincial governments have set-up policies to create research centres and to fund the costly development of new planes.

Finally, recent work by Giuliani (2007) underlines the fact that within the same cluster, knowledge can be very unevenly distributed. If the secrets of industry are in the air, some companies seem to breathe a more healthy air than others; large firms usually have more information and better quality information than smaller firms in the same cluster. Such intra-industry differences depend on the absorptive capacity of the firms, and this on R&D capabilities and size (Cohen and Levinthal, 1990).

Giuliani (2007) makes a distinction between business networks and knowledge networks. The former are the normal links that a firm establishes to exchange inputs and outputs, while the latter are channels by which knowledge may flow. Although business networks can indeed be the carriers of knowledge, Giuliani (2007) shows that this is not always the case. From the policy point of view it is important to distinguish between these two networks. As we are going to see in section 1.3.3, policy should pay attention to those links that carry on knowledge that could lead to innovation, and not only to business links. Moreover, this explanation implies that only certain firms are able to absorb external knowledge. Giuliani and Bell (2005) call these firms technological gatekeepers because they are the intermediaries between external knowledge and cluster's firms with less developed absorptive capacity. In this sense, an aerospace anchor tenant is expected to act as technological gatekeeper, and as such it is important that an aerospace cluster promotes the development of those types of firms.

In the next section we are going to present a technology transfer cycle based on the product life cycle industry life cycle theory to understand what are the activities more likely to be transferred to Mexican clusters.

1.2 The civil aircraft manufacturing industry's technological trajectory

Introduction

The civil aircraft industry is constantly changing. Changes occur at various levels. At the technological level it is clear that the knowledge base underlying the aircraft as a product is experiencing important technological changes like the introduction of new materials (ultralight alloys, composites), propulsion systems with a high bypass ratio, and the massive use of digital electronics for the instruments of the aircraft (Esposito, 2004: 453), even though these changes might be considered incremental by some (Kehayas, 2007). These changes have allowed an important increase in performance regarding fuel saving, reliability, safety and speed (Esposito, 2004: 453). Also, these new technological developments have implications at the organizational level on which firms seek ways of coordinating the ever increasing exchange of knowledge within and among different organizations (Brusoni and Prencipe, 2001). The increasing importance of some of these parties and the emergence of new actors in developing countries have an impact at the industrial structure level, where there have been numerous collaborations and joint ventures among a series of relevant players in the industry, not seen in previous decades (Mowery and Rosenberg, 1985; Niosi and Zhegu, 2005).

As it will be argued in this section, the changes noted above have very important implications in the localization (or delocalization) of the different activities pursued by different firms in the industry. According to Niosi and Zhegu (2008), the Product Life Cycle (PLC) theory coupled with the Industry Life Cycle (ILC) Theory, developed originally by Vernon (1966) and Klepper (1997) respectively, can be useful for understanding some dimensions of the internationalization strategies followed by relevant firms in the civil aircraft manufacturing industry. In this sense, the aim of this section is to show how the PLC and the ILC coupled with concepts pertaining to innovation (the concept of technological trajectory, and its underlying knowledge base) and management (modularity) research streams, can explain the current delocalization processes in aircraft manufacturing. The emphasis is on newcomer countries like Mexico with no previous capabilities in that industry, which can be considered net technology receivers of the internationalization trend.

Many countries like Argentina, Indonesia, South Korea and Turkey, have attempted to nurture the aerospace industry within their borders (Zhegu, 2007: 221). Most of these attempts have resulted in failure or limited success. Understanding the knowledge base dynamics beneath the technological trajectory of this industry is crucial for national governments to have a more complete idea of the economic and institutional infrastructure needed to support this industry. Ultimately, an assessment of the civil aircraft manufacturing PLC and ILC is needed to be realistic about the degree of development that newcomer countries like Mexico can achieve.

The rest of this section is structured as follows: section 1.2.1 briefly describes the main tenets of the ILC-PLC and some of their extensions. Section 1.2.2 by means of four concepts describes the aircraft as a technological artefact with very idiosyncratic characteristics. Section 1.2.3 integrates the notions of the previous two sections, and it explains how the very nature of the aircraft and the firms' internationalization strategies in that industry limit the type of activity that can be expected to be found in newcomer countries like Mexico.

1.2.1. The ILC-PLC and its implications for delocalization of industrial activity

The goal of this section is to present the main elements of the PLC theory and ILC. Pioneered by Vernon (1966), PLC theory is concerned with the location decisions of firms as depending on the particular stage of the product in the PLC – new, maturing, or standardized. In the first stage, a firm will be more likely to establish production facilities in the market it originally tries to serve. Even if there are other potential production locations apparently more cost efficient (once taken into account transport, inputs and other operative costs), the decision to undertake production near the intended market is based on communication opportunities and external economies (p. 194). According to Vernon (1966), in the early stages of introduction of a new product, it can be un-standardized for some time requiring changes in inputs, processing, and final specifications (p. 195). In this sense, the ability to change inputs, more than lower its price, is crucial to capture market share; this is also possible by the low price elasticity of demand typical of new products, that allows charge of a high price without much loss in demand; all this requires a good deal of communication between customer, suppliers and even competitors, that is achieved by locating production near the firm (Vernon, 1966: 195). In terms of the industry structure, Klepper (1996) argues that in this first stage the entry of new firms rises, and the most recent entrants account for a disproportionate share of product innovations (p. 564-565).

In the maturing stage of the PLC, some processes of production of the product begin to standardize, with consequent effects on scale economies by mass production, and the consideration of minimum production costs (Vernon, 1966: 196). Also, market and design uncertainties decline. In terms of the industry structure, the number of new entrants decline, the leadership of the industry stabilizes and firms are busier in process than in product innovation (Klepper, 1996: 564-565).

Going back to Vernon, he proposes that in the mature stage, if demand for the product has increased in foreign markets, firms begin to consider serving markets outside their home country. In a strict sense, this opens the discussion of internationalization because, for the first time, the firm (that already developed and produced a successful product in its home market) has the possibility of establishing operations in other countries. According to other internationalization authors like Caves (1971) and Hymer (1976), at this point firms have acquired specific-assets, which can be exploited in other markets. The eclectic OLI (Ownership, Location and Internationalization) paradigm developed by Dunning (2000) refers to these specific-assets as an ownership advantage. Caves (1971) argues that those specific-assets are built by means of product differentiation, which means that they operate in an oligopolistic market in their home countries. This is in line with the argumentation of the ILC, which claims that in the standardization phase, scale economies take relevance and some firms are driven out of the industry; an event that is known as the shakeout (Klepper, 1996). However, Klepper (1997) shows that there are some industries in which the shakeout does not occur. He explains that the PLC does not take into account that as the product moves along its cycle, specialization due to learning, might lead to a division of labour within the industry. Therefore, the design, manufacturing and marketing of the product usually is not done by the same firm. Based on that idea, Bonaccorsi and Giuri (2000) argue that this division of R&D (both for product or process), manufacturing and marketing impedes the possibility of appropriability (of R&D results) and increasing returns which makes difficult to erect entry barriers. Thus, on one hand internationalization authors agree that in the standardization stage there is an ownership advantage that the firm can exploit elsewhere, but on the other hand, the industrial structure authors comment that there can be many structural arrangements, and as such the way in which this delocalization takes places may also vary.

The decision to go international can be essentially made in three ways: exporting, licensing or establishing foreign subsidiaries. Vernon (1966) does not provide a definite answer as to which of these three modes is preferable. He asserts that cost considerations and scale economies definitely play a role in this decision. Caves (1971, 1982) argues that if the knowledge about the specific-assets is intangible by nature and refers to organizational procedures and marketing abilities able to differentiate the product, the firm is more likely to establish its own subsidiary in foreign markets because of the difficulty to transfer that kind of knowledge. Regarding location characteristics, Dunning (1981: 27) explains that "the larger the number and the greater the differences between economic environments in which an enterprise operates, the better placed it is to take advantage of different factor endowments and market situations." It means that the ownership-advantages gained by firms in their home countries can be better exploited in settings different from the home country. In a similar lane, Kuemmerle (1997) developed a typology about R&D subsidiaries:

> "the home-base-augmenting site –is established in order to tap knowledge from competitors and universities around the globe; in that type of site, information flows from the foreign laboratory to the central lab at home. The second type of site, home-base-exploiting site- is established to support manufacturing facilities in foreign countries or to adapt standard products to the demand there; in that type of site, information flows to the foreign laboratory from the central lab at home."(p. 62).

This typology recognizes that the main locus of innovation is the home base site; although R&D subsidiaries can also contribute to the enhancing of home-created advantage and not just to the adaptation of technology to foreign markets. However, Niosi (1999: 114) points out that new realities show that expatriate R&D units can have different mandates that go from acquiring new technologies to sustaining existing core technologies. This author explains that the mandate of a specific expatriate R&D unit may depend on technologically strategic issues like for instance the differences in technology inputs in the home and host country, but also on other factors not much strategic in terms of technology, like the acquisition or merger with firms that have R&D units. The point we want to stress is that even if R&D in the home country is important in creating an original advantage in a firm, the sustaining of this advantage or even the creation of new ones, can potentially rely on the firms' expatriate R&D units.

Going back to the original PLC-ILC line, it suggests that once the product reaches the standardization phase (Vernon, 1996) an industry shakeout occurs and the leaders reinforce their position (Klepper, 1996) and gain valuable specific-assets (Caves, 1971, 1982) or ownership advantages (Dunning, 2000) that can later be exploited in other markets (Vernon, 1996; Dunning, 1980), although in some instances other markets provide a way to extend those advantages too (Kuemmerle, 1997). According to these authors the way in which internationalization should be done is not a simple decision because it depends on the differences in the home and foreign location and in the way in which that foreign location can be a way to advance capabilities. Thus, the delocalization decision may not necessarily by the most economically "efficient" in the short run. As we saw above, under the framework of the ILC, that internationalization decision should also be dependent upon the particular labour division within the industry in the home country and the foreign country industry structure. This is a very important issue since the aircraft industry displays a labour division among firms and among countries.

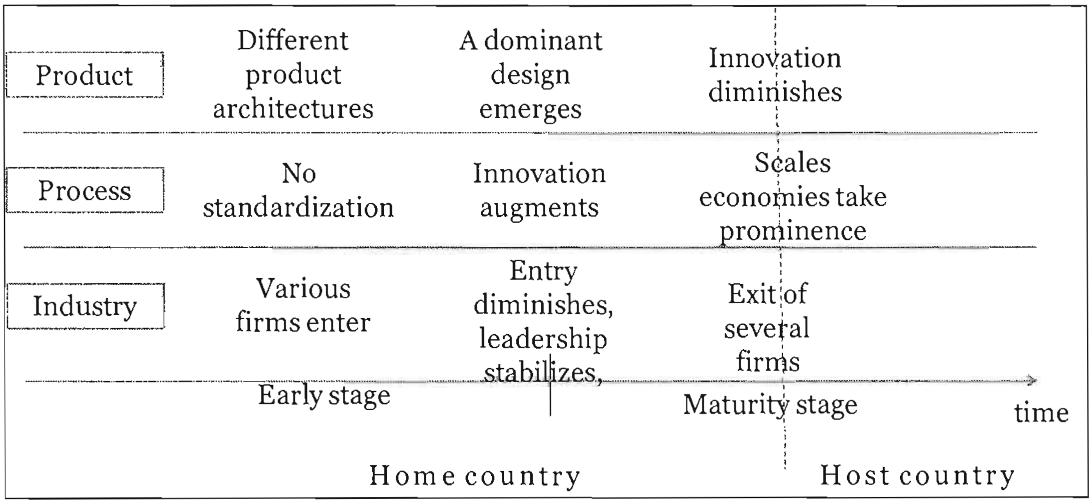
Following the reasoning line of Vernon (1966) when the product is standardized:

> "...foreign investors seeking an optimum location for a captive facility may not have to concern themselves too much with questions of market information; presumably, they are thoroughly familiar with the marketing end of the business and are looking for a low-cost captive source of supply."(Vernon, 1966: 203)

It is at this point that Vernon acknowledges that developing countries can play a role in the internationalization decision. Before this, all considerations pertained more to firms in developed countries serving the markets of developed countries. Figure 1.2 illustrates the main tenets of the PLC-ILC presented so far.

Figure 1.2

Representation of the PLC-ILC theory



Vernon (1966) also acknowledges the possibility of a decomposition of the production activities, situation that will allow firms to locate different parts of this process at different sites. Thus, even if the product is well standardized, in some cases its production process can be divided in information-intensive, thus expensive operations, and low-cost operations. This division allows for a good number of possibilities of productive arrangements that Vernon did not analyze in depth. Other pioneering authors in internationalization studies inspired by the product life cycle approach, like Knickerbocker (1973), Ronstadt (1978) and Fagre and Wells (1982) propose a richer scenario of possibilities.

Knickerbocker (1973) explains that the delocalization process described by Vernon is driven by strategic issues and not just by cost reduction considerations. Paradoxically, contrary to the assumption that delocalization of production is a process driven by a reduction of uncertainty in the architecture of the product; establishing activities overseas implies a high degree of uncertainty about the local environment (Knickerbocker, 1973). This author argues that a lot of rival firms follow the steps of leader firms when going overseas. Given the uncertainty about the advantages and obstacles that foreign locations may provide, once a leader firm takes the decision to go to a specific location, rival firms cannot afford to lose the potential advantages. If the location turns out not as promising as it seemed, at least all firms will face the same fate. Therefore, except for the first-mover firms, the majority of firms delocalizing activities do so more as a defensive move than as a carefully planned strategy. Knickerbocker (1973) calls this move the oligopolistic reaction, because it is observed in oligopolistic producer structures in the home countries. It is important to recall that the aerospace industry is oligopolistic, at least in aircraft integration, as well as in major subsystems, such as engines, avionics, and landing gear.

If the oligopolistic reaction is the impulse behind much of the delocalization strategies followed by firms towards newcomer countries, the way in which this strategy actually takes place depends also in the home country. When talking about the relationship between host governments and foreign firms, Fagre and Wells (1982) analyzed some factors that could influence the degree of ownership of the foreign firm's subsidiary (with the assumption that normally, foreign firms prefer to have complete ownership over their subsidiaries, and host governments prefer to have a capital mix arrangement). Among those factors, the access to export markets is relevant for our study purposes. These authors argue that usually foreign firms took a high share of ownership over their subsidiaries when they represented export bases. This is because governments in host countries are eager to increase exports. Moreover, when the output of the subsidiaries are intermediate goods which have value only when combined with other intermediate goods made by the same firm in other location/country, governments may be willing to accept even full ownership by the foreign firms (Fagre and Wells, 1982: 13).

Although the bargaining model just described, has lost certain relevance (see Ramamurti, 2001) given the widespread of liberalization policies[11] followed by developing countries like Mexico; it is important to note the importance of producing a complete product or sub-system. As we are going to stress later, this is an essential element for bargaining as well as for learning. In the same token and in a Mexican context, studies using the global value chain concept, like Bair and Gereffi (2001) and Bair and Dussel-Peters (2006) highlight the importance of full-package production (as opposed to assembly subcontracting) in the garment sector, as a condition for upgrading in the value chain. These studies explain that full-package production[12] represent not just an upgrade, but also in some cases the possibility to continue in the value chain and avoid competitive threats from other locations. The net balance of these authors for the Mexican case (which comprised a lot of foreign firms) is negative, as most of the firms in Mexico have not achieved the full-package option, as opposed to some firms in Asian countries.

While producing a complete module or sub-system is a very important achievement in technological terms, the next step should be related with R&D. Ronstadt (1978) analyses the different mandates of overseas R&D units of US based firms. This author's scheme is very rich since it illustrates that production and R&D can be located either in the US or abroad and either coupled or de-coupled from one another. Moreover, the type of R&D activity in foreign R&D units might be used to serve markets whether in the home country, the host country or both. A very important feature is the evolutionary character of these foreign R&D units. Ronstadt (1978) argues that for a foreign R&D unit to leave behind the function of mere technology

---

[11] Private property is seen as the more efficient ownership in liberal economic ideas, and in principle, private foreign ownership is ok as far as it be the more efficient option in terms of resources allocation.
[12] Contrary to assembly subcontracting, full-package production implies: purchasing the fabrics needed for a particular garment, contributing to design specifications, producing a sample for the buyer to approve, grading and marking a pattern, laundering or finishing the garment, and occasionally shipping directly to retail outlets (Bair and Dussel-Peters, 2006: 207).

transfer (its initial purpose) and become a generator of technology for the host country or even serve the home country market or the global market, the firm has to have a substantial investment in production operations in that location (p. 12). More recent authors like Mariani (2002), calls the attention to the scientific content of the overseas R&D. This author claims that R&D-only affiliates usually are dedicated to activities with high scientific content while R&D-and-production affiliates are dedicated to more user oriented aspects that usually do not require much scientific content. This trend would be more likely for high technology sectors in which science is very important. One conclusion of Mariani (2002) is that localities with a science infrastructure are more akin to the establishment of R&D-only affiliates that belong to firms in high technology sectors. Newcomer countries in aerospace should be aware of this general trend, in order to have realistic expectations about the technology that will be transferred from foreign firms.

1.2.2 The aircraft as a modular system

This section, by means of four concepts, analyses the main technical dimensions of the aircraft as an artefact. The first is the concept of ***product architecture*** that dates back to the work of Simon (1962) and Alexander (1964), and has been framed in more modern terms by Ulrich (1995) and Baldwin and Clark (2000). The second concept is ***dominant design***, first developed by Abernathy and Utterback (1978). The third is the concept of ***technological regime*** inspired by the work of Nelson and Winter (1982). Finally, if we are interested in complex products like aircraft, Hobday (1998) makes the claim that the concept of ***complex product systems*** (CoPS) may help because this kind of product exhibits major differences compared to simpler ones.

Although they come from different research streams, these four concepts – product architecture, dominant design, technological regime and complex product systems - are complementary to a great extent. Nevertheless, some important differences exist, and they represent obstacles to their integration. What follows is a brief analysis of these concepts, as they relate to aircraft.

Some authors like Sanchez and Mahoney (1996) and Langlois (2002) argue that the architecture of a product has implications in the way knowledge is created and shared among the different organizations participating in its conception and production. Thus, we are going to briefly discuss how the product architecture influences the organizational coordination within and among the different parties, especially regarding knowledge creation and sharing.

Product Architecture

The concept of product architecture originates in the seminal work of Simon (1962) and Alexander (1964). For instance, in his work on the architecture of complexity, Simon (1962) discusses the properties of complex systems. This author claims that social action (whether economic interaction or human-made artefacts) shares the underlying principles of systemic complexity that characterize the natural world. By complex system he means "...one made up of a large number of parts that interact in a non simple way" (p. 468). One property of these complex systems is hierarchy. The property of being hierarchical means that "...a system [...] is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem" (Simon, 1962: 468). Simon (1962) clearly shows how the hierarchy property, together with a near-decomposability property, helps to reduce the complexity arising from having too many parts interacting in non-simple ways. The near-decomposability property is what will later be known as modularity. Therefore, it can be argued that the study of product architecture is needed for the design of products as a strategic activity in the management of product development.

Later, authors like Henderson and Clark (1990), Ulrich (1995), Schilling (2000) and Baldwin and Clark (2000) used Simon's (1962) insights to build a framework for analyzing the architectural properties of products in order to understand their evolution and to devise product design strategies. Specifically, these later works stress the advantages of modular architectures. The first step to understand what the implications of modularity are is to give a definition of product architecture, and of the term "modular".

Although the works cited above have some things in common, not all agree on all aspects related to the definition of product architecture. Next, we are going to show the main differences and commonalities of these works.

In an article about architectural innovation, Henderson and Clark (1990) describe architecture as a system. A component is defined as a physically distinct portion of the product that embodies a core design concept and performs a well-defined function (p. 2).

According to Ulrich, there are three main relevant dimensions for defining product architecture: "(1) the arrangement of functional elements; (2) the mapping from functional elements to physical components; (3) the specification of the interfaces among interacting physical components."(p. 420)

Baldwin and Clark argue that, "a module is a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units."(p. 63). Regarding the system, they propose that "[a] complex system can be managed by dividing it up into smaller pieces and looking at each one separately. When the complexity of one of the elements crosses a certain threshold, [a separate abstraction that has a simple interface can isolate complexity]. The abstraction hides the complexity of the element; the interface indicates how the element interacts with the larger system."(p. 63-64). This means that the intricate interactions among some components are embedded in the module and the rest of the system does not have to deal with that complexity, for that reason, the complexity is said to be hidden.

According to Schilling, all entities can be viewed as system of components, and each of those components is, in turn, a system of finer components (Schilling, 2000: 314).

All four definitions share the idea that a system or product is made up of elements, components, or modules. The way these modules are attached to the system reveals the architecture or configuration of that system. A system may itself be part of a larger system in a hierarchical fashion.

Defining modules

The definition of a module is more problematic. For instance, Ulrich (1995) defines a component as a separable physical part or subassembly (p. 421); for Schilling (2000), the definition of a component depends on the level of analysis, or on the ultimate possibility of having an elementary particle (although in the case of human-made products, this last possibility is not relevant). It seems that for these two authors the definition is completely dependent on the level of analysis. The assertion of Ulrich (1995: 421) about architecture as a mapping between physical elements and function structures that can go from one-to-one, many-to-one, or one-to-many does not reduce the relativity of his definition. This is because Ulrich recognizes that the function of a given structure is dependent on the level of abstraction. But even if we take a structure at a specific level of abstraction, the problem is to what ultimate physical element we have to assign a specific function. In the end, these two definitions seem to rest on practical judgments.

In Henderson and Clark (1990), a module embodies a core design that performs a well-defined function. Instead of defining a module by its physical properties or characteristics, the module is defined by a core design. Here, core design is understood as the technical way to solve a problem. Thus, all physical elements needed to realize the core design principle are part of the module. Of course, establishing what is a core design is not without problems, and also implies some degree of relativity.

Trying to build a more solid definition, Baldwin and Clark (2000) based their concept of module on the strength or weakness of the connection between structural elements. This definition is very close to the spirit of cluster analysis, in the sense that elements in the cluster are more related among themselves than with other elements in other clusters, although this does not mean that cluster elements have no relationship outside the cluster. Again, this definition has relativity aspects, not just because of strength or weakness as a criterion, but also because of the problem of defining the number of modules. Let us recall that in the statistical cluster analysis the number of clusters must be set according to a certain judgment; in the same vein, the number of groupings of structural elements in a CoPS must be set based on some judgment.

Yet, when can product architecture be said to be modular? As we have seen, since definitions of module vary, the answer must vary to some extent, depending on the author.

Henderson and Clark (1990) do not make a specific statement about this issue; they just assume there are modules in the system. Nevertheless, it can be argued that to the extent that core design principles depend on specific elements, and those specific elements are mainly involved in specific core design principles, the architecture has a greater degree of modularity.

Ulrich (1995) puts it this way: "A modular architecture includes a one-to-one mapping from functional elements in the function structure to the physical components of the product, and specifies de-coupled interfaces between components. An integral architecture includes a complex (not one-to-one) mapping from functional elements to physical components and/or coupled interfaces between components." (p. 422)

Based on their previous definition of module, Baldwin and Clark (2000) define modularity as "a particular design structure, in which parameters and tasks are interdependent within units (modules) and independent across them." (p. 88).

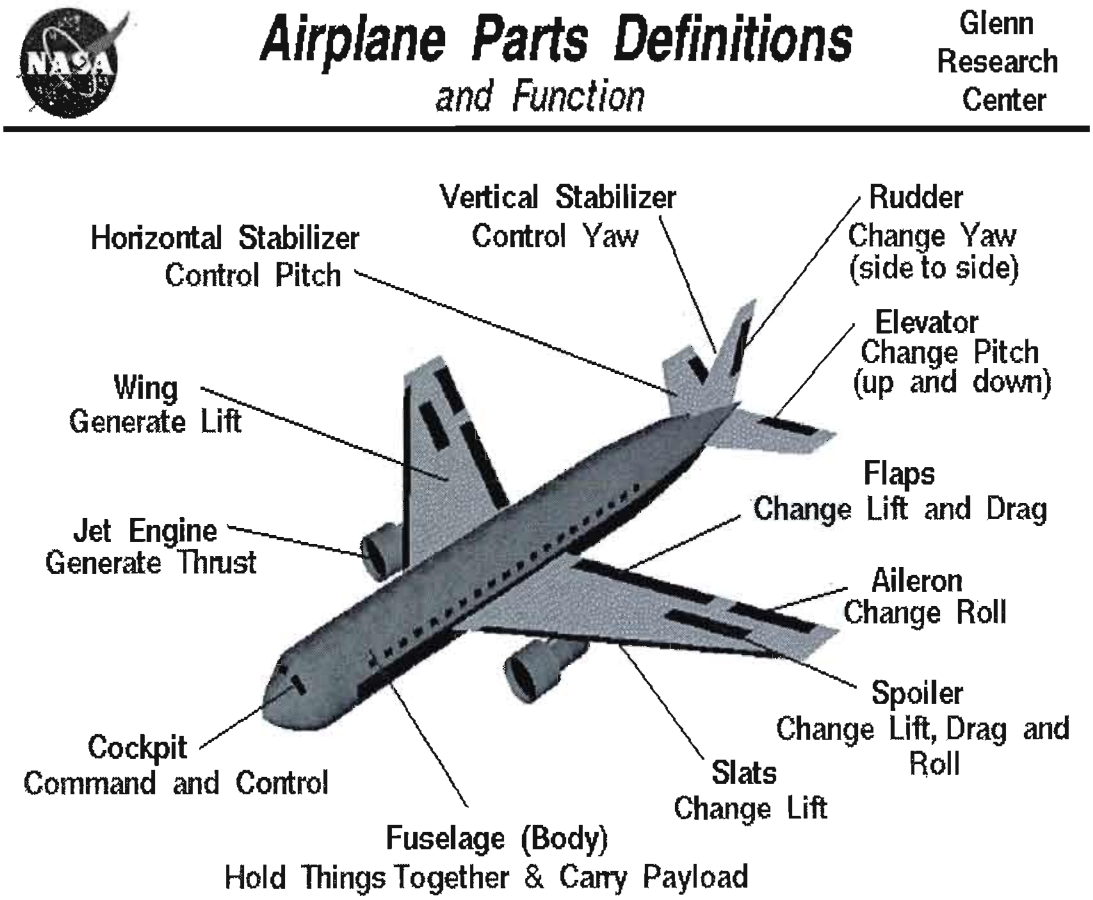
Schilling (2000) argues "systems are said to have a high degree of modularity when their components can be disaggregated and recombined into new configurations – possibly substituting various new components into the configuration- with little loss of functionality."(p. 315)

There is a general consensus about the fact that all architectures have some degree of modularity. In this sense, integral architecture – a system with no identifiable modules (like the famous pin of Adam Smith) - and modular architecture should be understood as ideal types. Most products will fall somewhere on the continuum between these extreme cases.

According to Brusoni and Prencipe (2001), Niosi and Zhegu (2005) and Frigant and Talbot (2005), the aircraft is a complex system with a high degree of modular architecture. In that case, the system is the whole aircraft and it is made up of different subsystems or modules arranged in a hierarchical fashion. These subsystems are in turn made up of other subsystems. Figure 1.3 by NASA, illustrates some of the main subsystem and their main function.

Figure 1.3

Aircraft modules



Source: NASA

Figure 1.3 coincides with a definition of architecture based on a structure of functions like the one proposed by Ulrich (1995). If we follow figure 1.3 and Ulrich's (1995) definition, the aircraft is a system whose modules accomplish one or several well defined functions, and thus the degree of modularity is important. Also, even if figure 1.3 is a good illustration, it lacks some subsystems, like the landing gear and hydraulic systems, and the avionics, which consist of the integration of the navigation and the flight control systems (Frigant and Talbot, 2005: 344).

In terms of its hierarchical features, Niosi and Zhegu (2005: 12) show how the aircraft can be viewed as three layers system that has other subsystems that in turn have modules. The first one is the aircraft itself conceived as a whole system; the second level is made up of the avionics system, the propulsion system, and the airframe structure; and the third level is made up of electronic and electric components that are attached to the avionics system, engine and components that are part of the propulsion system, and fuselage parts, cabin, fuel systems, landing gear system and hydraulic systems that are attached to the airframe structure.

In terms of the interfaces, Fringant and Talbot (2005) explain that the avionics system has a large number of interfaces, like the flight control system and the electronic power supply; various fuselage parts like the wings are attached to the main airframe by simple mechanical attachments and so is the landing gear; the engines are attached to the wings by means of engine pods and pylons, with the help of mechanical and electric connections which also control the wings ailerons and the retractable landing gear (p. 344-345).

The current state of modularity of the aircraft is the result of a particular evolutionary path involving technical advancements, market demand, and strategic manoeuvres. One major result is that the degree of modularity may not be the same even for aircrafts in the same class (Frigant and Talbot, 2005). To have a better idea of this evolution, we will re-examine the concept of dominant design.

Dominant design

The concept of dominant design was developed before the new conceptualizations of product architecture that we have already seen. In fact, Baldwin and Clark (2000) recognize the influence of this concept on their work.

Abernathy and Utterback (1978) developed the concept of dominant design to address the dynamics of innovation at the industry level. They stress that the focus of innovation is different as the life cycle of a product advances. They arrive at the conclusion that innovation in product – understood as a radical improvement in product characteristics - is prominent in the first phase of a product's life cycle, while innovation in process – understood as radical improvement in the way the product is made - is prominent in the latter phase of the product's life cycle. The reason is that once a product achieves enough market acceptance over its rivals, its design becomes dominant in that segment. In other words, the product becomes the standard to which all participants must adhere if they want to be in the business.

Other influential authors like Tushman and Anderson (1986) used the concept of dominant design to explain how the change in the type of innovation – whether product or process - presents different risks and opportunities for incumbent firms and new entrants. These authors make the link between changes in the dominant design and changes in the industrial structure. According to these authors, in terms of previous knowledge, there are two types of discontinuities, competence-enhancing and competence-destroying knowledge, the latter related to the establishment of a new dominant design. The explanation is that competence-enhancing change favours the current industrial structure, while competence-destroying change gives new entrants the opportunity to get a position in the industrial landscape.

Murmann and Frenken (2006) integrate various contributions that deal with dominant designs. They claim that the dominant design concept can be useful for hierarchical complex systems like the aircraft. Much in line with Simon's (1962) explanation, these authors presents the idea of dominant design as a strategy to facilitate the production of an artefact by fixing some dimension. However, it is important to point out, that in the case of the aircraft, even if some technical dimensions of the architecture have been fixed (e.g. like the existence of two wings) the complexity within those dimensions has been increased (e.g. modern wings are made of numerous parts that interact in a non-simple way compared to wooden wings of prior aircrafts). In this sense, the overall complexity of the aircraft has been increased in spite of the existence of a dominant design.[13] As we are going to see below, this seems to be the consequence of the constant technical and markets needs which the aircraft has to meet.

Murmann and Frenken (2006) explain that normally there are several technical dimensions involved in the consecution of a general function embodied in a product or system. How to choose the parameters of these technical dimensions is a complex task, since changes in one of them may bring changes in others, very much in the spirit of Baldwin and Clark's (2000) definition of architecture. Faced with this challenge, engineers and designers usually reduce this complexity by fixing the parameters of some of these technical dimensions. Which technical dimensions must be fixed and how to do it depends on the particular circumstances of a technology. Once some critical technological dimensions get established and accepted by other actors (e.g. competitors, suppliers, customers) they become part of the dominant design in a product class.

The establishment of a dominant design in a product class is a guidepost that serves to explain the unfolding dynamics of innovation (Abernathy and Utterback, 1978),

[13] Perhaps this overall complexity would be even greater if those fixed technical dimensions were not in place; e.g. had an aircraft company the task to chose among different wings configurations each time a new plane is developed, the complexity sure would be enormous.

organizational forms (Henderson and Clark, 1990) and the industrial organization involved in that product class (Tushman and Anderson, 1986).

Before proceeding to explain dynamics, it is important to know how to delimit the boundaries of a product class. Murmann and Frenken (2006) suggest that fundamental operational principles should be considered when defining a product class. It is not the goal of this work to review all the operational principles that differentiate the aircraft from other human-made artefacts used for air travel: in this work we are focusing on civil aircraft. In terms of sector delimitation, Niosi and Zhegu (2005) show that civil aircraft manufacturing generates more employment than military aircraft manufacturing. In terms of technology, according to Kehayas (2007), subsonic civil aeronautical technology shows important differences from supersonic military technology[14].

Before a dominant design in a product class is established, several firms compete to get the acceptance of the relevant actors. Although Abernathy and Utterback (1978) presented markets as the most relevant actors, Murmann and Frenken (2006) argue that in the case of complex products there are also other key actors on the institutional landscape (e.g. system integrators, R&D alliances, specialized suppliers, governments, etc.), who participate in the negotiation of the main technical dimensions and their parameters. This is a period of ferment (Tushman and Anderson, 1986) in which innovation is carried out mainly at the product level or, in the framework of Murmann and Frenken (2006), at the level of fundamental operational principles, and the main objective is to achieve performance.

Once a specific architecture or design is selected by the combination of market, technological, and institutional forces, a dominant design emerges. This architecture

[14] Subsonic makes reference to planes that do not have the capacity to overcome sound velocity, while sonic makes reference to planes that can go above sound velocity. The Concorde is an example of a sonic plane. Almost all civil aviation planes are subsonic.

contains in most cases some degree of modular features since one of the objectives is precisely to facilitate the production process. Different modules have different impacts on operational principles. In most cases, the fundamental operational principles are mostly related to certain modules.

This implies that, once the dominant design is established, the fundamental operational principles of the artefact change more slowly, and innovation centers on secondary operational principles. According to Abernathy and Utterback (1978), dominant design opens a period of process innovation and only minor incremental innovation at the product level, or a competence-enhancing period according to Tushman and Anderson (1986). However, for complex products like the aircraft, Murmann and Frenken (2006) argue that innovation can be radical or incremental after the dominant design emerges, and at different levels of hierarchy. In fact, in modules with high-hierarchy and with close relationship with operational principles, innovation will be incremental, but in modules on the lower levels of the hierarchy, innovation can be either incremental or radical. This last type of innovation makes reference to great performance improvements, or completely new knowledge and skills needed for its accomplishment. Therefore, parts of the system can experience radical innovation at the subsystem level, but at the system level will be considered incremental. Even some core modules can suffer important changes, but unless those changes lead to great modification in the way those modules interact with others, the changes in those core modules may be radical at the module level but with no major alteration of the product architecture (e.g. fly-by-wire systems may allow a better control and monitoring of the different mechanical systems, but the relationship among those systems remains more or less the same).

The relative stability of the dominant design at the system level makes possible incremental changes (and radical changes at lower subsystem levels) that enhance customer value. Nevertheless, once the system can no longer perform as expected, or when new needs appear, there are again incentives to experiment with new principles in order to address these issues. This marks the beginning of a new ferment period in search for a new dominant design. Sometimes, not all fundamental principles change, but changing even one requires a reconfiguration of the system architecture. The current adoption of composites in the aircraft construction seems to be the case in which a change in one of the parts implies important changes in other parts of the system.

Murmann and Frenken (2006) posit that the dynamics of dominant design in complex systems imply different risks and opportunities for incumbents and new entrants. These will vary depending on the level of the change and the position in the hierarchy. For example, a change in architecture promoted by a system integrator involves certain adjustments at that level of the hierarchy, but lower levels will need bigger changes if they want to adjust.

A comprehensive description of the fundamental operational principles that may form the dominant design of aircraft architecture is beyond the scope of this revision; however, some authors do state some major arguments regarding these principles.

Although it may exist more than one account about the actual number of aircraft configurations that can be labelled as a dominant design, here we are going to present three historical moments on which three works more or less coincide (Esposito, 2004; Niosi and Zhegu, 2005; Kehayas, 2007)[15]. It is important to note that these three works go in depth about the technical characteristics of the aircraft and their impact in its development. Table 1.2 shows the characteristics of three historical dominant design configurations.

---

[15] Esposito (2004) uses the concept of technological paradigm; Niosi and Zhegu (2005) use the concept of dominant design; Kehayas (2007) refers to revolution in the aircraft configuration.

Table 1.2

Subsonic civil aircraft dominant designs characteristics

1935	Late 1950s-1960s	1985-1990
DC-3: • All metal • Two wings attached to fuselage • Two motors • Propellers • Retractable landing gear (Niosi and Zhegu, 2005)	B-707: • A jet propelled airliner • Four engines, all metal (Kehayas, 2007; Niosi and Zhegu, 2005) • Old piston changeover to the jet engine (Esposito, 2004)	• Supercritical wings • Composite • High by-pass turbofans • Fly-by-wire (Kehayas, 2007) • Use of advanced materials and electronics (Esposito, 2004)

Niosi and Zhegu (2005) explain that the DC-3 plane designed by the Douglas Company in the US was the prototypical model in this first dominant design architecture, and it sold over 10,000 units all over the world. Among the "...key characteristics were an all-metal fuselage (replacing wooden bodies), retractable landing gear (substituted for fixed gear) and monoplane wings with two piston engines (instead of biplane wings)." (Niosi and Zhegu, 2005: 11). Regarding the DC-3 plane made by Douglas, Bagley (1990) asserts that it was "...the first truly effective civil airliner capable of providing a regular, reliable transport service generating a profit for its operator from passenger revenue alone." (p. 631).

The introduction of the B-707, in the end of the 1950s and beginning of the 1960s, signalled the era of the jet engine in civil aircraft. The massive adoption of the B-707 and the adoption of the jet-engine by others make that plane the second dominant design (Niosi and Zhegu, 2005; Kehayas, 2007). According to Esposito (2004: 454), the changeover of the engine industry from the old piston engine to the new one based on the jet engine was truly a paradigmatic change. If we consider thrust as a critical function and the propulsion system as a high-hierarchy module, we can consider that the change indeed modified in some way the dominant design of the aircraft: the new speed required massive reinforcement in airframes, adjustments of cabin noise insulation among other major changes.

Although there is not a prototypical plane for a third dominant design, there are some elements that have been introduced that seems to be mandatory for new planes like the introduction of new materials such as ultra-light alloys and massive use of electronic instruments." (Esposito, 2004: 453). These improvements affected the three main high-hierarchy modules: airframe, propulsion systems, and avionics. Thus, it can be certainly argued that some of the dominant design features changed. According to Esposito (2004), this change brought about incredible improvement in speed and fuel-efficiency.

The three authors coincide in signalling the inclusion of the jet engine in the late 1950s as a break-through moment. Only Esposito (2004) shows the more recent inclusion of new materials and electronics as another paradigmatic moment. There may be several reasons for the other authors not to claim this. First, for Niosi and Zhegu (2005), the important issue is how, among competing technologies, one is chosen as the dominant. In this case, it may be the new technologies applied to aeronautics which were born outside of aeronautics, like composites, and may coexist as long as they accomplish their function. Thus, there is not a need for just one solution. Second, it may be that it is too early to determine which navigation electronic system is best, for instance. Third, and perhaps more important, it may be that the new aeronautical technologies enhance the actual architecture and as such they do not represent a departing from it. Fourth, as it can be inferred from Kehayas (2007)[16], it may be that Esposito (2004) by including safety and comfort in his index

[16] Kehayas (2007) defines aeronautical technology as being composed of aerodynamics, structures, propulsion, and systems and configuration (p. 600). Thus, according to him, since the introduction of jet-powered planes like the Comet and the B-707, all new aeronautical technologies introduced have been evolutionary instead of revolutionary. Kehayas (2007) states that for an aeronautical technology to be considered revolutionary, it should have a great impact on direct operation costs (DOC): ownership (depreciation and interest), insurance, fuel, maintenance and crew costs, and landing and navigation fees. He recognizes that other improvements outside the aeronautical technology can have an impact (for instance, a better manufacturing process or the sharing of common parts among different generations of planes) on the DOC.

is going beyond strictly aeronautical technology. Although safety and comfort issues are critical to the well- functioning of the air navigation system as a whole, it may not be a change in terms of aircraft architecture. In any case, it is true that the inclusion of new technologies (that may or not be strictly aeronautical) like composites (Esposito, 2004), avionics (Niosi and Zhegu, 2005) and supercritical wings (Kehayas, 2007), and the focus on issues like comfort and safety (Esposito, 2004) are changing the knowledge needed to succeed in the design and manufacturing of commercial aircraft.

Integral to current aircraft organizational architecture (or architectures) is its modular division. In terms of modularity, the aircraft has migrated from intra-firm modularity to inter-firm modularity. Fringant and Talbot (2005) explain that inter-firm modularity was encouraged by European governments in the context of the creation of Airbus. The four participant firms in the Airbus consortium – Aerospatiale from France, DASA from Germany, BAE from England, and CASA from Spain - were assigned a specific part of the Airbus aircraft. Thus, the first factor toward inter-firm modularity was political (Fringant and Talbot, 2005). These authors claim that a second factor was the choice of Airbus to use electronic controls that allowed for the suppression of a large part of the mechanical and hydraulic connections, that eventually allowed a better partitioning of the aircraft (Fringant and Talbot, 2005; 344). Since the model offered by Airbus had considerable market success, its competitor Boeing in the US, as well as Canada's Bombardier and Brazil's Embraer rapidly followed similar strategies.

Another major element in inter-firm modularity is that aircraft is a global product, and an expensive one. In order to get international markets and reduce their dependence on just one government for the funding R&D, and thus reducing market and technological risk, large systems integrators had to rely on foreign independent suppliers of subsystems, that would co-develop wings, landing gear or avionics with them.

The modularity achieved by Airbus and Boeing has allowed them to develop de concept of "family" in which different aircraft models share some component with other models (Fringant and Talbot, 2005). For instance, the Airbus models "A318/A319/A320/A321 and A330/A340 have the same instrument panels, the same piloting procedures, the same avionics and several of the same systems. There is practically no difference in the cockpits. The wings of the A318/A319/A320/A321 are all identical, only the length of the fuselage (and consequently the number of seats) differs." (Fringant and Talbot, 2005: 345). This description of modularity is very much in line with the concept of architecture developed by Schilling (2000) in which this author stresses that the possibility to change modules from system to system is what makes a product modular. We can even talk about intergenerational modularity in these cases.

Several factors have contributed to the increasing trend of modularity in the aircraft industry. From the technological perspective, the existence of a dominant design in at least two moments in the history of the commercial subsonic aircraft means that the main modules are defined, and both subsystems and interfaces become standardized. Also, the ever increasing complexity of the knowledge needed (see CoPS below) is a factor that encourages division of labour and thus administrative modularity. Authors like Benzler and Wink (2010) even talk about modularization of R&D (p. 324). These authors stress the ever increasing importance of new technological systems –like composites– used on new generation planes. Since much of the knowledge pertaining to those new technological systems fall outside of the traditional or core (Ehret and Cooke, 2010) capabilities of final assemblers, these have to rely on specialized suppliers not just for manufacturing but also for R&D. Ehret and Cooke (2010) make the distinction between "core" and "strategic" capabilities in the context of aerospace.

According to these authors, the new technological systems represent "strategic" capabilities possessed by specialized suppliers, and for final assemblers these same capabilities are "non-core" in the sense that they do not posses them. This situation encourages the seeking for partners and places that have relevant knowledge on the new technological systems, which in turn favours further modularity (Benzler and Wink 2010). From the market and political perspective, the goal of leading firms to sell more planes leads them to sign offset agreements that drive them to manufacture part of the plane in a foreign country (MacPherson and Pritchard, 2007; Benzler and Wink, 2010).

Technological regime

Taking as a departure point that knowledge is the bottom line of innovation, Nelson and Winter (1982) developed the concept of technological regimes, and Dosi (1982) developed the concept of technological trajectory to explain the differences between the natural trajectories of different technological sectors. Expanding that concept, Malerba and Orsenigo (1997) propose four dimensions that capture the logic of technological regimes: a) innovation opportunity – the efficiency of R&D investment in terms of innovation/investment; b) appropriability – the capacity of a firm to appropriate the benefits of its innovative efforts-, c) characteristics of the knowledge base – the degree of tacit/codified- and d) cumulativeness – the degree to which new knowledge depends on older knowledge. Evidently, the analysis scope of this concept is broader than the previous ones, because the aim is to understand the evolution of a complete technological sector, not just a product or industry.

The knowledge base relevant for the design and manufacture of aircraft has both tacit and codified characteristics. In terms of codified knowledge, it can be argued that ever-increasing inter-firm modularity implies the standardization of interfaces in order to develop modules in an independent way. This standardization is reflected in the clear definition of the interfaces between the main subsystems and the overall aircraft. Also, there are numerous licensing agreements between the leading firms and companies based in developing countries. These licensing agreements imply that firms in developing countries receive a complete set of instructions regarding the aircraft for which they will produce some component or module. Of course, this can be done for aircraft models developed previously for which there is already a good deal of codification. Thus, in this industry, like in most other ones, time plays in favour of codification, however, new aircraft models imply a good deal of tacit knowledge thanks to the constant addition of new technologies to these models.

On the other hand, there are always tacit characteristics of the knowledge base. Authors like Ehret and Cooke (2010) point out that the overall design and final assembly of planes is the final assemblers' core and strategic capability, which they try to keep secret. In this sense, final assemblers, like Bombardier or Airbus, have embedded that ability in their organizational routines. For these reasons, alliances to develop new aircraft between leader final assemblers - like Embraer from Brazil - with other firms in developing countries like China, involve an intense technology transfer program. Mitsubishi from Japan has also received technology from Boeing in order to develop and produce new wings for the Boeing 787 (MacPherson and Pritchard, 2007; McGuire et al, 2010). If we follow this explanation, even if the development and manufacture of new aircraft or just certain modules is an ability with a high tacit component embedded in organizational routines, this does not mean that it is not possible for potential competitors to eventually develop such an ability. This is more so when leading companies install factories in other countries. Paradoxically, alliances and agreements between leader assemblers and firms in developing countries to produce new models (or adapt older ones) have shown precisely that technology transfer programs must include the tacit element required to design and manufacture aircraft modules and even the whole artefact.

Cumulativeness is overwhelming, but like in all industries, useful knowledge fades out in time. On the one hand, it can be argued that in fact, the knowledge to design new models is related to a high degree with the knowledge to develop previous ones, since many aspects in the dominant design architecture are relatively fixed as argued by Kehayas (2007). On the other hand, even if strictly speaking the dominant design architecture of the aircraft has not changed much, too many technologies are continuously been added or modified (Esposito, 2004). This represents a whole array of new abilities that have to be mastered in order to keep pace with the advancement in this industry. According to Fringant and Talbot (2005), new developments in avionics systems are giving this module of the aircraft more prominence in the overall architecture. These arguments imply that even if old knowledge is important, its prominence over new knowledge will certainly diminish with time.

There is another factor that makes the assessment of cumulativeness in the knowledge base even trickier. Benzler and Wink (2010) use the distinction between synthetic and analytical knowledge to illustrate that the new technologies used in new generation planes are more related to the scientific inquiry –analytical– way of learning than to the traditional engineering know-how –synthetic–. According to these authors, the way of making planes is changing from a product centred approach style to an integrated innovation approach. Put it in rough terms, now the challenge is how to integrate technologies –like composites and electronics– that require an R&D expertise usually located in other agents. In this sense, the problem is not just of cumulativeness, but also the widespread of this knowledge into more players, like specialized suppliers and research institutes.

According to Esposito (2004), in terms of innovation opportunity, "even a modest increase of technology is only obtained through large investments." (p. 463). Nevertheless, that investment is often well compensated for by future payoff in technology and sales (Mowery and Rosenberg, 1985).

Complex Product Systems

Hobday (1998) defines complex product systems as "high cost, engineering-intensive products, system, and constructs."(p. 690). He continues: "The term complex is used to reflect the number of customised components, the breadth of knowledge and skills required and the degree of new knowledge involved in production, as well as other critical product dimensions." (p. 690).

Sometimes products can be mislabelled as CoPS. Acha et al (2004) argue that the automobile is usually classified as CoPS, but they mention that the fact that it is mass-produced and a consumer good prevent to classify the automobile as a CoPS. Jin et al (2004: 2) complement the previous argument and explain that even if the automobile has a lot of components and needs interdisciplinary knowledge and skill, most of the components are standardized and can be produced in volume. Hobday (1998) argues that these particularities make CoPS exhibit different evolution patterns and thus need different managerial approaches.

In line with the definition of CoPS, the aircraft is a high-cost hierarchical product system that requires knowledge in diverse areas. A major characteristic of aircraft development is its high up-front cost; according to Esposito (2004), the cost of developing the Boeing 777 was US$5 billion. This cost has been increasing from the beginnings of the industry. According to Esposito (2004), the "...sharp increase in price is strictly related to the cost of aircraft development, which grows rapidly in step with technological growth." (p. 451). Continuous pressure for improvement (implying not only advances in aeronautical technologies or production methods, but also the incorporation of new technologies), constant changes in demand, and the lack of standardization of several parts, makes the development of a new aircraft more onerous than has previously been the case (Hobday, 1998).

The wide range of abilities and knowledge needed to design, produce and assemble an aircraft sets it apart from other hierarchical products. Even for just one module like the engine, Prencipe (1997) shows how Roll Royce had maintained and nurtured a knowledge base that encompasses several areas. Sometimes, Roll Royce does not use all that knowledge in a direct way; instead, it uses it to verify the pieces and services that may eventually outsource to third parties. This leads to the assertion that system or subsystem integrators know more than they do (Prencipe, 1997; Fringant and Talbot, 2005; Niosi and Zhegu, 2005). In this sense, knowledge management is a critical activity for system and subsystem integrators. They should maintain a certain in-house capability in several fields, in order to design the overall module or system, transfer it and/or verify the work done by third parties.

Other authors like Benzler and Wink (2010), Ehret and Cooke (2010) and McGuire et al (2010) suggest that the situation just described may be in transition to a scenario in which the final assembler or system integrator will indeed lack some relevant knowledge given the diversity of technologies employed nowadays. For instance, Ehret and Cooke (2010) when using the division between "strategic" and "non-strategic" capabilities, argue that the former are possessed not only by system integrators and high-level companies in tier 2 such as engine manufacturers, and landing gear producers. Moreover, system integrators do not posses all "strategic" capabilities. Benzler and Wink (2010) put emphasis in what they call "technological platforms" as the main factor for future relocations of the aerospace industry. According to these authors, in the future, the aerospace clusters able to nurture firms and research organizations active in the new technologies –i.e. composites- will have better chances to attract relocation activities from incumbent aerospace firms. The argument of these authors is that the importance of those complementary technologies is such that they will influence the localization decision of incumbents in a way that was not thinkable before. McGuire et al (2010) interpret Boeing's decision to rely on the Japanese Mitsubishi for the construction as well as some design work for the wings of the 787, as a loss of competitiveness by the American firm (p. 371). The authors cited in this paragraph give the impression that in the near future, system integrators will use more technologies than the ones they are actually competent at. Yet, nevertheless, it seems early to assess the extent of the importance in strategic terms of those new technologies. Ultimately (at least if we follow theory), only a change in aeronautic technology able to transform the dominant design[17], will be able to greatly diminish the strategic importance of current leaders' knowledge.

1.2.3 Expected delocalization strategies

Since leading aerospace companies are concentrated in few countries, a main motive to go international is precisely to exploit the proprietary assets developed in home, that other countries do not posses. One may think that exports could be a good way to accomplish that objective since a lot of countries cannot afford to build their own planes, and that is actually the case in many instances; although for countries which have some capacity at aircraft production, conditions are different. Some of them use offset agreements to oblige those leading firms to carry on a percentage or the totality of the production in the host country. However, even if offset agreements may play a role in driving firms to internationalization, other factors are important too. For instance, the ever rising up-front costs of R&D, makes sharing risks with local firms a reasonable strategy by leading firms. In some of these instances knowledgeable local partners have been developed (like in Japan) which makes internationalization of activities more pervasive than before.

Thus, leading aerospace firms may pursue either the exploitation of their specific assets, and/or take technological advantages like knowledgeable partners, labour pools and host government incentives. Benzler and Wink (2010) argue that there is another motive to go to international in the case of aircraft. They explain that

[17] As it was explained, accordding to Kehayas (2007), the incorporation of composites materials does not represent a change in the dominant design of the overall aircraft architecture.

different markets may present different conditions in terms of the customer, and for that reason, it is important to be present to know how to better service those markets. However, we think that the importance of the customer is somehow overstated in that argumentation, because the civil aircraft industry satisfies a more or less standard demand worldwide.[18] Thus, we do not see market segmentation to be as important as for instance in the auto industry in which differences in road conditions, weather, income, and even cultural values do play a very important role in shaping crucial dimensions of the vehicle as an artefact.

We contend that there is another motive to go international that is not much related with market considerations. It has to do with the simple motive of costs reduction. This motive is relatively new, apparently because leading aerospace firms did not think that the high quality standards could be easily met. However, delocalization of production driven by low-cost considerations is taking force and Mexico is a vivid example of that trend. Thus, we think that the original concern of the PLC, namely to study the pattern of delocalization of activities towards low cost location as the product matures, is very pertinent. While some authors neglect the importance of this theory for the case of the aircraft, Niosi and Zhegu (2008) argue that there are several aspects of the evolution of the industry (mainly those related to final assemblers) that conform to the theory. The purpose of this section is to stress those aspects of the PLC theory that, when coupled with the concepts reviewed so far, explain the possible delocalization strategies followed by leading aircraft manufacturing firms.

---

[18] Benzler and Wink (2010) argue that the trend to customize a plane model into different ones (like different cabin interior and passenger electronics (p. 325)) in order to accommodate different demands of airlines, gives some role to the market. Since Asia is seen as the more dynamic market, these authors argue that eventually some parts of the aerospace activity should be located close to the market in order to be responsive to its demands. If markets do matter to the extent the authors suggest, (According to the authors the US market has shaped the development of current aircraft carriers), perhaps we all will be flying on Chinese-costumed planes in the future, because, given the huge costs and scale economies present in aerospace, it seems unlikely to expect market segmentation in the most important systems. Thus, customization may be present in minor designs and modules, and as such, its effect will not be as large as to be a decisive factor for delocalization.

In the original work of Vernon (1966) new products were produced in places where there were no cost advantages, but proximity to an affluent market is crucial. Behind that answer lays the assumption that critical inputs – human, financial, capital - were present in the original firm location. The presence of those inputs is what set the innovator firm's locations apart from other locations that lacked those inputs and sophisticated demands. Although some authors have criticized Vernon for failing to predict actual internationalization modes of entry (Mowery and Rosenberg, 1985; Cantwell, 1995), we contend that the aircraft industry – by means of the special market and techno-economic characteristics mentioned above - represents an almost ideal case that evokes the original concern expressed by Vernon: if more and more information in the industry is being codified, if telecommunications and transport are much more efficient, and if leading firms already have some experience overseas, why do planes continue to be assembled in Everett, Toulouse or Montreal? Part of the answer is great sunk costs[19] and the development through decades of a specialized labor pool not easily mobile (Niosi and Zhegu, 2005). However, new realities, like the desire of new countries to nurture the industry, and the cost reducing strategies of leading firms towards low-cost locations, may challenge established clusters. In some way, the intention of this work is precisely to throw light on how these new realities (in this case the development of China or Mexico as cost efficient locations) may alter the current state of affairs in the aircraft manufacturing industry.

The first issue to asses from the PLC standpoint is precisely if the stages view is pertinent to aircraft. Although there is not a single product life cycle, it can be argued that there has been a succession of cycles each time a new dominant design emerged (Niosi and Zhegu, 2008). The problem is that even if different specific product architectures have been accepted as the dominant design at a specific period; that

[19] Sunk costs are investments for which value is foregone upon exit (Cabral, 1995: 161). Since those investments cannot be put to alternative uses, but are essential to current operations, firms have to make the investments, and the only way to recuperate them is when closing and selling them.

architecture is made up of several modules, each of them following a kind of PLC of its own. As mentioned before, a dominant design implies by definition the establishment of a series of interfaces among the modules. These interfaces remain more or less fixed for the duration of the production cycle of the model, and that is what gives the architecture a sense of stability. This does not prevent the eventual changes within each module (as long as those changes do not modify the interface of the module with the whole system in a serious way). Those changes may imply the use of new skills and capabilities, and as such, the opportunities for innovation within the module may vary across modules. For that reason, the prominence of the different modules through time may vary greatly. This situation may have enormous implications for predicting the stages in the cycle for the whole complex product system. One implication in terms of delocalization is that modules in their final stage of their PLC, with less importance in the overall architecture and with a good deal of codified characteristics in their knowledge base may be the ones most easily transferred to more cost-efficient locations. Yet, as Ehret and Cooke (2010) explain, even if final assemblers outsource a lot of components, they continue to carry on activities that are neither "core" nor "strategic" (perhaps for political-economical reasons, such as maintaining a level of employment that justifies government subsidies). If we couple this situation with the fact that subsystems are themselves modular, we have a situation in which the most likely activities to be outsourced in the near future to countries like Mexico, would be parts (perhaps large and/or relatively complex ones), but not the integration activities needed to have the module completely ready to couple with other parts of the plane. As Fagre and Wells (1982) explain, this situation has important consequences for the learning process. This can also slow the process for setting R&D units like the ones described by Ronstadt (1978).

The second issue is related to the division of labour. As mentioned before, Vernon does not examine in depth the possibilities of division of work for the same product by the same firm. However, following Ronstadt (1978), we propose the following tentative explanation. First, like in almost any industry it seems reasonable to divide aircraft activities into manufacturing and R&D.[20] When firms are experimenting with different product architectures it seems likely that they can gain advantage by locating R&D activities and production together. Once a dominant design emerges, and product and process technologies are standardised, it seems more fruitful to transfer production to more cost-efficient locations. However, if the firm wants to tap other markets it may have to establish manufacturing activities in those markets (even if those markets do not represent low-cost efficient locations in the strict sense). Additionally, if these locations represent an opportunity for learning, R&D-units may be established (Kuemmerle, 1997). If the location is not a dynamic growing market or if it does not have a technological infrastructure to benefit from, the most probable reason a firm would establish there is to obtain low-cost manufacturing, and R&D activities might remain in the original centers where they can profit from existing resources. In any case, system design and R&D are the core activities of the firms and the last that they would delocalize. As we have seen, for a foreign company to establish a foreign R&D unit, it should have already a heavy investment in production, but passing that production threshold is not evident in all cases (Ronstadt, 1978).

Although logical, the above explanation raises some questions. If the aircraft industry has already experienced the existence of dominant design architectures, why just until recently aerospace firms are transferring some of their activities to low-cost regions? There are several reasons. First, at its origins, civil aircraft technology was related to military technology; thus, dominant countries were reluctant to allow the transfer of these technologies, and when it occurred, it was for old plane models (of course geopolitical issues were part of the story). Second, aircraft facilities are a long-lasting

---

[20] Perhaps a more thorough division will be design, R&D, testing, manufacturing and assembling.

phenomenon given their high sunk costs and economies of scale (Niosi and Zhegu, 2005). Third, it may well be that the current dominant design of the whole plane and its main modules is just more amenable to this partitioning of tasks. Fourth, as Vernon (1979) and Ronstadt (1978) point out, once firms take steps toward delocalizing activities, they gain valuable learning about how to manage activities overseas. Fifth, some developing countries have already achieved a very good level in human skills and infrastructure for manufacturing activities not seen in previous decades. And above all, the emerging countries (the BRICs) are now the largest markets for civil aircraft, while the US and Western Europe are fairly saturated. The governments of some of these markets (particularly China) trade market access for technology.

Another important point in the discussion is the fact that many countries (e.g. Argentina, Indonesia and Rumania,) have attempted, and most failed, to create a complete aircraft industry – R&D and manufacturing included - almost from scratch (McKendrick, 1992; Steenhuis and de Bruijn, 2001). The importance in military terms and the high technology reputation of that industry has always been a powerful drive for some countries. Some accounts reveal how these countries support the building of that industry even at the expense of financial considerations. In this sense, the development of an aircraft manufacturing industry in some countries can be better explained by purposeful efforts of national governments than by some derivations of PLC. These efforts include offset agreements like in the case of some Asian countries like Japan. These agreements condition the purchase of foreign planes on the inclusion of local content. Since Asian governments have control over major national carriers, they can coordinate that effort. Another major example is Brazil, which has achieved the development of the world player Embraer. The focus on indigenous R&D capacity from the start (Steenhuis and de Bruijn, 2001), and strategic government support and guidance (Hira and De Oliveira, 2007) played in favour of the consolidation of an indigenous high technology firm – Embraer - in a developing country. A priori, it seems very unlikely that Mexico in its current circumstances could implement an independent strategy of the sort mentioned above. As we are going to explain in section 2.7, Mexico has followed free trade policies in order to promote production for exports, although with poor results in terms of technological development. These conditions make the PLC an adequate framework to analyze the case of Mexico.

Summarizing the concepts seen in this section, it can be argued that the modular architecture of the aircraft is in principle the main enabler of vertical disintegration at the industry level. Inter-firm modularity makes reference to the relationship of different firms carrying out the production of a specific module that ultimately fits the overall architecture of the final product, in this case the aircraft.

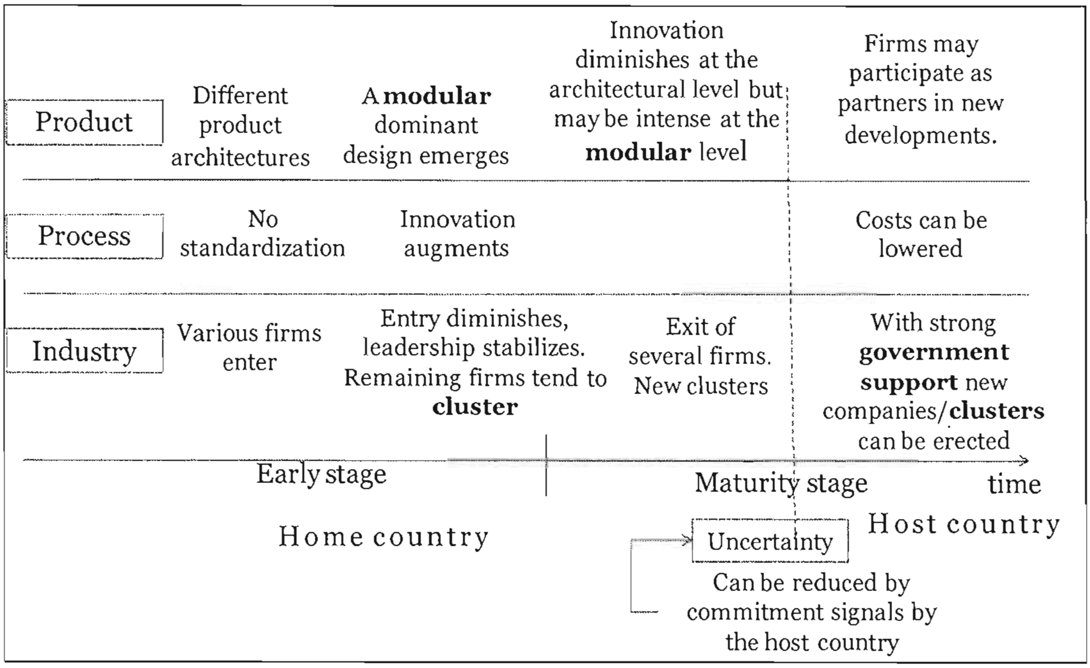
The evolution of the aircraft product architecture and the achieving of a Dominant Design depend on the complex interaction of very different modules and their connection to the overall architecture or system. Some authors stress ever increasing costs for the development of new plane models due to the new knowledge (Prencipe, 1997) needed to accommodate ever increasing new technical, safety and comfort market demands (Esposito, 2004). This reinforces the complex nature of the aircraft (Hobday, 1998). However, even if this is true, other authors suggest that the current Dominant Design has remained unchanged for some decades (Kehayas, 2007). This does not prevent the different modules from continuing to exhibit important innovation features (Niosi and Zhegu, 2005; Fringant and Talbot, 2005) and consequently rising costs and performance. Indeed, According to Murmann and Frenken (2006), when a Dominant Design in a hierarchical and complex product like the aircraft is fixed for some time, innovation should be incremental at the whole system level, while it could be incremental or radical at different subsystem or modular levels.

According to PLC logic, the setting of a Dominant Design opens the door to relocate standardized and codified activities in cost-efficient locations. According to this explanation, it should be expected that Mexico receives an important transfer of that kind of aircraft manufacturing activity. However, it should be stressed that since Mexico does not have important indigenous aircraft manufacturing firms, nor a government drive to establish them or create high-level academic institutions or public research labs in aerospace, the type of activity most likely transferred to Mexico has to be related to manufacturing and not to R&D. Its closeness with the US, a leader in that industry, plus its manufacturing experience, skills and infrastructure make Mexico a natural target for foreign firms trying to reduce costs in the most codified parts of their production processes.

In figure 1.4 we incorporate the technical dimensions of the aircraft and the cluster characteristic of the aerospace industry to our previous model of the PLC-ILC (see figure 1.2). Also, we added the host government involvement as a crucial factor for aerospace companies to overcome the uncertainty to move overseas. This last issue is precisely the subject of the next section.

Figure 1.4

A proposed PLC-ILC for aerospace



1.3 Innovation and Technology Policy (ITP)

In section 1.1.1 we introduced the concept of innovation system, in which it was stressed that different organizations -firms and non-firms- contribute to the knowledge producing effort. As Malerba (2002) suggests, a sectoral production system can eventually become a sectoral innovation system. For that to happen, the development of knowledge-complementary organizations and institutions should be created. As we are going to explain in this section, in order to transit from an aerospace production system to an innovation system some policy measures are needed. This is even truer for newcomer countries with limited innovation capabilities like Mexico. The rest of this section goes as follows: first, section 1.3.1 describes the theoretical bases for policy intervention in the realms of technology and innovation; second, section 1.3.2 discusses the evolutionary character that a policy should show; section 1.3.3 stresses the systemic features of an innovation system; and section 1.3.4 integrates the previous elements to illustrate the main features of an innovation and technology policy.

1.3.1 Pertinence of an ITP

Some economists have long recognized that markets alone are not enough to achieve an optimal allocation of resources in the case of funds for investments (Scitovsky, 1954) and more specifically in investments for R&D and innovation-related activities (Arrow, 1959). Scitovsky (1954) presents a thorough classification of the different external economies (now known as externalities) and explains how in the presence of some of these, predicting future profits is rather difficult and so is the right amount of investment funds. Arrow (1959) explains that innovation-related activities usually exhibit increasing returns, inappropriability, and uncertainty, and thus markets are not well suited to guide the optimal allocation of firms' funds to innovation (and in some cases the markets are not even yet developed). More recently, economists like Krugman (1991), have retaken the concepts of externalities and increasing returns to explain geographical agglomerations of economic activity. A common conclusion of these authors is that when economic activity exhibits the characteristics just mentioned, the government has a role to play in helping the economy as a whole to achieve a better allocation of resources. This conclusion has grounds on historical data, as the works of authors like Scott (1993) Mowery and Rosenberg (1995) show. The first author stresses that one of the components that made possible the advanced high-technology industrial system in southern California were the "lavish Department of Defense procurements"(p. 55). In their analysis of the role of basic research in the United States, Mowery and Rosenberg (1995) document how in 1985, 48% of basic research was done by universities and colleges (p. 10). Next, we are going to briefly present some of these concepts. Next, we are going to further explain how the very nature of high technology activities deserves other mechanisms to support them other than the market.

One fundamental assumption in mainstream economics textbooks is the existence of diminishing returns, which states that a certain point average costs per unit rise as output grows. Thus when the marginal cost of producing an additional output unit exceeds the marginal income expected from that output unit, production should stop, and companies do not grow anymore. Arthur (1994) explains that this assumption leads to a predictable equilibrium for prices and market shares, and represent an obstacle to the permanent growth of firms. However, in real economic activity there are a lot of activities that exhibit increasing returns, which means that as output grows average cost per unit decreases. Reinert (2007) illustrates this situation:

> "The first copy of a Microsoft product may cost $100 million to produce, copies number two to 200 million – if distributed electronically – may cost only a few cents of less to produce and distribute. High fixed costs create important economies of scale or increasing returns. This, in turn, creates very high barriers to entry for competitors, and leads to an oligopolistic market structure far removed from the standard assumption of economic theory." (p. 108)

Contrary with what happens with diminishing returns, Arthur (1994) argues that the existence of these increasing returns make for multiple equilibrium points and predictably, market shares are no longer guaranteed. Moreover, with the same idea of increasing returns, Arthur (1989) developed a model of competing technologies, to explain how difficult is to predict which one will prevail. He explains that small events that initially may favour the adoption of one of those technologies in the early stages may prove critical for later market dominance of that technology. This introduces us to the concept of path dependence sequence of economic changes that Paul David (1985: 332) defines as a "one [in] which important influences upon the eventual outcome can be exerted by temporally remote events, including happenings dominated by chance elements rather than systematic forces." Without going in depth in the discussion about path dependency, here we want to stress that history matters, and this is more so when increasing returns are in place, because early adopters or developers may prevents or diminish future development of other players (or places). Indeed, Arthur (1989) highlights that early adopters (of nascent technologies) impose externalities on later ones by rationally choosing technologies to suit only themselves (p. 127). Therefore, history matters not only in deciding which players take more relevance, but also in the way in which the technology evolves. The previous quote introduces us to the issue of externalities.

Although the concept of externality is widely used, it is important to clarify the meaning of it, since there are different types, and sometimes different authors mean different things when using the concept. When the "output of the individual producer may depend not only on his input of productive resources but also on the activities of other firms", there are externalities (Scitovsky, 1954: 144). Scitovsky stresses that there are two ways in which this can happen: 1) a direct one in which the activity of the other firm enters directly in the production function; and 2) an indirect one in which the activity of the other firm alters the price of inputs. The former is a technological externality that is now known as a spillover, and the latter is a pecuniary externality. Krugman (1991) cites Marshall (1890) to exemplify the type of externalities that leads to geographical concentration of economic activity. Following the definition put forward by Scitovsky (1954), Breschi and Lissoni (2001) characterize the two first Marshallian externalities as pecuniary externalities, and the third one as a technological externality. While authors like Audretsch and Feldman (1995) claim that technological externalities (known also as spillovers) are present in clusters, Breschi and Lissoni, are careful and recognize that in fact technological externalities may be present, but they not necessarily have to be confined to a certain geographical area.

In the presence of increasing returns and externalities it is very difficult to predict with accuracy future states of affairs, which necessarily introduces the issue of uncertainty. Arrow (1959) highlights uncertainty as an element that prevents the accurate calculus for an optimal allocation of resources to inventive activities. He mentions that "[b]y the very definition of information, invention must be a risky process in that the output (information obtained) can never be predicted perfectly from the inputs" (p. 11). A concept better suited to handle this issue is bounded rationality. Taking ideas from "behavioralists" scientists like Herbert Simon, Nelson and Winter (1992) explain that "real-life decision problems are too complex to comprehend and therefore firms cannot maximize over the set of all conceivable alternatives, [instead], in the short and medium run the behaviour of firms can be explained in terms of relatively simple decision rules and procedures" (p. 35-36). In line with this reasoning, Arthur (1994) stresses that in ill-defined or complicated situation humans look for patterns to simplify the problem and create hypotheses. By putting in practice those hypotheses and evaluating which one achieve a satisfying result (that is not necessarily an optimal result), humans learn by discarding poor performing hypotheses and generating new ones with the benefit of hindsight (Arthur, 1994: 406-408). Therefore, human rationality (and by extension organizational rationality too) is said to be bounded by human cognitive limitations and by the cumbersome amount of information relevant for a given situation.

Evolutionary approaches of economic change (Nelson and Winter, 1982) incorporate the concepts seen above and represent a foundation to explain why and more important how the government should intervene to promote innovation and technological development (Metcalfe, 1994; Teubal, 1997). In broad terms, evolutionary approaches stress two characteristics that should be taken into account when it comes to foster innovation; namely the evolutionary and the systemic character of innovation. As we saw, the first characteristic implies that learning is a process that is not automatic (bounded rationality), takes time, and requires purposeful efforts to set the positive feedback effects (increasing returns) to roll on, and build a virtuous path. In this sense, governments should help firms and other relevant organizations in the building of capabilities that result from those learning processes. Since different stages of the capabilities accumulation process present different challenges, policy measures should vary accordingly. It is for this reason that policy need to evolve. Regarding the systemic nature of innovation, it is well known that no single firm has all the relevant knowledge for innovation. Thus, firms have to seek out for other firms, universities, and research laboratories in order to complement their capabilities and knowledge. We are going to outline the main features of those two broad aspects of innovation and how they should be considered in an ITP.

1.3.2 Evolutionary character of innovation

Within this feature of innovation there are two main emphases. Authors like Metcalfe (1994) have put forward the notions of variety and selection applied to the ITP arena. According to Metcalfe (1994) "The aim of technology policy is... to stimulate the generation of variety through innovation and to ensure that feedback from the selection process does not operate to the detriment of variety creating mechanisms"

(p. 933). Thus, this author uses the evolutionary concepts of variety and selection, and suggests that policy should be targeted to those processes. Other authors like Teubal (1996) and Lall and Teubal (1998) have concentrated in how some policy measures can catalyze learning processes that could eventually upgrade firms' technological capabilities. The difference in these two approaches lies in the degree of technological development of the countries studied. When Metcalfe (1994) talks about variety and selection, he refers to the capacity of a firms' population to regenerate their R&D and innovation routines, while Teubal (1996) and Lall and Teubal (1998) provide guidance to develop that kind of routines on firms without that previous expertise. Given that our study focus is on a developing country like Mexico, we are going to go in depth into the second approach.

A first aspect of evolutionary ITP is the evolution of that policy itself. Teubal (1996) proposes that an evolutionary policy should at least have two stages, an infant stage and a maturity stage. The main objectives of the infant stage of an ITP are spreading endogenous R&D processes in the private sector; nurturing collective, multidisciplinary and cumulative learning process; achieving critical mass of projects; developing policy capabilities; and defining incentives to encourage the adoption of learning routines in the firms (Teubal, 1996: 452). In the infant stage, horizontal policies are recommended to catalyze R&D activity in the economy as a whole. Teubal (1997) defines horizontal policies as market-friendly programs supporting R&D/innovation in the business sector irrespective of industrial branch or even technological area (p. 1163). Lall and Teubal (1998) put forward the concept of market-stimulating technology policies, needed to complement those horizontal policies, and as some sort of intermediate phase before moving into the mature stage. These authors identify the technological problems of some developing countries in the following way:

> "Learning is needed to identify and to gain access to technologies, and to master, adapt and improve upon them. It may involve considerable risk,

> costs and time. Learning and developing routines are incremental and path dependent processes, requiring conscious decisions by firms rather than the mere accumulation of production experience (passive learning-by-doing does exists, but generally plays a small role in capability development). Given these costs and risks, vertical policies may be required to promote entry into activities with "difficult" technologies, and horizontal policies to encourage the undertaking of complex, new technological functions."(p. 1374)

There are three elements of market-stimulating technology policies. The first has to do with setting the priorities of the policy in order to shift the economy from a low to a high technology growth path. This implies the identification of activities that have a significant technological potential and that may generate beneficial externalities for other activities (Lall and Teubal, 1998: 1375). The second has to do with the government efficiently signalling the intended policy by different promotion mechanisms. Finally, the third is the institutional building around those policies. The generation of capabilities within the bodies designing, implementing, evaluating and monitoring the policy, and the set up of new institutions and/or organizations is the third part of the policy (Lall and Teubal, 1998: 1375).

In the mature stage, targeted policies are common place. "In contrast to horizontal programs, targeted programs are focused on a particular sector or technology and their main goal is the creation of a new multiagent structure...Their impact may crucially depend on the prior accumulation of favourable background conditions, including a clear vision."(Avnimelech and Teubal, 2008: 157). Clusters are among the multiagent structures proposed by these authors. Thus, targeted policies have also an implicit regional dimension[21], which is very helpful for our purposes given that we are interested in factors that can help foster aerospace clusters.

---

[21] Interestingly the authors do not remark this regional dimension. Perhaps this is explained by the fact that these authors are familiar with a small country like Israel in which the regional dimension is not much important as for instance in Mexico.

1.3.3 Systemic character of innovation

The other characteristic of innovation and technical change is its systemic character. Since agents have bounded rationality, no single one is able to have all relevant knowledge and capabilities needed for innovation, they have to seek other agents in a continuous basis. A departure from the neoclassical economic theory is the recognition that other agents besides firms, like research laboratories, play a fundamental role in the generation of knowledge leading to innovation. Moreover, institutional patterns of support and communication play a crucial role too. In this sense, governments need to adopt a proactive role in ITP to create synergies among the participants. Based on the national innovation system perspective, Teubal (2002) proposes the following component sub-systems: the business sector; the supporting structure; interactions and links; institutions and markets; and culture and social structure (p. 235). Since the supporting structure and the institutions and markets components have already been addressed, we are going to outline the business sector and the interactions and links (the culture and social structure is out of the scope of this work).

Teubal (2002) considers the business sector to be the "backbone of the system and its restructuring is the central axis of the process of transformation of systems of innovation."(p 236). This clearly recognizes that for-profit firms are the ones that ultimately will materialize innovation by means of their resources, including their routines, knowledge, links and strategy. This author puts also attention on the diversity of this business sector. According to him, achieving a critical mass of firms and at the same time a certain level of diversity is a condition that will facilitate a further restructuring of the sector.

Regarding interactions and links, Teubal (2002) states: "While not denying the importance of non-market links, well functioning of SI also require significant market links e.g. among firms in different stages of production, strategic partnerships or alliances due to technology or other complementarities; or inter-firm links flowing from market-based processes of diffusion of new generic technologies,...the non-market interactive learning is related in some way to market links and market transactions" (p. 237). Similar to the argument of Breschi and Lissoni (2001), that states that most of the knowledge spillovers are mediated by well defined membership exchanges, Teubal (2002) stresses that most transfers of technology have to be made mainly by formal and explicit links.

1.3.4 Theoretical implications of an evolutionary and systemic approach to ITP

In this section the objective is to show which elements of the ITP outline described above may (or may not) apply in the context of Mexico's aerospace. Derived from the evolutionary and systemic perspective presented above, there are some implications for the development of an independent aerospace sector in a developing country like Mexico. In principle, fostering a new sector implies targeted policies. However, according to Avnimelech and Teubal (2008), those kinds of policies are better introduced once the R&D routines have been already promoted in the economy as a whole by means of horizontal and market-building policies. Teubal (1996) mentions that for Mexico the need of an R&D policy was evident in the early 1990s when the country liberalized its trade (p. 449). The logic was that Mexican firms had to upgrade their capabilities to be competitive *vis-a-vis* international firms either in domestic or in international markets. Indeed, Mexican authorities created some programs and institutions directed to the promotion of technology in the years the Teubal (1996) mentions. However, after almost twenty years, the results have been poor (Foro Consultivo, 2000-2006). Therefore, the problem is how to formulate a targeted policy towards the development of an aerospace sector, in an environment in which the R&D activity is underdeveloped.

This situation presents two obstacles. First, if we take the aerospace sector as a techno-economic system in its own, the first priority of the system is to get acquainted with the basic technological activities of the sector. In the same way that Teubal (1996) identified the liberalization of the 1980s to be the time for Mexico as a whole, to put forward R&D activities; it follows that for the aerospace sector a similar event should come up before going into promoting R&D within the sector. Thus, there should be a period of technological learning that anticipates an infant stage of an ITP. Tentatively we are going to call that stage a preliminary stage of technological learning. The second obstacle is somehow a logical sequence of the preliminary stage and also has to do with the poor results of ITP in Mexico. This means that before going into targeted policies (that are more pertinent in a mature phase) there should be an infant stage dedicated to promote R&D (by means of horizontal policies) upon the already technological-experienced aerospace sector.

Although the description just made resembles a linear sequencing, real techno-economic activity requires most of the times some mixing of the policies regardless of the time frame. There are at least two reasons for that. One is that aerospace, although being an old sector, is constantly evolving, and that implies that catching-up requires certain speeding up. No country can afford to wait to promote R&D until all firms are totally acquainted with all technological activities. Second, other countries are also making serious attempts to enter the industry, and being late might mean to be left out in an industry characterized by huge scale economies (partially reflected by "regional-economies") that engenders cumulative advantages, thus reserved for few players (Krugman, 1986: 7-8). Keeping in mind that these three proposed stages - preliminary learning, infant stage and mature stage- overlap, the next step is to describe what type of policies will be better suited to accomplish the objectives of these stages.

It seems clear that horizontal policies, market-building policies and technological infrastructure policies (Justman and Teubal, 1995) are greatly needed in the first two phases proposed. Teubal (1997) states that the objective of horizontal policies is the "promotion of socially desirable technological activities (SDTAs) and associated management and organizational routines within business enterprises/.../SDTAs include firm-based R&D (or, more generally, innovation), technology transfer, adoption, and diffusion..."(p. 1165). Although Teubal (1997) does not limit horizontal policies to small and medium enterprise (SME), he did put emphasis on SME as the ones that may face major obstacles in developing R&D and management capabilities. However, in the aerospace sector most tier 1 and tier 2 firms are large corporations; perhaps some suppliers (often specialized) may enter into the category of SME. In this sense "big firms" should also be addressed heavily in a horizontal policy for the aerospace sector in Mexico.

Teubal (1996: 453) highlights that "building markets refers first and foremost to markets of services supporting R&D and innovation-consultancy and advisory services; tests and analysis, and financial services". Justman and Teubal (1995) define technological infrastructure as "a set of collectively supplied, specific, industry-relevant capabilities, intended for several applications in two or more firms or user organizations. They are embodied in human capital, and include also elements of physical capital and knowledge (p. 260). Given that Mexico is relatively new to the industry, it is very likely that those kind of specialized services and dedicated infrastructure exist in limited amounts in the country or they are even non-existent. Therefore, in this regard, the efforts of a policy should be directed to the construction of those specialized services and infrastructure, since they will not be an automatic market consequence of the presence of aerospace subsidiaries.

Also, Teubal (1996: 453) argues that "Market-building is relevant for only a small fraction of the R&D process itself – for numerous reasons the penetration of R&D into the economy is done first and foremost by user organizations rather than by specialized suppliers of knowledge (this may be increasingly be less true due to the emergence of world markets for certain types of technology, a result of the process of globalization)". This means that firms and related organizations are the main actor in the R&D process. The R&D carried by institutional suppliers is somehow complementary. What Teubal mentioned in parenthesis in the quotation creates a paradox though, at least for developing countries. If R&D is the best vehicle for learning, the fact that firms need to do less R&D (given that specialized suppliers fulfil that role, at least partially) limits their cognitive process of learning. This implies that specialized suppliers are becoming more and more important organization that should be supported also in terms of R&D routines.

If the business sector is the backbone of the innovation system, it is normal that policy efforts be directed to help firms (and other private organizations involved directly in the added value) in their capabilities accumulation. Apparently the identification of the business sector is a straightforward exercise. Nevertheless, the nature of the firm deserves some discussion. Many of the aerospace firms established in Mexico are part of a much larger network under a well-defined corporate mandate. These companies are more and more distributing different tasks among its subsidiaries in a way that requires a high degree of coordination. Since part of the policy should be precisely to encourage firms to carry out activities with more technological content, an ITP should pay attention not just to the subsidiary and the current state of its capabilities, but also to the capabilities the headquarters could eventually transfer to the subsidiary or even the capabilities that the subsidiary could eventually develop that could be even novelty for the corporate parent. Apparently no single aerospace subsidiary in Mexico has the freedom to nurture more complex capabilities than the ones it already has. As an example of a subsidiary that has strategic manoeuvre to enhance its capabilities, Pratt and Whitney Canada, the subsidiary of a US firm, is a very active player in aerospace innovation at a world scale. One implication of this discussion is that policy makers should have communication not just with subsidiaries but also with corporate headquarters. This pattern of communication among these actors should eventually lead to learning not only in firms, but also in government agencies, which have to learn from their experiences promoting the sector (both, good experiences and pitfalls).

Under these circumstances, it is clear that subsidiaries have to be a crucial element in the learning processes. Thus, in the short run a great deal of the policy efforts should be directed to promote the transferring of some parts of multinationals' R&D activities to their Mexican subsidiaries. Nevertheless this is not a straightforward result, because multinational firms will be unwilling to transfer R&D activities in an environment in which complementary assets, infrastructure, and R&D services are absent. Indeed Lall and Teubal (1998) clearly illustrate this situation:

> "In developing countries...not only is the internal base of knowledge for mastering technologies relatively weak, the supporting network of other enterprises, institutions and human capital is also underdeveloped. This makes even relatively "easy" tasks difficult, costly and unpredictable. With industrial maturity there is a shift in technological effort from these to more demanding tasks or minor or major innovation, calling for higher levels of skill and more formal R&D effort."(p. 1371)

Therefore, to encourage foreign firms to transfer R&D activities it is important to develop a technology infrastructure. In the case of aerospace, specialized suppliers, research laboratories and universities with modern infrastructure (like wind tunnels and state-of-the-art machinery and electronics), are agents whose capabilities must be supported, and in most of the cases created given their absence. However, building that technology infrastructure takes some time and huge amount of investment. Thus, it is not likely that that kind of infrastructure and supporting agents will be in place soon. For this reason it is important to underline the fact that a preliminary stage of technological learning is needed before embarking in a more R&D-oriented stage.

CHAPTER II

OVERVIEW OF THE AIRCRAFT INDUSTRY AND INNOVATION SYSTEM IN MEXICO

The objective of this chapter is to put in context the evolution and current situation of the aircraft industry in Mexico. Some historical facts are shown along with the main attraction factors, policy measures and incentives. Figures of main indicators like exports, number of firms, employment are presented and compared with other developing countries like Brazil, China and India. A brief characterization of the major firms in the main locations is presented. Additionally, the main characteristics of Mexico's innovation system are presented. In the end, some historical examples about new comer countries in aerospace and the automobile industry in Mexico are presented as historical implications that should be kept in mind when proposing policy measures.

2.1 Historical attempts at building an indigenous aircraft industry (1910s-1940s)

Historical accounts reveal that Mexico had an interesting attempt at building aviation and aerospace sectors back in the 1910s. Indeed, the country bears some records in these areas. For instance, in 1910 in Mexico City took place the very first plane flight in the country (on a French plane) that was also the first flight ever in Latin America; the first plane ever used in actual military air-naval bombing was used in a battle in the Sonora coast; Francisco Madero, winner of presidential elections after the fall of Dictator Porfirio Díaz in 1911, was the first head of state to ever flight in a plane[22]. More important perhaps, is the figure of Juan Guillermo Villasana, a Mexican engineer who, among other achievements, designed and patented a propeller ("hélice

[22] Archipiélago. 2006. "Inicios de la aviación en México". *Archipiélago*. 14 (54): 55-59. Retrieved from: <http://www.journals.unam.mx/index.php/archipielago/article/viewFile/19897/18888>

Anahuac") that was exported to countries in Central and South America and Japan[23]. Under the presidency of Venustiano Carranza, and the leadership of Villasana, an official aeronautics construction facility was created (*"Talleres nacionales de construcción aeronaútica"*) in 1915[24]. In this facility, 100% Mexican made planes, called Series A, B to H were manufactured. One of these planes is said to be employed for the very first time in the world as a commercial courier delivery servicing the Mexican postal service (Jáuregui, 2004: 138).

Although the facility was able to develop an indigenous helicopter and a multipurpose plane, it fall in demise, and was acquired by Canadair in 1941. It was shortly nationalized again in order to pursue indigenous projects for the military, but agreements with the US, who was very active in World War II, forced to redirect activity at servicing US planes. The manufacturing of indigenous models (or for that matter of any model) ended and the aerospace activity in Mexico was dedicated to maintenance and service of planes brought from the US[25].

Therefore, it can be said that there is a break in the accumulation process of aerospace capabilities. In this sense, later activity in the sector is not dependent on this previous one. 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.

---

[23] Hernández Domínguez, E. J. 2007. "Alas de México, Los Talleres Nacionales de Construcción Aeronaútica". *Excelsior*. February 11, 2007, sec. 6. Retrieved from: <http://www.inehrm.gob.mx/pdf/exc_alas_mexico.pdf>

[24] Ibid

[25] Ibid

2.2 Early attraction of manufacturing subsidiaries (1960s-2000)

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[26]. One of the first documented cases was the facility opened in Mexicali, by Allied Signal, a US company which was a supplier of another American firm, Garrett aero-engines[27]. The main motivation was to lower costs following the example of companies in other industries like auto parts and electronics that had already some years of experience in south of the border operations. Thus, the *maquiladora*[28] program was the main attractor to these first companies that opened manufacturing facilities in Mexico and they were located in the border.

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, as it was later corroborated in the field study, 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

---

[26] Ornelas, S. L. 2010. "Mexico's aerospace industry climbs higher", *MexicoNow*, September-October, 2010, 21-25.

[27] Flight International. 1988. December 10. Retrieved from: <http://www.flightglobal.com/pdfarchive/view/1988/1988%20%203564.html?search=mexicali%20allied%20signal>

[28] The *maquiladora* is a fiscal regime established in Mexico back in the 1960s that allows duty-free inputs under the condition of subsequent export.

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. US California 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.

2.3 Explicit intent to foster the aircraft industry (2000-2005)

In year 2000, there were only 20 aerospace companies in Mexico, and they exported products worth 150 million USD to the United States[29]. 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[30]. However, it was until the next presidency that the main efforts in terms of policy support were materialized. 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. Although it is difficult to assess in an objective measure, according to interviews with the firms, the feeling is that these promises have been only partially fulfilled, with the last one to a much lesser extent.

---

[29] Ramírez, F. 2005. "Alas mexicanas". CNN Expansión.com, December 21. Retrieved from: <http://www.cnnexpansion.com/xslTransform.php?xmlurl=http://www.expansion.com.mx/articulo.asp?cve=931_31&xslurl=http://www.cnnexpansion.com/xsl/exparticulo.xsl>

[30] Ibid

2.4 A visible support policy (2006-date)

It was by the middle of the decade that concrete steps to support the sector were materialized. Aware of the fact that aircraft manufacturing would need some extra attracting factors in order to migrate to Mexico in important numbers, government authorities have devised support in terms of infrastructure and incentives. In terms of infrastructure, the main steps have been the building of the Querétaro aerospace park (now occupied by Bombardier), located near the airport, and the development of education and training programs related with aeronautics. Regarding the latter, a brand-new aeronautics university has been created in the city of Querétaro. Established universities in other cities of the country opened engineering degrees in aeronautics as well. Also, some training institutes have opened programs for aeronautics technicians, and some institutes have even been created expressly for that purpose, like the CENALTEC in the city of Chihuahua. In this sense, the development of a work force prepared in aeronautics has been taken as an important step in the policy to foster the sector. However, it is important to mention that currently, most of the firms employ engineers and technicians from diverse backgrounds. The educational infrastructure that has been created is taught to be important in the years to follow.

Although there are no incentives targeted specifically to the aerospace industry, firms in this industry can apply to different programs that are available to other firms irrespective of the sector they operate in. The Ministry of Economy and Promexico[31] present the incentives to invest in Mexico under four headings: support for R&D, fiscal credits, training support, and local-government incentives[32].

---

[31] Promexico is an office dependent of the Ministry of Economy, which is in charge of both, promoting Mexico as a recipient of foreign investment, and helping Mexican firms that want to go international.
[32] Promexico. 2010. Power point presentation.

One of the most important attractors is precisely the first one. From year 2001 to 2009 there was a fiscal stimulus program[33] 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 specialized personnel essential for the attainment of the previously established objectives (Dutrénit, 2009: 250). This program was changed in 2009 and now it is called fund for technological innovation[34]. This new program started with a budget of approximately 210 USD million in 2009 (2,500 million Mexican pesos), and has three subdivisions: the technological innovation program for high value-added business targeted to small and medium enterprises (24% of the fund); the development and innovation of precursor technologies program targeted to firms with links with universities and research centres (28%); and the competitiveness program targeted to big firms (48%)[35]. Starting in 2009, the new R&D program does not reduce taxes; instead, it gives direct financial support prior to initiation of the project. Dutrénit (2010)[36] reports that for year 2010 these three programs amounted to 190 USD million, supporting 707 projects in 543 firms. Figures for aerospace are 5.3 USD million supporting 25 projects[37]. 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.

The second group of incentives are fiscal incentives that are awarded to firms that either do strategic projects, capital investments, or exports. The third group has to do with labour training. And fourth, state and local governments have implemented incentives like infrastructure, land, and tax credits on payroll and property. Under the

---

[33] In Spanish, Programa de estímulos fiscales (PEF).
[34] In Spanish, Fondo de innovación tecnológica (FIT)
[35] Olivares Alonso, E. 2009. "El CONACYT reorienta los planes de apoyo a empresas", January 14. Retrieved from:
<http://www.jornada.unam.mx/2009/01/14/index.php?section=politica&article=015n1pol >
[36] Dutrénit, 2010, Power point presentation.
[37] The number of firms and the specific fund that was applied were not available.

head of Promexico and with representation of different Mexican states, the federal government promotes the country in international air-fairs.

2.5 The Mexican aircraft industry in figures

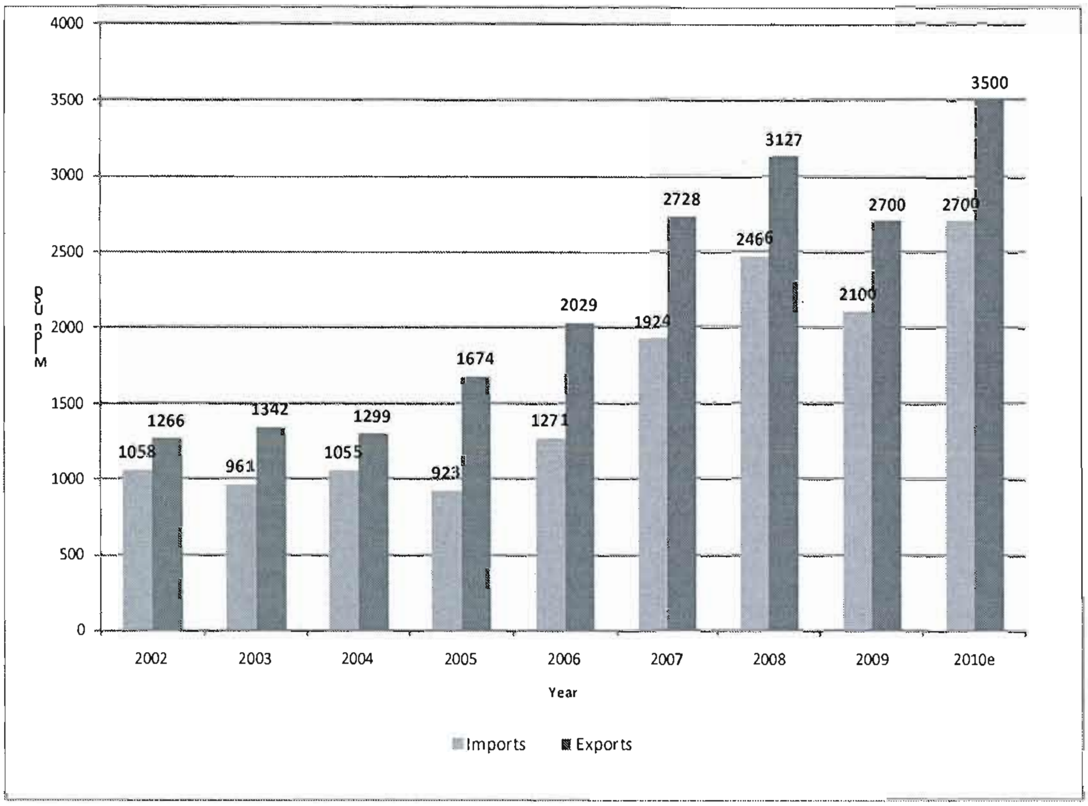
According to the FEMIA[38], product exports of aerospace firms based in Mexico represented approximately 3.5 billion USD for the year 2010[39]. In Mexico the exports value is a figure that represents production since almost all sales in this industry are exported, at least for the moment. Available data for year 2008 reveals that Brazil[40] industry had an output of 7.55 billion USD from which 90% were exports (Maculan, 2010: 1). For year 2008 Mexico had exports for 3.127 billion USD, thus if we take the exports from Brazil, we have that Mexico 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: 46) which represents 39% of the Mexican exports. Therefore, Mexican exports are almost half the exports of a country that has an OEM like Brazil.

In terms of evolution it can be seen in figure 2.1 that from year 2006 on, the industry started an upward trend in exports. If we relate this trend to the historical facts laid out in the previous sections, it can be argued that the strong government promotion did coincide with the increase in the output. However, figure 2.1 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[41].

[38] FEMIA is a non-profit association that group aerospace firms in Mexico (Federación Mexicana de la Industria Aeroespacial).
[39] FEMIA web site: http://www.femia.com.mx/
[40] Although Brazil, China and India do not present identical aerospace circumstances compared to Mexico –Brazil has Embraer a leading OEMs, and China and India have final assemblers, e.g. Comac and Hal respectively-, these three developing countries are indeed competitors in terms of attraction of new aerospace investments. For this reason some comparison with these three countries are pertinent.
[41] FEMIA. 2009. Report presented at the Foro Internacional clusters 2009. August 13, Reynosa-McAllen.

Figure 2.1

International trade of the Mexican aerospace industry (Years 2002-2010, USD millions)

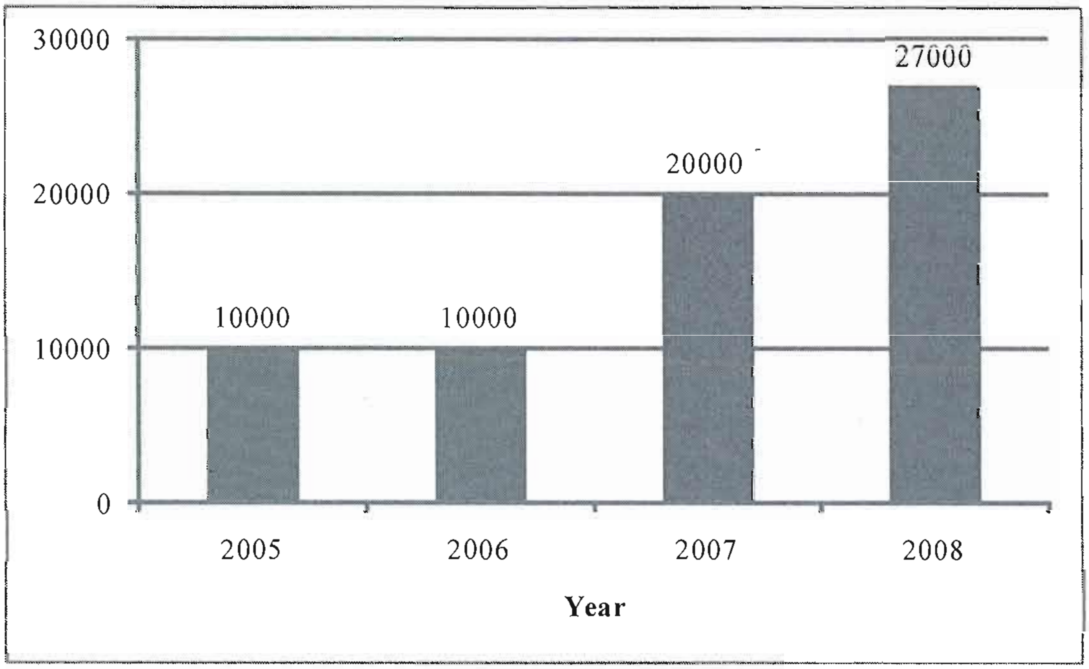


Source: FEMIA web page (2010) with data from DGIPAT (General Direcction of Heavy and High Technology Industries) with data from DGCE (General Direcction of External Commerce) from the Ministry of Economy.
*Figures in USD millions.

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

Figure 2.2

Employment in the aerospace industry in Mexico



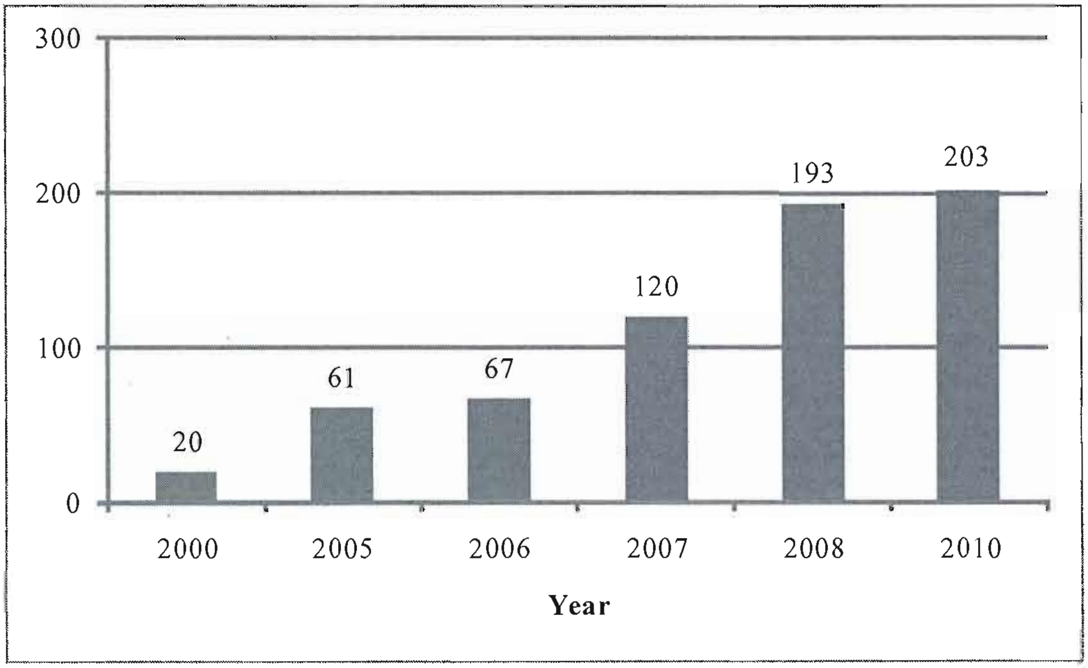
Source: data from Promexico web site: http://www.promexico.gob.mx/wb/Promexico/aeroespacial

Information for the year 2010[42] regarding the number of organizations related with aerospace reveals that there are 203 located in sixteen Mexican states. In figure 2.3 it can be seen how the number of firms has grown rapidly since year 2006. Let's remember that in year 2000 there were only twenty 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).[43]

[42] FEMIA web site: http://www.femia.com.mx/
[43] 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 firms.

Figure 2.3

Number of firms in the aerospace industry in Mexico



Source: data from:
Promexico web site,
FEMIA web site,
Ramírez, F. 2005. "Alas mexicanas". CNN Expansión.com, December 21.

However, in addition to private productive firms, this list also contains organizations such as universities, research centers, airlines and sales representative offices. For example in Mexico City there are two universities UNAM (Autonomous National University of Mexico), and IPN (National Politecnic Institute) that are classified as E&D because they have degrees and laboratories totally or partialy dedicated to aerospace; also, the five remaining organizations are either airlines or sales offices that sell imported spare parts, and for that reason they are classified as MRO. 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 M. After doing the field work, it was also evident that some firms that are classified as M, are indeed firms that may give some service (e.g. heating treatment to metal parts) to firms that do directly participate in aerospace activity. Thus, the number of aerospace productive firms should be about 150. Moreover, from this last figure, some firms are only partially dedicated to aerospace (from which some are just metal workshops). Thus, although it is difficult to calculate, the actual number of firms which are devoted completely to aerospace has to be well under 150.

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 all the 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. In any case, the number of companies established in Mexico and the rate of growth of this number, reveals the importance of the country for the world sector. This assertion is also supported by a study shown below that reports the number of aerospace investments in different parts of the world.

According to the consulting group AeroStrategy[44] (figure 2.4), from 1990 to 2009, Mexico is the country that has received more manufacturing investments in aerospace.[45] Other countries that are pursuing aggressive strategies include China, second, Russia, fourth, and India in fifth place. It is important to note that that study takes into account the discrete number of investments and not the actual amount invested. For instance, since China hosts an Airbus manufacturing facility to assembly a complete A320 plane, it seems logical to expect the level of such investment be higher than the ones that have been done in Mexico so far. The important point in this piece of information is to stress that several players are setting foot in Mexico, and eventually that may provide a major ecosystem of different firms active in the country.

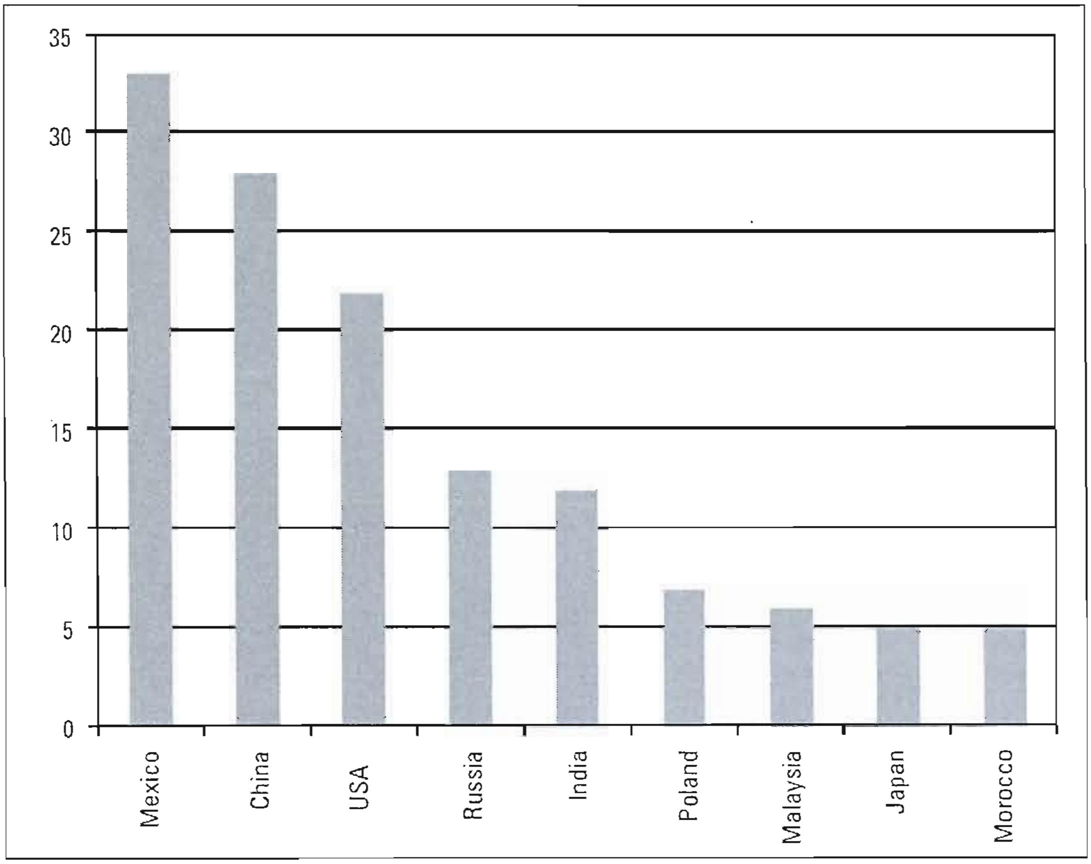
---

[44] Aerostrategy. 2009. "Aerospace globalization 2.0: the next stage", September, pp 1-8. Retrieved from: <http://www.promexico.gob.mx/work/sites/Promexico/resources/LocalContent/1092/2/Aerostrategy2.jpg.pdf>

[45] 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: p. 2-3).

Figure 2.4

Number of manufacturing investments in aerospace, period 1990-2009



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 2.5). Again, we should be cautious with this figure, since countries like Brazil, which is ninth, has an OEM like Embraer, thus the amount and the level of engineering/R&D may be bigger.[46] Moreover, recently Honeywell[47] and General Electric[48] have announced the opening of research labs in China. While these two new investments will make China has more R&D investment, the important point is that both Honeywell and GE will form a joint venture with a Chinese counterpart. Therefore, those investments will support the development of capabilities in local firms. Indeed, 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.

---

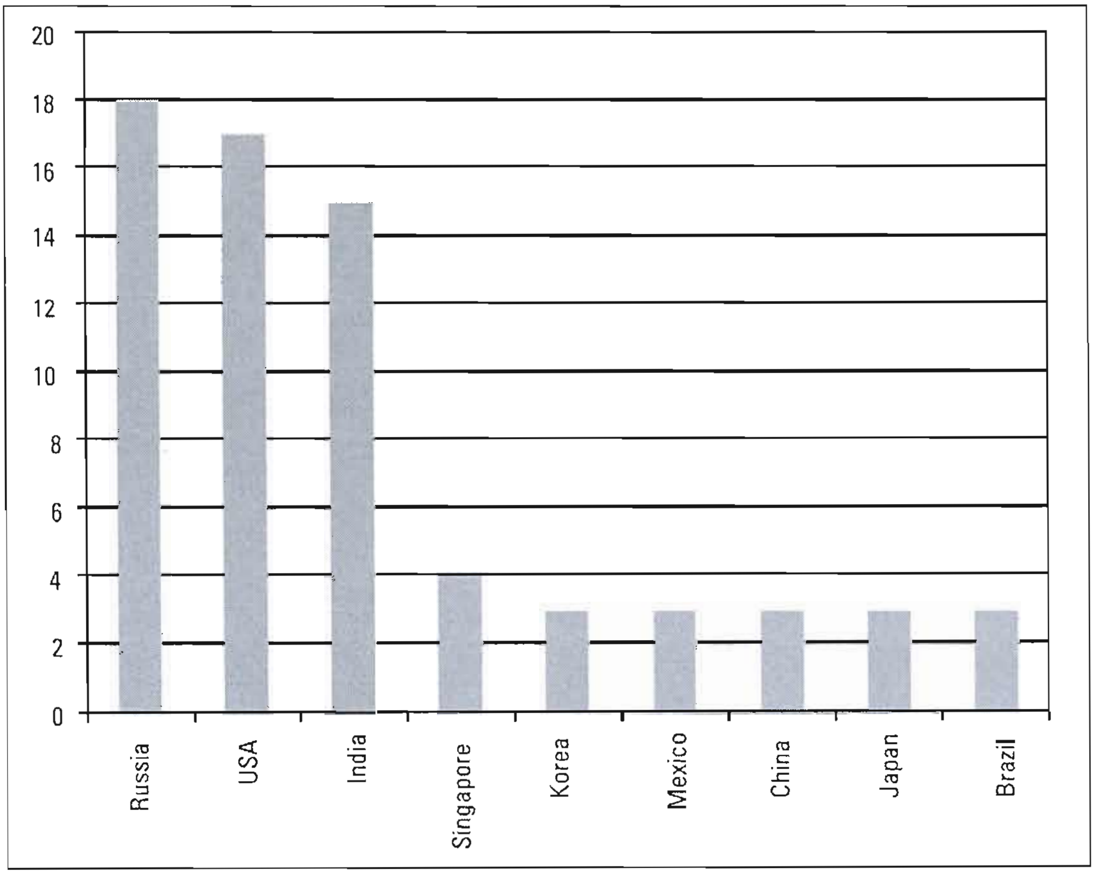
[46] However, Bernardes and Guilherme de Oliveira (2003) explain that by corporate policy, Embraer purchases all the commercial systems and technological packages that are included in its planes, because these are not considered as a competitive differential for the company; consequently, the innovation strategy of Embraer, is directed more to technological adaptation than to development of creative innovation (p. 506). In this sense, having an OEM assembler sure gives place to R&D activities, but the nature of these activities depends on other factors too.

[47] Gupta, A. and Wang, H. 2010. "Comac: China's challenge to Airbus and Boeing", *Businessweek*, June 30. Retrieved from: <http://www.businessweek.com/globalbiz/content/jun2010/gb20100630_522595.htm >

[48] Barboza, D., Drew, C., and Lohr, S. 2011. "G.E. to share jet technology with China in new joint venture", *The New York Times*, January 17. Retrieved from <http://www.nytimes.com/2011/01/18/business/global/18plane.html>

Figure 2.5

Number of engineering/R&D investments in aerospace, period 1990-2009



Source: Aerostrategy (2009)

The previous discussion leads us to the issue about the type of firms that are being established in the country. As it was shown in GRAPHS 4 and 5, Mexico has a similar value as China for the number of investments in manufacturing, as well as in Engineering and R&D. However, there are two main aspects that are not captured by those indicators. First of all, contrary to Mexico, countries like China, Brazil and India have final assembler firms. The most well known case is that of Brazil which has a national owned firm Embraer; a leading world company able to design and integrate whole planes. China and India also have final assemblers, AVIC and HAL respectively. China has foreign firms forming joint-ventures with local firms to assembly licensed planes, and national-owned firms that pursue proprietary models. Examples of the first case are Embraer and AVIC joint-venture to assembly the ERJ-145 regional bi-reactor in Harbin[49], and the Airbus and AVIC joint-venture for the final assembly of A320 planes in Tianjin[50]. Examples of the second case are the regional jet ARJ-21 whose first delivery has been delayed[51], and the recently announced C919 (a single aisle plane with over 150 seats that will compete with the A320 and the B737) that is scheduled to flight in 2014; both developed by Comac[52]. India has the Hindustan Aeronautics Limited (HAL), a government-owned firm, which is mainly concentrated on the military sector, but who also has civil capabilities able to integrate planes under licence like the Dornier 228[53].

---

[49] Tison, M. 2010. "La rivalité Embraer-Bombardier se transporte en Chine", *La Presse*, November 18. Retrieved from: <http://lapresseaffaires.cyberpresse.ca/economie/transports/201011/18/01-4343853-la-rivalite-embraer-bombardier-se-transporte-en-chine.php>

[50] Bradsher, K. 2006. "Airbus and China select assembly plant site", *The New York Times*, June 9. Retrieved from: <http://www.nytimes.com/2006/06/09/business/worldbusiness/09airbus.html>

[51] Sobie, B. 2009. "Querétaro prepares for massive aerospace growth", *Flight International*, April 20. Retrieved from: <http://www.flightglobal.com/articles/2009/04/20/325253/queretaro-prepares-for-massive-aerospace-growth.html>

[52] Einhorm, B. 2010. "China takes aim at Boeing and Airbus", *Businessweek*, November 24. Retrieved from: <http://www.businessweek.com/magazine/content/10_49/b4206017295460.htm>

[53] Govindasamy, S. 2010. "HAL sets sights on global presence", *Flight International*, March 1. Retrieved from: <http://www.flightglobal.com/articles/2010/03/01/338726/hal-sets-sights-on-global-presence.html>

Two issues are salient in the above description. First, the three countries, Brazil, China, and India, have at least one final assembler firm while Mexico does not. Although Bombardier is a final assembler, it does 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.[54] 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.[55] 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 relies in the activities of foreign subsidiaries with just few

---

[54] Since the announcement of the establishment of the Bombardier plant in Querétaro, government officials predicted that a whole plane would be assembled in Mexico by that company by year 2012. That event is unlikely to happen. The point we want to stress is that it seems that government officials think that to assembly a plane is the logical next step for a manufacturing firm. It is difficult to predict if Bombardier (or for that matter any firm in Mexico) will find the technological capabilities (its own and the surrounding infrastructure), the financial logic, and market imperative to do the final assembly in Mexico; however, if international experience is a guide, it seems very unlikely given the absence of a strong locally-financed partner firm and the still embryonic conditions of aerospace supply in Mexico.

[55] In general terms as will be explained in section 4.3, since the aftermath of the economic crisis of 1982, all Mexican presidencies have followed privatization of public firms under the framework of liberalization policies. The few remaining government-owned firms are related with energy and health (e.g. PEMEX in petroleum; CFE in electricity; Birmex in vaccines). A new national government will be elected in 2012. If the current political party (right-wing) remains in power or if the long-lasting previous ruling party (the centrist PRI) returns, the more likely scenario will be the continuation of those privatization policies since those two political parties were the ones that agreed on that agenda, and do not seem to be changing direction any time soon. If the left-wing political party wins, the more likely scenario will be to stop privatization but it will not be able to agree on an agenda to build new government-owned firms.

exceptions of local firms dedicated to minor activities (although with interesting integration capabilities)[56].

---

[56] We will see some examples in the following paragraphs. Other interesting examples of local firms with integration capabilities were found while doing the field study, unfortunately for confidentially issues we cannot illustrate them.

2.6 Characteristics of aerospace firms and Mexican regions

The aerospace firms located in Mexico are distributed in 16 Mexican states (Mexico has 31 states and a Federal District). Table 2.1 lists the states that have aerospace firms and shows the principal cities where the firms are located within each state. Also the table shows the classification of these firms according to Manufacturing (M), Maintenance, repair and overhaul (MRO), and Engineering and development (E&D). The total number of firms given in table 2.1 is older (it is for year 2009) and smaller than the one given previously for year 2010. For the new figure there are still no specifications about M, MRO, and E&D.

Table 2.1

Mexican Aerospace Industry by Activity and State, 2009

STATE	Main cities	(M)	(MRO)	(E&D)	TOTAL
BAJA CALIFORNIA	Tijuana Mexicali	48	1	2	51
SONORA	Guaymas/Empalme, Nogales	32	0	0	32
CHIHUAHUA	Chihuahua, Ciudad Juárez	25	0	0	25
NUEVO LEON	Monterrey MA	13	7	4	24
QUERETARO	Querétaro MA	8	3	3	14
TAMAULIPAS	Matamoros, Reynosa, Nuevo Laredo	10	1	0	11
MEXICO D.F.	Mexico D.F.	0	5	2	7
COAHUILA	Saltillo, Ramos Arizpe	5	1	0	6
JALISCO	Guadalajara MA	2	0	3	5
SAN LUIS POTOSI	San Luis Potosí	5	0	0	5
STATE OF MEXICO	Toluca MA, Mexico City MA	0	5	0	5
PUEBLA	Puebla	3	0	0	3
YUCATAN	Mérida	3	0	0	3
AGUASCALIENTES	Aguascalientes	2	0	0	2
GUERRERO	Zihuatanejo	0	1	0	1
ZACATECAS	Zacatecas MA	1	0	0	1
TOTAL		152	26	18	194

(M) = Manufacturing
(MRO) = Maintenance, Repair and Overhaul
(E&D) = Engineering and Design.
MA: Metropolitan Area
Source: FEMIA (2009)

As it was explained before, these figures overestimate the actual number of for-profit productive firms completely dedicated to aerospace. Both MRO and E&D include non-firms organizations (like universities, research centres, sales offices, and airlines), also M includes firms that are not completely devoted to the aerospace sector, usually metal mechanic firms that are listed as potential suppliers or that only supply a limited amount of pieces for aerospace purposes. Therefore, it is difficult to know the exact number.

As will be explained in section 4.2 we selected four states for the field study. Those four states are Baja California, Chihuahua, Nuevo León and Querétaro. In order to illustrate the kind of aircraft activity that has been carried on in Mexican firms, we are going to present the public information about the activities of some important firms established in the locations just mentioned. We have chosen to present Bombardier: only the OEM final aircraft assembler of the big four; General Electric and Honeywell: two firms that stand out for their testing and R&D activity; Cessna and Hawker Beechcraft: although not the only OEM of business jets established in the country, they are working with composite materials; MD Helicopters: OEM for this type of aircraft; ITR, Volare Engineering and Frisa: national-owned companies with important projection to the future.

Baja California

The state of Baja California is a logical choice since it is the place with older firms in the sector (like Rockwell Collins) and with almost a quarter of the companies. Tijuana and Mexicali are the most important cities in economic terms. The former is the most populated city in the state while the latter is the political capital of the state. Both cities border the state of California, US; however, Tijuana is closer to big US urban centers like San Diego. The Autonomous University of Baja California has an engineering degree in aerospace in its Mexicali campus, although the Tijuana campus has several other engineering degrees.

Located in Mexicali, Honeywell installed a 40 million USD testing center in Mexicali, which employs 300 Mexican engineers to perform system integration tests for the new Airbus A350[57].

Volare Engineering is a spin-off that benefited from the experience gained by some employees by working for a foreign subsidiary. The company is 100% Mexican and designs and manufactures aircraft interiors and accessories. This firm was founded by three Mexican ex-employees of a Dutch firm that closed its operation in Mexicali after the September 11, 2001. Among the products that Volare designs and gives manufacturing support are kitchenettes, closets, cabinets and meal carts for flight attendants. Their main clients are in the US and Canada[58].

Querétaro

The state of Querétaro is the one that has received more support from the federal government. It has the National University of Aeronautics, and an aerospace industrial park adjacent to the airport. One of the advantages of Querétaro is its closeness to Mexico City (approximately a two hour drive), which provides international flights to Europe and North America and in which good engineering universities, like the National Polytechnics Institute, are located. Also, climate conditions and quality of life are often cited as advantages of this colonial city.

Bombardier started activities in Querétaro in 2006. From the four big aircraft assemblers –Airbus, Boeing, Embraer and Bombardier- this firm is the only that has some kind of productive activity in the country. The inauguration of the Querétaro plant had media coverage in Mexico, and was used as a strong signal to the world that the country wanted to be a player in the industry. Currently (2010), the plant

---

[57] Negocios, 2010. "Mexican aerospace industry: reaching higher altitude", *Negocios*, October, Promexico, México. pp 22-25.

[58] Negocios, 2011. "Volare Engineering: a high-flying company with solid foundations", *Negocios*, December 2010-January 2011, Promexico, México. pp 34-35.

employs approximately 1,200 workers and is in charge of the manufacture of structural aircraft components, including the Global business jet family aft fuselage, the Q400 NextGen aircraft flight control work package (rudder, elevator and horizontal stabilizer) and the CRJ700/900/1000 NextGen and Challenger 605/850 aircraft rudders, as well as main harnesses and electrical sub-assemblies for Bombardier business and commercial aircraft[59]. In September 2010, Bombardier announced that the manufacturing facilities, tools and equipment were already ready in Querétaro for the manufacturing of its first all-composite materials Learjet 85[60]. The responsibilities of the Querétaro plant will be the manufacturing of the fuselage lay-up, subsystem installation, wiring harness fabrication and installation, wing assembly, and horizontal and vertical stabilizer assemblies[61].

General Electric has a long history in Mexico. It started operations in 1896, although its division for aerospace, GE Infrastructure Querétaro (GEIQ), was only created in 2000. Interestingly, this GE division was the result of a partnership with a public technology centre located in Querétaro (CIATQ), although it was always 100% GE property. GEIQ provides engineering services in technical disciplines such as mechanics, electrical thermodynamics, electronics and software development. The firm stands out for its flight simulator, unique in Mexico, which is used to test the software developed in the engineering center itself[62]. The center employs 1,300 engineers (all of them Mexican), and it is dedicated to designing airplane turbines and power generation systems. At the moment, the main programs for the aviation

---

[59] Dana-Jo. 2010. "Bombardier Inaugurates Learjet 85 Aircraft Component Manufacturing Facility in Querétaro Mexico", *Aviation News*, October 22. Retrieved from: <http://www.aviationnews.us/articles.php?art_id=12424&start=1>

[60] Bombardier web site: < http://www.bombardier.com/fr/aeronautique/galerie-de-presse/communiques-de-presse/details?docID=0901260d8013a499>

[61] Dana-Jo. 2010. "Bombardier Inaugurates Learjet 85 Aircraft Component Manufacturing Facility in Querétaro Mexico", *Aviation News*, October 22. Retrieved from: <http://www.aviationnews.us/articles.php?art_id=12424&start=1>

[62] Negocios, 2011. "A home for technology", *Negocios*, December 2010-January 2011, Promexico, México. pp 36-37.

industry are GEnx for the Boeing 787, CF34-10A for the ARJ21-700, and GP7200 for the Airbus A380[63].

Located in Querétaro, ITR is a MRO firm, which has been active since 1998 overhauling Pratt and Whitney JT8D engines. It has also some experience in manufacturing turbine pipes for Honeywell and Rolls-Royce. Recently it announced plans to open in 2011 a plant to manufacture low-pressure turbines and expand its pipe production[64].

Nuevo León

The metropolitan area of Monterrey, the capital state, concentrates most of the aerospace firms in Nuevo León. Monterrey counts with renowned public and private higher education institutions like the Autonomous University of Nuevo León (UANL) that has an aeronautics engineering degree, and the well known Instituto Tecnológico de Monterrey that teaches several engineering degrees. The UANL plans to build a center of research and innovation in aeronautics engineering that will be located in the Monterrey airport[65].

Among the aerospace firms located in the metropolitan area of Monterrey, a major success case in terms of advanced supply is Frisa which manufactures rings (that are later reworked by other firms) to be assembled in aeronautic engines[66]. MD

---

[63] Ibid

[64] Sobie, B. 2009. "Querétaro prepares for massive aerospace growth", *Flight International*, April 20. Retrieved from: <http://www.flightglobal.com/articles/2009/04/20/325253/queretaro-prepares-for-massive-aerospace-growth.html>

[65] Torres, A. 2011. "Avanza industria aeroespacial de Nuevo León", *El Economista*, January 25. Retrieved from: <http://eleconomista.com.mx/industrias/2011/01/25/avanza-industria-aeroespacial-nuevo-leon>

[66] Ibid

Helicopters, a US based OEM of helicopters, manufactures the fuselages of its helicopters in Monterrey[67].

Chihuahua

Other developments have been also taking place in Chihuahua. Although Ciudad Juárez has a bigger share of the state's production, so far big names in aerospace are established in the capital city of Chihuahua. The Autonomous University of Chihuahua in its Chihuahua campus has opened the engineering degree in aerospace. Also, a training center, CENALTEC, is devoted mainly to aerospace technicians. The state has also other higher education technical institutes and a public research centre in advanced materials.

Two OEM of business jets are currently located in Chihuahua City. Cessna is currently employing 550 workers and produces wire harnesses, metal structures, composite components and composite fabrication[68]. The other business jets manufacturer present in the city is Hawker Beechcraft, which opened in 2007 a sheet metal assembly in Chihuahua[69]. Recently the firm announced a 12 USD million investment to manufacture the fuselage of its King Air 350[70].

---

[67] Negocios, 2010. "Mexican aerospace industry: reaching higher altitude", *Negocios*, October, Promexico, México. pp 22-25.
[68] Harrison, K. J. 2010. "Bizav manufacturing jobs continue to move south", *Aviation International News*, October 1. Retrieved from: <http://www.ainonline.com/news/single-news-page/article/bizav-manufacturing-jobs-continue-to-move-south-26473/>
[69] Epstein, C. 2007. "Hawker Beechcraft opens shop in Mexico", *Aviation International News*, December. Retrieved from: <http://www.ainonline.com/ain-and-ainalerts/aviation-international-news/single-publication-story/browse/0/article/hawker-beechcraft-opens-shop-in-mexico-11817/?no_cache=1&tx_ttnews[story_pointer]=4&tx_ttnews[mode]=1>
[70] El Diario. 2011. "Fabricará Beechcraft fuselajes en la capital", El Diario, February 23. Retrieved from:
<http://www.diario.com.mx/notas.php?f=2011/02/23&id=afad299e1cbe2956df294b2253039cc6>

2.7 Economic policy and innovation system in Mexico

Introduction

Since the debt crisis in 1982, the Mexican government has adopted a series of economic reforms that have been labelled by several authors as neo-liberal because they are based on the alleged efficiency of market forces in all realms of economic activity. Among these reforms are the control of inflation rates, the opening of the economy to foreign capital and trade, the attraction of FDI (Foreign Direct Investment), and the pursuing of industrial export activity (mainly by means of temporal import schemes) (this last dates back to the 1960s, but has since been acquiring a central place on the government agenda). Although it is true that these reforms have achieved partial success[71], the overall picture is that Mexico has stagnated in two of the most important macroeconomic indicators, namely GDP and employment growth, as well as productivity increases.

According to several authors (Cimoli, 2000), these reforms are not only insufficient but can be misleading in promoting economic development, at least in the way they have been implemented. One crucial aspect that has not been addressed adequately in these economic measures is the role of technology and innovation in economic development. The main argument is that these reforms (inspired by neoclassical economic principles), do not take into account technology in all its complexity, and instead consider it as a good that can easily be transferred and traded by market transactions. Following this vision, Mexican policy has taken few actions to support indigenous R&D, attracting foreign R&D and the upgrading of technological and organizational capabilities of Mexican or foreign firms active in Mexico. One

[71] In the sense that beginning in the mid-1980s, Mexico went from being essentially an oil-exporting country to becoming a major export platform of manufactured goods (Moreno-Brid, Santamaría and Rivas, 2005)

consequence of these measures is that the Mexican innovation system is poorly developed.

Even if the innovation system in Mexico and the measures taken by the government are incomplete and insufficient (and perhaps misleading), the particular history of industrialization in this country reveals some accumulation of technological capabilities in certain regions, and in certain technological areas (see Cimoli, 2000). At present, the relatively recent establishment of aerospace firms in Mexico and the apparent commitment of national and regional governments to that industry might be seen as an opportunity to upgrade the technological level of the country given the high-tech character of that industry. This chapter sketches the environmental elements –in terms of current technological capabilities, innovation system and public policy– that are more likely to accelerate or to hinder the technological level of the aerospace industry in Mexico.

In this sense, one question emerges: before and after liberalization reforms, Mexico has undergone major industrial developments (e.g. steel, glass, automotive, electronics) but has achieved limited results in terms of technological capabilities, and only very limited results in terms of innovation on a worldwide basis (if we consider innovation as the whole uncertain and partially serendipitous process that begins with the conception of a new product or technology, goes through R&D, continues to manufacturing and ends in successful introduction on the market). What would be different in the case of the aerospace industry? Will Mexico play an important role in higher parts of the chain value of the aircraft? Will this foreign direct investment in aerospace have spillovers to other industries or services? Or will this industry follow the incomplete development pattern that other industries, such as the auto industry, have followed?

In order to shed light on these questions, this section is organized as follows: section 2.7.1 briefly describes the liberalization strategy followed by the Mexican government since the 1980's, illustrating main objectives and especially the engine growth of that strategy; section 2.7.2 makes some remarks about the impact on technological capabilities of the liberalization strategy in Mexican industrial development via FDI, particularly the export oriented segment known as the *maquiladora*; section 2.7.3 analyzes how these previous issues affect the Mexican innovation system and what this might mean for the development of the aerospace industry in Mexico; and finally section 2.7.4 shows some historical examples about the development of the aircraft industry in new comer countries and some remarks about the experience of the automobile industry in Mexico.

2.7.1 Liberalization Strategy

The main goals of the liberalization strategy in the early 1980s were to achieve a stable macroeconomic environment and to pursue an export-oriented growth based on free trade. Reinhardt and Peres (2000) argue that the ultimate rationale behind these reforms was the belief that markets were more efficient in allocating resources than governments. In practical terms, these reforms did achieve partial success in achieving macroeconomic stability and export promotion, although under a more critical eye the results are completely insufficient in terms of long-term development, a more equal income distribution, or social stability. As far as macroeconomic stability is concerned, even if low inflation rates have been achieved, such stability was accompanied by an increase in interest rates, with subsequent negative impact on investment.

Growth Engine

As it has been said, Mexican officials wanted to change the previous inward orientation of industrialization with an external orientation based on a competitive manufacturing export sector. The local industrial sector was considered inadequate to the task; therefore, liberalization of trade and capital was a crucial part of this strategy. The signing of free trade agreements (mainly the NAFTA) and the attraction of FDI were thus the practical side of the strategy. Somewhat paradoxically, history shows that in the following years, the surge of Mexican exports was headed by two sectors that were already well established before the "liberalization strategy"; namely the automobile industry (Dussel-Peters, 2000: 125) and the in-bond factories known as the *maquiladora* (composed mainly of electronics, auto parts, and garments firms) (Gereffi, 1996: 85). Moreover, only some old big national-owned firms in traditional sectors founded in the ISI period– e.g. Cemex (cement), Vitro (glass), and Grupo Modelo (brewery)- managed to thrive in international competition (see Casas, 2005; Dutrénit, 2000; Torres and Jasso, 2005).

In this sense the measures adopted by Mexican governments consolidated processes that were already taking shape. Therefore, it is important to understand how these processes started and how they have evolved, in order to have a better understanding of the potential and limits of that engine of growth. In this review, the emphasis is on the manufacturing segment known as the *maquiladora* because many aerospace firms in Mexico are operating under this fiscal regime.

The *maquiladora* is a fiscal regime established in Mexico back in the 1960s that allows duty-free inputs under the condition of subsequent export. Initially, this concerned mainly US owned factories dedicated to very simple assembly procedures. The main objective of the Mexican government at that time was to create jobs in the border regions of the country. On the other hand, the US firms were cutting costs on the more basic production processes. Over the years (and perhaps exacerbated by the liberalization strategy), some of these *maquiladoras* accumulated technological capabilities well above basic assembly. In some products like television sets and automobile harnesses, some border localities in Mexico, Tijuana and Ciudad Juárez respectively, achieved worldwide reputation for the manufacturing capacity of the *maquiladoras* located there. Also, the inland city of Guadalajara was dubbed the "Mexican Silicon Valley" for the manufacturing capacity of foreign owned subsidiaries (notably IBM) in computer-related parts and peripherals (Gallagher and Zarsky, 2007). With the advent of manufacturing in China and other Asian countries, some of these advantages in Mexico were eroded (Gallagher et al 2008).

Critics of the policy say that the *maquiladora* has created few backward linkages with national suppliers, and that it has remained a manufacturing enclave of foreign firms with limited potential for upgrading in the value chain of their respective product segments (Gallager and Zarsky, 2007). Dussel-Peters (2003) argues that all export fiscal programs in Mexico based on free temporal imports, of which the *maquiladora* is just one, produce disincentives on linkages with the local economy. The main argument is that these programs procure the advantages of zero import tariffs to firms using it, but no value added tax, and a small income tax. In order to have these advantages, the *maquiladoras* have to export their entire production. For these firms, a more active approach in terms of national integration by means of backward and upward links will mean the loss of these cost advantages that represent approximately 50% of their overall costs. However, the other side of the story is poor technological development of the local supply base. Thus, even if the maquiladoras seek to locally procure their more sophisticated inputs, it will be very difficult for them to find local suppliers.

Given this scenario, there are two main opinions about future paths of action. One of them is to limit the advantages of temporal-imports programs and instead concentrate on other segments (e.j. Dussel-Peters, 2003). The other is to try to build an institutional environment that favours knowledge generation and transfer, in which *maquiladora*-type firms will play a prominent role (Dutrenit and Katz, 2005). Supporters of the first school of thought say that the *maquiladora* program is almost 50 years old and integration or spillovers toward the local economy have not been significant. Supporters of the second option argue that the limited role of technology as portrayed by the liberalization strategy has limited the number and effectiveness of policies intended to improve collective learning and its subsequent knowledge transfer and value chain upgrading.

2.7.2 Impact of the Mexican liberalization strategy on technological capabilities

Industrial specialization pattern

Several authors (Amsden, 2001; Cimoli and Katz, 2003; Cimoli et al 2009) have pointed out how the liberalization strategy implemented in several countries of Latin America has influenced the industrial specialization of these countries. Cimoli and Katz (2003) claim that two main specialization patterns have arisen for countries rich in natural resources like Brazil, Argentina and Chile, and low-wage labour-abundant countries like Mexico and the Caribbean, respectively: the first is the orientation of natural resource-processing industries producing commodities to world markets, and the second is the assembly and *maquiladora*-type industries oriented mostly to the US market. Palma (2009) shows that even if these strategies have increased exports, the increase in GDP has been of a lower proportion.

Amsden (2001) explains that the rationale behind those liberalization strategies followed in Latin America was to "get the prices right" by eliminating economic distortions like captive markets, subsidies and trade restrictions very common in the ISI period. However, this author explains that even if those measures were used and failed, the reason lays more in the way they were implemented and not in the measures per se. Khan and Blankenburg (2009) named this situation institutional failure. By this term they refer to the inability of the state to redirect society's resources toward learning industries and the lack of institutions to provide rents in these industries. As Amsden (2001) argues, one important element in a policy trying to develop a new sector is to "get the prices wrong" in order for local firms to be profitable and able to compete against established firms in developed countries.

Cimoli and Katz (2003) and Palma (2009) stress that these liberalization strategies have changed the way in which technological capabilities accumulate in Latin American countries including Mexico. One important point is that firms that are part of a more extensive network in terms of ownership or the kind of technologies used (e.g. MNC subsidiaries) were suddenly confronted with optimization processes that limited their technological responsibilities and thus their accumulation.

Although it is true that Mexico and the Caribbean countries have followed a similar path in terms of liberalization, there are clear differences. While in both areas MNC subsidiaries are the main agents in this trend, in Mexico the sophistication of the manufacturing processes seems to be well above that of the Caribbean. Moreover, there are accounts of some firms in Mexico that are devoted to capital-intensive activities, and some firms are even devoted to secondary development. This should be understood in the path-dependency logic of technical change. As was stated in the previous section, the *maquiladora* program in Mexico has its origins back in the 1960s. As Cimoli and Katz (2003) rightly stress, the state-of-the-art techniques and organization employed in Mexican maquilas is completely dependent on transfers from parent companies. However, the efficient use of those techniques seems to be dependent on Mexican workers' experience with them, and that experience takes some years to build. Moreover, that experience expresses itself in the fact that only some cities in Mexico are able to host sophisticated manufacturing processes; and these cities are precisely the ones with more experience in manufacturing. Indeed, according to the OECD, "FDI flows in Mexico are highly concentrated within two regions (Centre and Northern Border) that account for more than 90% of Mexico's FDI from 1994 to 2007. And while it is presumed that big manufacturing firms (BMF) and FDI will bring technological spillovers through S&T expenditures, greater productivity and higher wages, this is not necessarily the case." (OECD, 2009: p. 18)

Even though the liberalization agenda is still important in Mexico, Peres (2009) mentions that some sectoral programs have been implemented (see section below). Nevertheless, this author shows that most of these programs are devoted to strengthening and expanding pre-existing sectors like the automotive industry, instead of promoting new sectors (p. 182).

2.7.3 Mexico's Innovation System

The national innovation system approach (Freeman, 1987; Lundvall, 1988) and more recently the regional innovation system (Cooke and Morgan, 1998) and the sectoral innovation system (Malerba, 2002) put the emphasis on organizational and institutional patterns needed in order to innovate. This means that firms do not innovate in isolation, on the contrary, there are numerous external factors that contribute either directly or indirectly to this innovation effort, and in some cases innovation is originally conceived and realized through collective effort.

Although some advances can be seen in innovation activities in Mexico, recent assessments of Mexico's innovation system reveal its still low level of development. In a comprehensive study about Mexico's innovation system, Dutrénit et al (2010: 86-88) show the low tendency of Mexican firms to do innovative activities in a sustainable fashion. Also, when these efforts occur they are more oriented to adapt foreign technologies than to create new ones (Ibid: 87). This is reflected in reorientation of indigenous R&D efforts to short term and quality issues instead of more long term issues; not well-developed supporting institutions, with the consequence of not being able to exploit technological advances made in other regions (Cimoli, 2000). In the same token, links among firms and other relevant agents are limited. According to Casas et al (2000), "Mexico is characterised by a small and not yet consolidated scientific and technological system, incipient innovation processes in firms, and emergent university–industry–government relationships." (p. 225). The OCDE report on Mexico also shows low indicators and lack of adequate measures to tackle innovation problems. For instance, the report shows that the investment in R&D as a percentage of GDP is at 0.5% (where business R&D plays a particularly small role), versus an OCDE average of over 2% (OECD, 2009: 17). Therefore, we have a scenario in which investment in innovation is weak, relationship between higher education institutions, research centers and industry is poorly developed, and the main focus of government is on regulatory and transportation infrastructure issues, with little attention given to knowledge-related factors (OCDE, 2009: 15).

Other important aspects are the regional and sectoral issues of the innovation system in Mexico. While there are some efforts at the state level to foster innovation, the constitution of Mexico concentrates resources at the federal level; thus, efforts by states are conditioned to a great extent on federal funding (OCDE, 2009: 15). An important issue regarding state support is the duplicity of efforts. Since any public program claiming to support a high technology industry requires important financial resources, it is unlikely that Mexican states, and the federal government itself, could sustain such an industry in several states at the same time. A major regional remark is that some authors have observed that inner cities tend to exhibit more local linkages than border cities (Gereffi, 1996: 88). This may be due to the fact that inland cities like Monterrey and Guadalajara have an industrialization experience previous to the *maquiladora*.

In terms of support for specific economic branches, the 2007-2012 Sectoral Economic Program[72] of the Mexican Economic Ministry does not contain a specific program for the aerospace sector. It only mentions the desirability for the Mexican economy to upgrade to a high value added sector like aerospace and aeronautics, among others (p. 50). Even if the national government does not have a structured plan

---

[72] See Programa Sectorial de Economía in the references.

to support the aerospace sector, it seems that some state governments do have some sort of programs in place. A priori, it seems that these states interested in aerospace have FDI-attraction programs as their main policy. Nevertheless, the detailed measures employed by these states are going to be part of the inquiry of this study.

2.7.4 Historical examples of the aircraft industry in new comer countries

This section illustrates some historical implications of other countries that have attempted to develop an aerospace sector, and some analogies of the automobile industrialization experience in Mexico. The purpose is to put in context the challenges for the Mexican innovation system in order to erect a solid aerospace industry.

Aerospace industry development in other countries

First of all, it is important to explain some initial conditions and strategic postures. Contrary to other countries, Mexico has not had, and it is not interested in domestic military aircraft production. For the case of Canada, it is crucial to see how military procurement was part of its aircraft capacity building. Overhaul and maintenance, and later the licensing of British aircraft military models by British subsidiaries marked the beginning of that industry in Canada (let's not forget that Canada was a part of the British dominion) (Niosi et al, 2005). Other countries with conditions more similar to Mexico, like Brazil and Argentina developed their aircraft industries originally based on military goals too, although only Brazil was successful (Hira and De Oliveira, 2007). These countries also started by acquiring licenses to produce foreign planes. Whatever the historical reasons for the absence of a military aircraft industry attempt in Mexico, the fact is that the country starts with only a very limited experience, based in the overhaul and maintenance of military and civil aircraft bought from foreign countries. One may add that experience in the manufacturing of motor vehicles and auto-parts are also important assets.

The countries mentioned above could learn from licensing military and civil aircraft models, or by acquiring or licensing in new models. However, that possibility is not clear for Mexico. As it was said, Mexico is not interested in developing a domestic military aircraft sector, which left out the possibility of licensing military aircraft production. Thus, the country has to depend on the civil sector alone.

These historical examples bear one implication: all countries, except the four original leaders (Britain, France, Germany, and the United States) that in one moment attempted to develop the aerospace sector had to rely at the beginning in the transference of foreign technology by established firms, combined with the development of local capabilities.

The next issue is what kind of technology is more appropriate to seek. According to Goldstein (2002): "the traditional trajectory for a developing domestic aerospace sector is a three stage process: first, countries begin with co-production agreements; second, as the industry develops, a viable set of subcontractors develops and finally, the domestic industry is capable of putting all the pieces together and become a final assembler of complete aircraft."[73] Nevertheless, the recent Japanese example shows that pursuing just one (or some) part of the plane could be a good strategy, instead of trying to build the whole aircraft. As was mentioned before, the Japanese firm Mitsubishi is now a world player in the design and construction of wings, thanks to the deal made with Boeing. Then it developed its own regional jet, which was recently put on the market. With the high degree of modularity and high costs, it is inconceivable for one firm or a newcomer country to master all the knowledge and technologies needed to build a new plane. Therefore, concentrating in just one of those modules could be a good strategy.

[73] Quoted from McGuire et al (2010: 368).

All the countries mentioned above, except Mexico, have one characteristic in common; in the early moments of the development of their aircraft industry, there were local-owned firms supported by the state. For instance in the case of Brazil, Embraer was a state enterprise, privatized in 1994 when it had already achieved a good technological standing. The Canadian firm Bombardier has benefited from government supports at different moments of its life. Therefore, two implications are drawn in this case; first, government support is an indispensable condition since high fixed upfront costs make new attempts unprofitable; and second, some nationally-owned enterprise seem to be a necessary condition for the further development of capabilities within the industry.

Summarizing so far, we have four important historical implications for the development of an aircraft industry in a new comer country: 1) in a first phase, technology has to be licensed or transferred from abroad; 2) in an early moment of the development (perhaps not at the beginning) a locally-owned firm should enter the industry; 3) this firm (or firms) should be specialized in one of the main modules of the plane (or in the assembly of the whole plane, although this option is becoming more difficult); 4) state support has to be present in the different phases of development.

Automobile industry in Mexico

The case of the automobile industry may suggest some lessons for aerospace in Mexico. One similarity is that both sectors were initiated thanks to a big influx of FDI by world leading firms. Nevertheless, the nature of that FDI was different. US, European, and Japanese automakers established plants in Mexico to tap the local market. The policy of import-substitution enforced by the Mexican government in 1962 required that automobiles to be sold in Mexico should be produced locally. Moreover, a certain percentage of the content had to be locally supplied. Before that enforcement, automobiles were imported or locally assembled from completely imported kits. Therefore, it can be said that foreign firms established in the country to comply with the rules that the Mexican government imposed. Retrospective studies (see Bennett and Sharpe, 1979) stress the inefficient productive scheme resulting from the overregulation of Mexican government and the unwillingness of foreign firms to improve some of their processes (which hinder the possibility of exports). With the end of the import-substitution era, in the early 1990s the liberalization policy pursued by the government reduced in significant ways the prior restrictions. This allowed foreign companies to restructure their operations, and decided to concentrate on manufacturing their Mexican plants (Carrillo, 1995).

Some years after the automakers, some auto-part producers established manufacturing operations in the northern border cities of Mexico under the *maquiladora* program. Two characteristics of these operations are that almost all inputs are imported from different parts of the world and very little produced in Mexico. Once transformed, with little added value, they are exported to a plant in which the part will be integrated in a subsystem or system. This plant could belong to the auto-part company itself or to a third party outsourcing company; but it is almost always located outside Mexico. Some scholars identify some improvements in the technological activities of these auto-parts subsidiaries (Carrillo, 1995). For instance, the establishment of a development facility by the leading auto-part company Delphi in Ciudad Juarez is shown as a step forward (Carrillo and Lara, 2005). However, those cases remain rare, and their interaction with the local environment is minimal.

This historical sketch of the automobile industry in Mexico shows that foreign firms establish whether to comply with regulations or to obtain some benefit. Automakers had no other option but to establish in the country if they wanted to tap the local market. Once the regulations were lifted, automakers took advantage of the already experienced subsidiaries and restructured them according to their new needs. This movement consolidated these subsidiaries as manufacturing bases with export quality, using significant amounts of imported goods. Indeed, the NAFTA was heavily promoted by the big three in Detroit, with the intention to lower their costs in order to face Asian competitors. In terms of local technological content (and perhaps learning), this restructuring has diminished the need for engineering activities in the subsidiaries (Cimoli and Katz, 2003). In the case of the auto-part companies, they began explicitly as subsidiaries that wanted to benefit from low-cost labour, with the majority of their inputs coming from outside the country. Over time, a handful of these auto-parts companies have opened development facilities being Delphi the most salient one.

On one hand, there are two positive points in this story: one is that automakers continued manufacturing cars in the country even when they could have looked for other alternatives once the liberalization policies were in place. In addition, the auto-parts companies have developed manufacturing capabilities and some of them even development capabilities. On the other hand, only one national-owned automaker (who was devoted to building trucks and buses) surged from that process of industrialization. Also, the auto-parts companies still remain from the most part detached from the local economy.

In the case of the aerospace sector, foreign firms are not in Mexico to tap the local market. In fact, it can be said that they already have the market. The Mexican aviation market has always relied on imported planes. Aerospace companies are established in Mexico to lower manufacturing costs.

In general, it can be argued that aerospace is more and more a world market in which firms should target different clients in the world to recuperate the huge cost of the development of aircraft. Also, given the stringent safety requirements and technical standards in the industry, whole aircraft, modules and sub-systems are relatively homogeneous no matter for which markets they are made for. For these reasons is very unlikely that Mexico, or any country by itself, can offer a market opportunity to develop new aircraft technology. The technical difficulties experienced by civil aircraft are almost the same in every country[74]. Also, Mexico (as explained in section 2.7.3) does not have a solid R&D system; thus is not a country in which aerospace firms could expand their capabilities or acquire new ones (Kuemmerle, 1997). The size of the Mexican aviation market although noticeable, it is not as dynamic and large as for instance the Chinese one. Therefore, the only reason for aerospace firms to establish subsidiaries in Mexico is to reduce costs. Moreover, making an analogy with the automobile industry, preliminary information indicates that the kind of aerospace subsidiaries present in Mexico resemble more the auto-parts than the automakers. Thus, whole assembly and system integration is not what is in the plans for Mexico, at least for now.

The implications drawn are the following: 1) before the Mexican government can think of some measures to enforce some Mexican content in planes bought by national airlines, some sort of system integration activity should take place in the country. In this sense, the attraction efforts should include system-integrator companies (that actually do that kind of activity, because it may be a system integrator company but manufacturing spare parts to be integrated in other places of the world). 2) Eventually, the Mexican government would need to heavily support the creation of a national-owned firm dedicated to system (or subsystem) integration for the learning process to continue.

---

[74] The only Mexican-owned automaker created in the import substitution period (and to date) is specialized in trucks and buses. Different countries indeed present different geographical conditions, highway infrastructure and business practices. Thus, each country represents indeed a market opportunity given the different needs and obstacles of the different geographies (perhaps this was more salient before than nowadays). In this sense being a local firm, in terms of ownership, did provide an advantage to exploit that opportunity. However, in the case of aerospace, local markets for civil aircraft are not much different from country to country. Perhaps in other segments of aviation like aquatic landing planes, water bombers, or forest recognition planes, local environments do present different technical problems and as a result market opportunities for learning and developing new technologies. In which case, being domestic, having public sector support and strategic freedom of action would be essential to pursue those opportunities.

CHAPTER III
HYPOTHESES FOR THE MEXICAN CASE

Research Objective

As stated in the introduction, the research goal of this work is to understand the type of activities being carried out by the aerospace industry located in Mexican clusters, and to assess if policy actions put in place to support the industry are conductive to master aerospace technology.

Theoretical Contributions

At least three main research streams are pertinent to this quest. The first relates to industrial clusters and regional innovation systems. In this sense, this research aims at advancing knowledge about the agglomeration forces that shape aerospace clusters in developing countries. At the same time, it is important to discuss the usefulness of the different competing concepts on innovative agglomerations. The discussion in the scientific literature has been scant and each author or current has limited itself to advancing their own positions without trying to reduce the number of alternative concepts or assess their historical, industrial or national limitations. Therefore, the theoretical contribution of this research is centered on the pertinence of the different concepts of industrial and innovation agglomerations. The second research stream has to do with the interrelated concepts of product and industry life cycle, dominant design, and modularity. Here the intention is to demonstrate how the complexity of the aircraft as a complex product poses challenges to traditional explanations (usually based on other types of products) of those concepts. A priori, it seems that the mere entrance of Mexico as a visible player signals the deepening of internationalization trends in that industry, with still poorly known consequences. Finally, the third stream deals with some aspects of catching-up policy. In this sense this work tries to join others in their claim that the Mexican government should pursue a more strategic hands-on innovation policy in order to accelerate catching up with industrial and emergent nations.

Hypotheses and Research questions

A priori, it seems that Mexico is not an exception to the tendency of the aerospace industry to cluster in a few regions. But a word of caution is needed. When we talk about the Querétaro or the Monterrey aerospace cluster, should we think about agglomerations similar to the ones found in Montreal or Toronto (Canada), Toulouse (France), or Everett (US)? Moreover, when newspapers and regional government agencies claim to have OEMs firms in their local clusters, should we think that these "OEMs" play a similar role to the role they play in their home countries or regions? Of course, the answer is no. While it is true that there is some important manufacturing capacity in place in Mexico that makes possible the transfer of some aerospace activities, the PLC-ILC approach predicts that the more likely activities to be transferred in the near future should be of a lesser technological level compared to the ones in advanced aerospace clusters. More important, the eventual upgrade of the technological content of those activities will depend greatly on the capacity to build a technological platform able to encourage that undertaking. This line of reasoning leads us to propose the following ***general hypotheses*** that summarize the conceptual discussion, ***research questions*** that will guide the inquiry, and ***empirical hypotheses*** that answer those questions.

General hypothesis 1: The relatively high codification of the technological knowledge base of the aircraft industry is related to the high degree of modularity that exhibits the production of this artefact. This is true also for the different sub-systems that made up the aircraft. Given this modularity, a modified version of the PLC-ILC approach for aerospace, predicts that system and sub-system integrators have the possibility to transfer the manufacturing of some of their simpler subsystems to low-cost locations while keeping integration activities in their home locations.

General hypothesis 2: Initial conditions in countries with underdeveloped innovation systems (like Mexico) cannot procure all relevant capabilities, knowledge and infrastructure needed to sustain the production of complete aircraft systems, complex sub-systems or R&D activities.

General hypothesis 3: Given the low technological profile of aerospace activities (at least in an initial state) more likely to be transferred to a low-cost country like Mexico, the main decision factors for firms looking for a place to establish there, are related to traditional manufacturing cost advantages rather than to Marshallian agglomeration forces.

General hypothesis 4: Given the stringent standards of the aerospace sector, the potential transfer of activities (as simple as they may be) by foreign firms to their subsidiaries requires certain degree of capabilities and infrastructure in the host locality.

General hypothesis 5: The technology needed to mount aircraft systems or subsystems should come from leading foreign companies, at least in a first stage of development of the industry in a developing country.

General hypothesis 6: Technological infrastructure and specialized services devoted to the aerospace sector should be developed to encourage foreign firms to take the risks to transfer more complex activities to their subsidiaries.

General hypothesis 7: For this infrastructure to be effective from the financial and learning perspectives, it should be targeted to selected aeronautic technologies on which firms seem to be more capable of learning, or niche opportunities available.

General hypothesis 8: A public-owned[75] firm or firms will eventually have to be created to benefit from the entrepreneurship that those kinds of firms usually exhibit thanks to the freedom to choose different strategic patterns. In a first stage, this firm should be heavily supported by the state given the high costs of operation.

General hypothesis 9: The designation of just two or three clusters as official aerospace clusters will allow to reach the critical mass of firms needed to sustain the growth and learning in the aerospace sector in Mexico, as well as to better implementation and use of the infrastructure and institutional setting dedicated to the industry.

Research question 1: What are the main reasons for aerospace firms for migrating to Mexico, and how they overcome the limitations of the local environment, which has an important industrial infrastructure but lacks a specific one for aerospace?

> Hypothesis 1: *Given the stringent quality and safety standards required for aerospace activities, including manufacturing, firms are likely to require external technical assistance at one point. Due to the limitations of the Mexican system, the more likely source of this firm-external knowledge would be located abroad.*

> Hypothesis 1a: *Even though manufacturing is the more likely activity to be transferred, some sort of innovation will certainly be introduced at the firm and country level, thanks to those external sources of knowledge and to the*

---

[75] We support the idea that a national-owned firm is important for the development of the aerospace sector in Mexico. This ownership could be either public or private (or a mix). Arguments in favour of a private ownership are that Mexico is not pursuing military endeavours; another Latin American country like Brazil has a local-private firm like Embraer; and in general Mexico is favouring private ownership. However, we think that given the scanty experience of Mexican entrepreneurs in aerospace, there will be few of them interested in investing huge sums of money in a business they do not know, also, let's remember that Embraer started too as a state-owned company. Therefore, we believe public-ownership would be more pertinent at least in the first stages of the development of such a firm, mainly because of the money.

previous industrial experience of the country,. Innovation at the world level will be almost nonexistent in the short and medium run.

Research question 2: What are the centripetal forces at work in Mexican aerospace clusters? Are there firms that can be considered anchor tenants?

Hypothesis 2*: attraction forces are related with low cost operations and the manufacturing capability of the country. Since no substantial R&D activity is expected, it is unlikely to find an anchor tenant firm.*

Research question 3: Are there elements that can be considered part of a nascent aerospace system of production (and innovation) in Mexico?

Hypothesis 3*: The lack of a sectoral program specific to aerospace and the underdevelopment of the overall innovation system in Mexico call for a rather limited production system.*

PART II. EMPIRICAL RESEARCH

CHAPTER IV
DATA AND METHODOLOGY

4.1. Questionnaire for the survey

The "Global outsourcing and R&D best practices in the aerospace industry Questionnaire"[76] (see Annex 1) is the main information source of this research. This is tool designed to gather information directly from aerospace firms in Mexico. I collaborated with Professor Jorge Niosi (research director), Professor Majlinda Zhegu (committee member) and in the elaboration of the questionnaire. The ample experience in the aerospace sector of Professors Niosi and Zhegu was of great help in identifying the cluster issues which firms in this sector face. The questionnaire and the research itself is part of an ampler research project that seeks to compare the development of the aerospace industry in different developing countries. Part I of the Questionnaire asks for general information about the size, ownership, markets and products of the firms. Section II.1 is about the firms' innovation and the sources of ideas for those innovations. Additionally, Section II.2 asks for the incentives that firms have received to locate in the places where they are currently located. Part III is about the role of the firm in the industry, and aspects of communication.

As we explained, the first step to characterize an aerospace cluster is to know the type of firms that make up the cluster as well as the interaction between the firms. Question 1 of the Questionnaire asks for the age, while Questions 4 and 5 are

[76] The Spanish version that was actually used is called "Cuestionario acerca de las prácticas de subcontratación e investigación y desarrollo de la industria aeroespacial en México", see Annex 2.

indicators of size. Questions 7, 11, 13, 14, 15 and Question 23 indicate the kind of product and activities carried on at firms. How the firm relates with external parties in terms of inputs and outputs is captured in Questions 7, 8, 9, and 10. The relationship with third parties in terms of technological knowledge leading to innovation is treated in Question 16. Other communication and control patterns are explored in Section II.2. The exploration of agglomeration forces and the incentives firms face for locating in those Mexican locations is treated in detail in Questions 17 and 18. Questions contained in Section II.1 will also be useful in evaluating firms' innovation activity and its sources

Other primary data sources include four semi-structured interviews with the four regional development offices in charge of promoting the aerospace industry in the four selected Mexican states –Baja California, Querétaro, Nuevo León, and Chihuahua-. In those interviews three open questions were asked: 1) what has been the support given to aerospace companies, 2) what measures are taken to attract aerospace companies; and 3) what are knowledge producing organizations that may support the aerospace sector. Secondary data sources include aerospace publications of the Mexican Ministry of Economy and coverage of the subject in specialized magazines.

4.2. Locations and sample

Prior to the field application of the Questionnaire that was carried on from May 25th to June 28th of 2009 at 30 aerospace firms in five cities located in four states; the Ministry of Economy had identified 161 companies distributed in 15 Mexican states. Attempting to cover all the localities and companies was neither necessary nor practical. Since the focus of this research is on the agglomeration forces and characteristics of aerospace clusters, the approach taken here was to concentrate the study on localities that exhibit some features that qualified them as potential clusters.

As was explained in Section 1.1, the analytical dimensions for this study are: *1) firms' technological characteristics 2) agglomeration forces* and *3) knowledge creation, diffusion and adoption dynamics.* Based on those dimensions, three criteria were used to select the locations for the field research. The first step in analyzing the structure of a cluster is the mere existence of such a structure. Given that firms are the most important organizations in aerospace clusters, the *1) total number of aerospace firms* that a location hosts is the first criterion. As explained in section 1.2.2, the aerospace industry is organized in layers or tiers in which final assemblers are at the top and as we go down we find tiers of system integrators, sub-system integrators, and numerous specialized suppliers. As we climb the layers, the firms are supposed to be more knowledge intensive. That knowledge generation serves as an attractor to other firms, and as such it becomes an agglomeration force. A system integrator firm is characterized for being a knowledge-intensive organization. This system integrator firm can have several facilities scattered around the world. It is important to note that the technological content of the activities carried on in those different facilities can vary broadly. However, *a priori* we are going to take the company's place in the aerospace pyramid as a signal of its technological level.[77] Therefore *2) the place in*

---

[77]It seems unlikely to expect the subsidiary of a leading firm to do activities with the same technological complexity as the parent company. We make the assumption that a subsidiary of a top

the aerospace pyramid of the parent firm in the location is the second criterion. In other parts of this text it was explained that the aerospace sector requires a strong commitment from government. Since it is a high technology sector, it requires support at the financial, infrastructural and educational levels. Thus, *3) the institutional support in terms of policy, infrastructure, and education,* that characterize the location in general and the aerospace industry in particular, is the third criterion.

Regarding the number of firms, table 4.1 shows the distribution of the aerospace firms in 15 Mexican states prior to the field work in June 2009.

---

tier company will have more chances to do activities with more technological content than a subsidiary from a low tier company. Although this assumption is not granted, it was a reasonable guide since information prior to the field study was scanty. Also, since Mexico is a newcomer in terms of aircraft manufacturing, we assumed national-owned firms would not be much developed in terms of technological complexity and thus we did not take them as a selection criterion. Again, this assumption is not granted, but it was practical at the time. Therefore, we decided to identify final assemblers' subsidiaries and tier1 subsidiaries. If a cluster had presence of this type of firms it meant it was in a better position than other clusters.

Table 4.1

Distribution of aerospace firms in Mexico (prior to the field study, May 2009)

STATE	TOTAL
BAJA CALIFORNIA	49
SONORA	26
NUEVO LEON	19
CHIHUAHUA	14
TAMAULIPAS	10
QUERETARO	8
COAHUILA	6
MEXICO CITY	6
SAN LUIS POTOSI	6
JALISCO	5
STATE OF MEXICO	5
AGUASCALIENTES	2
PUEBLA	2
YUCATAN	2
GUERRERO	1
TOTAL	161

Source: Promexico (2009) PowerPoint presentation with data from the Ministry of Economy

As it was explained before, not all organizations listed here are private productive firms. There was no unique criterion to set apart the states which (by their number of firms) could eventually be identified as an aerospace cluster. However, it seemed intuitive to set the lower threshold by including either Tamaulipas or Querétaro (ten and eight firms respectively). Given the attention Querétaro was receiving at that moment we decided to set the lower limit to include Querétaro. Therefore, initially we selected Baja California, Sonora, Nuevo León, Chihuahua, Tamaulipas and Querétaro.

In terms of the place in the aerospace pyramid of the aerospace firms we listed all the firms that were either final assemblers or Tier 1 subsidiaries. Baja California stood first with the presence of companies like Honeywell Aerospace (Tier 1 firm in avionics and turbines), Gulfstream (final assembler of business jets), Lockheed Martin Aeronautics (final assembler of military aircraft), and Rockwell Collins (Tier 1 firm in video systems). In a second group, the states of Querétaro and Chihuahua counted with firms like Bombardier (Final assembler of regional jets), Messier Services (Tier 1 in landing gears) in the former, and Honeywell Aerospace, and Cessna (final assembler of business jets) in the latter. Following the list, the states of Sonora and Nuevo León had within their borders companies like Goodrich (Tier 1 firm in landing gears) in the former, and MD Helicopters (final assembler of helicopters). At the time of this evaluation there was little information about the state of Tamaulipas, but recent accounts reveals only one medium profile company like Chromalloy. This information leaded us to left out Tamaulipas and to continue with the exploration about the institutional environment prevailing in the states of Baja California, Querétaro, Chihuahua, Sonora, and Nuevo León.

By means of their web pages, regional development offices in Baja California, Querétaro, and Nuevo León were the ones that stood up with more information about the firms, institutions and activities related to the aerospace sector. The three regional development offices of these states were promoting three specific aspects of their respective clusters: 1) existence of a business chamber grouping aerospace firms, 2) the setup of education and training programs targeted to the sector in universities and technical schools, and 3) the support of state government in attending and promoting the sector. Information about Chihuahua and Sonora was scanty.

With just the preliminary information mentioned so far, Baja California and Querétaro were the states that had the highest potential for developing an aerospace cluster. Accordingly, those two states were automatically selected to be included in the field work. Even if there was scanty information regarding the institutional support and promotion of the regional development office in Chihuahua, we decided to keep it for the research because of the firms established there, and because of the weight of the state in the national economy in general. If the contribution of Chihuahua to the national economy is important, the Nuevo León contribution is even greater; also, the educational institutions in that state are considered among the best in the country. Therefore we included Nuevo León in spite of the lack of big names located there. The few high profile firms in the state of Sonora, plus the scanty evidence about the infrastructure targeted to support the sector were factors for not including it in the research.

Once the four states were selected, the second step was to select the cities. In Baja California two cities accounted for the majority of firms, Mexicali (the state capital) and Tijuana (which, together with Ciudad Juárez is the most important border city in terms of manufacturing). In the state of Querétaro, some firms were scattered around the capital state city of Querétaro while others were within. Thus, choosing the city was not a problem. The metropolitan area of Monterrey that is comprised of several counties is where the aerospace activity takes place in Nuevo León. Although no firm is located in the city of Monterrey, which is the capital of the Nuevo León state, all of them are accessible by car from Monterrey City. The state of Chihuahua has two main cities and industrial centers, Chihuahua (the state capital) and Ciudad Juarez. Although preliminary information showed that Ciudad Juarez had some aerospace activity, it turned out that some firms were mislabelled as aerospace and the others were only partially involved in aerospace. The city of Chihuahua is both the host of important aerospace firms, and the target of state government support. All firms in the city of Chihuahua were located within the city.

Once the cities of Mexicali, Tijuana, Querétaro, Monterrey, and Chihuahua were chosen, the next step was to choose the firms. For Mexicali and Tijuana, the information that the regional development office provided regarding the firms was very complete. The interest of the research is centered on big firms with a substantial activity in aerospace. For that reason we targeted firms with more than 100 employees and with a major involvement in aerospace activity. All firms with those characteristics contained in a report of the Baja California government were asked to participate in the research. In the end, fifteen firms agreed to respond to the questionnaire; eight from Mexicali and seven from Tijuana. The process was similar for Monterrey, in which 4 firms took part in the study. It turned out that most of the firms in Monterrey were Mexican-owned firms that supply metallic parts. For Querétaro, the process was similar and five firms agreed to respond the questionnaire. Finally, thanks to the guidance of the regional development office of the state of Chihuahua we contacted six important firms that were not initially contemplated. After our arrival the regional development offices of the four states were cooperative and provided guidance about which firms were worth to be included. Thanks to that information, some smaller firms with a very high involvement in the industry were also included. In the end, thirty firms distributed in five cities answered the questionnaire in a face-to-face interview (see map below in figure 4.1). From those thirty firms, seven are Mexican owned- and controlled, one is a joint-venture of mixed domestic and foreign capital, and the rest twenty-two are subsidiaries of foreign corporations.

Figure 4.1

Five selected cities in four Mexican states.

4.3. Statistical treatment

Since most of the questions included in the Questionnaire represent categorical statistical variables, descriptive statistical tools are used to illustrate the clusters characteristics. Almost all hypotheses raised in this work claim that aerospace firms in Mexico will be similar in several aspects. In statistical parlance, it is expected that firms exhibit the same value for a determined variable. For instance, for the *variable* "level of innovation", Hypothesis 2 claims that the most frequent *value* for that *variable* will be "new to the country processes and products" as opposed to other *values* like "new to the world processes and products" or new to the firm.

When using likert scale questions, 1 corresponds to not important and 5 to very important. When firms declared that that particular characteristic did not apply for them, the value was 0. When using cross tabulation, the chi-square test for independence of two variables[78] 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[79], a non-parametric test, is also shown. This non-parametric test returns a p-value using a Monte Carlo simulation (Verzani, 2005). Below is a list that summarizes how the research questions are going to be addressed

[78] The statistical software used to obtain this statistic was SPSS.
[79] The statistical software used to obtain this statistic was PSPP and verified with the R program (both free programs).

Table 4.2

List of questions, variables and information sources

Research question	Variables	Information source
1. How manufacturing firms from a high technology industry overcome the limitations of the local medium, which has an important industrial infrastructure but lacks a specific one for aerospace?	• Type of activities: manufacturing, R&D, or MRO. • Innovation: process or product, and at firm, country or national level. • Sources of knowledge: firm's departments, location of and type of external organizations	• Reports from Promexico and Femia. • Questionnaire (section II.1 and III.1)
2. What are the centripetal forces at work in Mexican aerospace clusters? Are there firms that can be considered anchor tenants?	• Advantages provided by being in specific clusters in Mexico • Business interaction among firms: input and output links • Differences between different clusters in Mexico	• Questionnaire (section I.1 and II.2)
3. Are there elements that can be considered part of a nascent aerospace system of production (and innovation) in Mexico	• Existence of knowledge-producing organizations • Policy measures and government support • General vision for the sector	• Interviews with regional promotion offices • Questionnaire (section II.3) • Report from the Ministry of Economy

CHAPTER V
RESULTS

5.1 Type of activities, innovation and sources of knowledge

As we saw in previous chapters, the majority of the aerospace firms located in Mexico are devoted to manufacturing. The sample selected for the survey is also composed by a majority of manufacturing firms. In this section we want to illustrate if these firms achieve some level of innovation in their activities as well as the internal and external sources of knowledge that in some way helped to develop that novelty.

Table 5.1

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%

Table 5.1 shows that almost all firms produced at least one new product in the last three years. It is important to clarify that manufacturing a new product does not automatically 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. Again, this does not mean that these firms

designed the product. The participation in the world novelty of these firms was due to either creating a novel process to manufacture a product designed (and even manufactured) elsewhere, or by manufacturing it for the first time. According to some personal communications with interviewees, this is the result of optimization 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 5.2

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

Firm's department	**Average contribution**
Research and Development	0.97
Marketing	0.62
Engineering	4.79
Management	4.17

Table 5.2 shows which part of the firms were the most important to tackle the obstacles that new products represent. In a scale of 1 to 5, firms were asked to evaluate the importance of these four firms' departments in their contribution to undertaking new products. The Engineering and Management departments were considered by almost of firms as very important. This is consistent with the idea that most of these firms have to tackle engineering problems to manufacturing processes for products made 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 the results are 3.5 and 3 respectively, still less than 4.79 and 4.17 for

Engineering and Management in table 5.2. Most of these firms were Mexican-owned firms. 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.

Even if internal sources of knowledge are important, the ability to obtain sources of knowledge external to the firm is crucial in this high technology sector. Table 5.3 shows the different sources of knowledge external to the firm according to the location of those sources. It is completely clear that headquarters are the main sources of novel ideas for the aerospace firms in Mexico with 70% of the firms declaring that to be their main knowledge provider. The second most cited source of ideas are clients located outside the country with 66.67%. Global suppliers were mentioned by 20% of the firms. The only relatively important local source of knowledge was local research institutes with 20%. All other factors received a response of less than 20%.

Table 5.3

Sources of knowledge external to the firm that had an impact in the new products introduced

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%

Practically all foreign-owned firms declared they received valuable information and training from their headquarters in order to put in place their manufacturing processes. Also, some firms (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. Thus we have a situation in which knowledge external to the firm comes from agents located outside the clusters, or for that matter outside the country. The only local sources of knowledge with some relevance were the local research institutes. However, it should be mentioned that the questionnaire asked for external sources of relevant knowledge and also to evaluate the importance of it on a scale from 1 to 5, being 1 low importance and 5 of high importance. 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 contrary, the average value firms assigned to knowledge coming from headquarters, global clients and global suppliers were 5.0, 4.2 and 4.2 respectively.

Although, as we explain before, in aerospace it is expected to exist a close relationship between the subsidiaries (or independent firms) and their headquarters (or system integrators), and as such, knowledge external to the cluster should be expected, in the Mexican case, the technological level of complementary-knowledge organizations such as research institutes, universities, and specialized suppliers seem low to represent an important source of innovative ideas for Mexican aerospace firms. In fact, the lack of specialized suppliers was a common complaint among interviewees.

5.2 Mexican clusters' advantages, interaction among firms, and differences between clusters

There are two pieces of information in the survey that are relevant to answer research question 2 of this thesis about the centripetal forces of aerospace clusters in Mexico. First, there is a question that lists possible local advantages, and asks firms if they benefit from those advantages or not. Second, there is an open question about why the firm chose that specific cluster to establish in the first place, and then the diverse reasons given by the respondents were compared and grouped.

Table 5.4

Local advantages

Advantages	Answer	Counts	Column %
Labour	No	4	13.30%
	Yes	26	86.70%
Industrial Areas	No	5	16.70%
	Yes	25	83.30%
Suppliers	No	29	96.70%
	Yes	1	3.30%
Clients	No	28	93.30%
	Yes	2	6.70%
Policy	No	11	36.70%
	Yes	19	63.30%
Co-location	No	15	50.00%
	Yes	15	50.00%
Infrastructure	No	2	6.70%
	Yes	28	93.30%
Universities and Research Centres	No	7	23.30%
	Yes	23	76.70%
Financial advantages	No	28	93.30%
	Yes	2	6.70%
Incentives	No	19	63.30%
	Yes	11	36.70%

Table 5.4 captures the local advantages that firms consider they have by being located in a Mexican aerospace cluster. From the ten local advantages listed, six were identified as such by more than 50% of the firms. The local advantage most cited with 93.3% of positive answers is the infrastructure. This means that almost all surveyed firms considered that the infrastructure of the locality provided an advantage. By infrastructure the questionnaire makes reference to the transportation and telecommunications infrastructure. The existence and quality of industrial areas was considered by 83.3% of the firms as an advantage. The third most cited advantage was the labour force with 86.7%. Respondents usually complemented their answer by adding that the workers were skilled and accustomed to the factory environment. The fact that the locality host universities and research centers was the fourth most cited advantage with 76.7%. It is important to mention that almost all the affirmative answers to this question did so because of the university and not because of the research centres. The fifth advantage was the existence of policy measures[80] with 63.3%. Virtually all the respondents, who answered positively, added that the policy measure they were referring to was the *maquiladora* program. This policy measure can be considered as a horizontal policy because is not specifically targeted to any sector in particular. The sixth most cited advantage was to be co-location with other aerospace firms. Half of the firms answered yes while the other half said they did not find any advantage by being close to other aerospace firms.

The items that received less positive answers were incentives, clients, financial aid, and suppliers. Particularly the last three items have a negligible percentage of positive answers, while incentives, as we are going to see in table 5.7 later, have an important role when the sample is divided. By policy measures we mean the broad vision

[80] In the questionnaire, the difference between Policy and Incentives is the following: by Policy we mean the broad and systematic government measures towards certain economic objective; by Incentives we mean single measures that are not necessarily under the framework of a broad policy. Although we are conscious that the two sometimes overlap, in the interviews respondents associated the word policy with the *maquiladora* policy.

behind government systematic actions, while by incentives we refer to specific instruments to accomplish that vision. In this sense, 63.3% of these firms (as others in other sectors) have a positive image associated with the *maquiladora* policy which is basically an export promotion policy aimed, but not exclusively, to foreign firms. It is important to note that positive answers were related to the *maquiladora* policy but not to a policy targeted specifically to aerospace. Nonetheless, although few, there are some positive opinions on which could represent some incentives that may be identified as belonging to a policy targeted to aerospace as table 5.7 shows. Regarding clients and suppliers, it is clear that these are not located in Mexico and as such they do not represent any advantage. By financial aid, the questionnaire makes reference to the possibility to tap banks or other financial entities to obtain resources. One problem of the Mexican financial system is precisely the mismatch between bank institutions and productive demands, and the results confirm that situation. In fact, in the last part of the questionnaire when asked about the sources of financial resources for new investments, 100% all firms declared that they come from corporate or own resources, and only two firms declared using credit (one from a development bank and one from a private bank) in addition to those sources.

Table 5.5

Former attraction factors

Attraction factors	**Answer**	**Counts**	**Column %**
US proximity	No	15	50.00%
	Yes	15	50.00%
Low labour costs	No	23	76.70%
	Yes	7	23.30%
Low operation costs	No	24	80.00%
	Yes	6	20.00%
Owner's region origin	No	24	80.00%
	Yes	6	20.00%
Experience in industrial sectors	No	22	73.30%
	Yes	8	26.70%

Another important piece of information is table 5.5, which shows the original attraction factors that firms took in account before establishing in Mexico. This was an open question in which similar answers were grouped (This may explain the lower percentages compared to table 5.4). From the several answers given to this question we are going to present the five most prevalent. Of all surveyed firms, 50% declared that proximity to the United States was among the reasons for establishing in Mexico. This is the attraction factor with major prevalence in aerospace firms in Mexico. The previous manufacturing experience of the Mexican localities was the second most cited reason with 26.67%. It is important to note that this experience is not necessarily related with aerospace. The low cost of the labour force was the third most cited attraction factor with 23.33%. Low operation costs and owners original location follow with 20% each.

The fact that proximity to the US stood up as an important factor for former attraction deserves some discussion. First, US subsidiaries and national firms that primarily sell their products to the US, are a big part of the sample, thus, the result may simply imply savings on transportation costs (whether for inputs or outputs). However, most of these interviewees declared that they work very closely with their parent firms in the other side of the border. In some cases, personnel from both sides visited each other on a weekly basis. Although, it is tempting to think that the manufacturing processes transferred from the parent company are completely codified and thus, they do not need too much supervision, it seems that indeed, tight coordination is needed. As we are going to see later, this means that those manufacturing processes are relatively complex, and involve both tacit and codified knowledge. Also, theoretically this may reinforce the notion put forward by Brusoni and Prencipe (2001) that says that aerospace activities are not completely codified, thus they should be coordinated. Even though this coordination can be enforced over long distances, it seems that geographical closeness coupled with sharing the same time zone has some advantages. Nevertheless this is only a tentative explanation that deserves further inquiry.

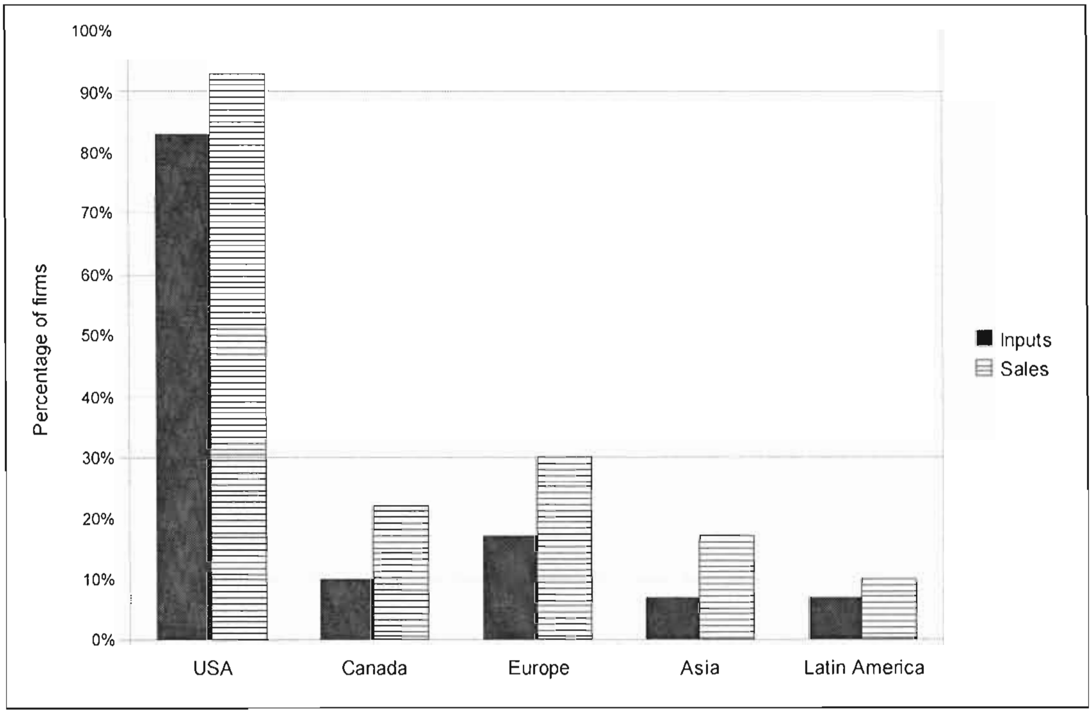
The appearing of answers like low labour costs, low operation costs and experience in industrial sectors reinforce what we already saw in table 5.4. It should be explained that labour and industrial experience are not necessarily related with specific aerospace abilities as it would be hardly the case in a country that does not have an important previous experience in the sector. However, the experience in manufacturing activities related with automotive and auto-parts industries may indeed be important assets. This seems to be the case for harnesses, in which Mexico has an important experience regarding automotive. Apparently, these electronic-related skills can be of good use in the case of aerospace. This case may be also true for others activities.

As Hypothesis 2 suggests, the centripetal forces that Mexico's aerospace clusters exhibit, are related to manufacturing advantages. Specifically, the advantages more valued by aerospace firms are related to the 1) industrial infrastructure, 2) the skilled labor force, and 3) the low operation costs. Regarding the first aspect, it is clear that the transport and telecommunication infrastructure [table 5.4, 93.3%], and the presence of industrial areas [table 5.4, 83.3%], procure firms the facilities needed to carry on manufacturing activities, and gives the overall impression that Mexican localities have a relevant experience in manufacturing [table 5.5, 26.7%]. On the second aspect, the presence of a labor pool that in addition to be cheap [table 5.5, 23.3%] is it considered skilled [table 5.4, 86.7%], makes possible the undertaking of manufacturing processes that sometimes demand technological sophistication. The presence of universities in these localities adds to this capacity [table 5.4, 76.7%]. In addition to the two mentioned aspects, the presence of the *maquiladora* policy [table 5.4, 63.3%] keeps operation costs on low levels.

There is also information about the inputs and outputs flows of the firms, which will be very useful to explore their degree of connectedness to the local environment.

Figure 5.1

Mexico's aerospace firms' inputs origin and sales destinations (year 2008)



Regarding the input-output links, there is a clear pattern that can be seen in figure 5.1[81]. When asked about the origin country of their critical inputs, it can be seen that more than 80% of the firms declared that the US was one of their sources of specialized inputs. If we take Europe as a whole the percentage was only 15%. The next source of specialized inputs is Canada with 10% of the firms. Finally, few firms sourced inputs from Asia and Latin America. In the same token, a very similar pattern

---

[81] This figure shows the countries to which Mexican firms send their exports or source their inputs. Some firms sourced 100% of their inputs or sold their exports to just one country, while other firms mentioned more than one country. Mexico is included in Latin America.

in terms of geographical importance can be seen when looking at the destination of Mexico's aerospace firms' outputs. One difference is that in this case the percentages were higher. This means that the number of countries to which firms send their outputs is bigger than the number of countries from which they receive their inputs. This also seems to suggest that the US continues to be a leading source of specialized inputs.

Since innovation to the world in the strict sense[82] is almost completely absent in Mexican aerospace firms, since no major system integrator has located in Mexico to produce entire planes, and most inputs are imported, it is difficult to claim that a firm can act as an anchor tenant. Moreover, the perspectives of one national anchor being developed are not very bright. As we have seen, the majority of the subsidiaries do not carry on R&D activities. These firms are concentrated in manufacturing and in fact it seems they have a good performance in that area. Also, in an informal question about possible venues for the plants, a lot of managers answered that the plans are to strength and wide the current manufacturing capacities. In the case of the national-owned firms the existing R&D efforts are limited, and moreover, they are conducted to tailor manufacturing processes to meet the standards of their clients.

Perhaps a first step to consolidate an anchor tenant firm will be precisely to strengthen the manufacturing capacity. However, the fact that some firms may eventually excel in manufacturing capacities does not automatically lead to the developing of R&D capacities[83]. In this sense it should be very clear that policy measures should be taken to build a technological infrastructure (not simply a transportation and communication one) and to deliver a set of incentives able to encourage firms (both domestically and foreign owned) to carry on R&D activities.

---

[82] This is if we consider innovation as the whole uncertain and serendipitous process that begins with the conception of a new product or technology, goes through R&D, continues to manufacturing and ends in successful introduction on the market.
[83] The historical example of the automotive industry is very revealing in this sense.

Contrary to well-known aerospace clusters, in Mexico there are no anchor tenant firms. This is consistent with what we saw in Question 1 in which centripetal forces were related with manufacturing advantages and not with Marshallian externalities. The majority of firms' links whether for knowledge or for business, are made with cluster-external agents, therefore, it can be argued that Mexican aerospace clusters are in a very embryonic state.

An important point in this study has to do with the differences among clusters. For this analysis the firms were divided into two groups, inland clusters and border clusters, each one, coincidentally with 50% of the observations. Mexicali and Tijuana were considered border clusters, while Querétaro, Monterrey and Chihuahua were labelled inland clusters. There are two reasons for this partitioning. The first one 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 US, 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 experience in the *maquiladora* program. Although that program 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* program compared to inland cities.

Table 5.6

Differences between border and inland clusters regarding local advantages

Advantages	Answer	Locality		Chi-square p-value	Yates correction for continuity p-value
		Border %	Inland %		
Labour	No	20.00%	6.70%	0.283[a]	0.59
	Yes	80.00%	93.30%		
Industrial Areas	No	26.70%	6.70%	0.142[a]	0.33
	Yes	73.30%	93.30%		
Suppliers	No	93.30%	100.00%	0.309[a,b]	1.00
	Yes	6.70%	0.00%		
Clients	No	100.00%	86.70%	0.143[a,b]	0.46
	Yes	0.00%	13.30%		
Policy	No	33.30%	40.00%	0.705	1.000
	Yes	66.70%	60.00%		
Co-location	No	80.00%	20.00%	0.001*	0.00
	Yes	20.00%	80.00%		
Infrastructure	No	13.30%	0.00%	0.143[a,b]	0.46
	Yes	86.70%	100.00%		
Universities and Research Centers	No	40.00%	6.70%	0.031[a,*]	0.08
	Yes	60.00%	93.30%		
Financial advantages	No	100.00%	86.70%	0.143[a,b]	0.46
	Yes	0.00%	13.30%		
Incentives	No	86.70%	40.00%	0.008*	0.02
	Yes	13.30%	60.00%		

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 is significant at 0.05.

Applying a standard test of independence of variables reveals differences between inland and border firms regarding some of the variables related with advantages obtained by being in a cluster. Table 5.6 shows that those variables are co-location, universities and research centers, and incentives. This means that firms in inland clusters value the fact of being co-located with other aerospace firms, while firms in border clusters usually do not consider that to be an advantage. Both valued the existence of universities, but inland firms showed a higher acceptance. Again, inland clusters valued more the incentives provided by governments than their border counterparts.

Although more information is needed, it seems that hypothesis 4 is confirmed. Two factors might explain the notorious difference in the values observed for Co-location and Incentives. One is that indeed more policy measures have been implemented in inland cities (see below table 5.7), and the other factor might be that the institutional environment in terms of the presence of research institutes and skilled labour is richer in these cities compared to border cities. Therefore, even if in general the Mexican innovation system is underdeveloped, regions show different conditions. Another important piece of information that may have some influence in this situation is the firms' age that on average is of 19.3 years for border firms while it is of 5.6 years for inland firms. A tentative interpretation is that inland firms were indeed attracted to Mexico at the time in which promotion of the aerospace sector started to be noticeable, and as such these firms were more informed about the possible incentives offered by Mexican programs. Also, our sample of inland firms contain more European and Mexican firms, and as a result lesser US firms compared to our sample of border firms, which may explain why these firms are not much interested to be specifically in the border (although being in Mexico in general, which is a bordering country to the US, seems to be an important factor anyway).

5.3 Knowledge complementary organizations, policy measures and government vision

Table 5.7 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 later 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 programs 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 listed. 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 program, according to the interviews with the firms and to the type of innovation these firms declared (see table 5.1), 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 international aerospace fairs, and subsidies consisted on considerable savings on land and energy. Inland firms feel more supported by being in a cluster than border firms; table 5.7 shows that indeed the former firms receive more R&D fund supports and more labour training support.

Table 5.7

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.%	20.0%		

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.

Interviews with regional governments and a report from the Ministry of Economy will allow us to have good insights about the policy measures taken to support the aerospace sector and thus be able to answer research question 3. The four states selected for our study claim to have a cluster approach to support the aerospace sector. Their definitions about what is an aerospace cluster are not quite extensive (at least in an explicit form). In the case of Querétaro, they claim to base their efforts in successful models seen in places like Toulouse, Wichita, Montreal, and Seattle[84]. In the case of the Monterrey Aerocluster (as it is called) the organization model includes the triple helix: industry, academia and government working in an interactive way[85]. Baja California government is relaxed in geographical terms, because it takes the two cities of Mexicali and Tijuana as being part of the state aerospace cluster, although it is fair to say that the two cities are 176 kilometres apart and the driving distance is

[84] Interview with the Secretariat of Sustainable Development of the State of Querétaro, and an unpublished document of the Secretariat (The Aerospace Industry in Mexico: p. 3).
[85] Interview with the Secretariat of Economic Development of the State of Nuevo León, and a promotional brochure of the *Monterrey Aerocluster*.

about two hours, which still makes feasible repeated contacts among people located in those cities. However, this state is more specific in their "Aerospace Cluster Strategy" which includes: investment attraction, support sector integration, human resources, regulations and certifications, technology development, and education institutions linkages[86]. The state of Chihuahua prefers the Spanish word *agrupamiento*[87] instead of cluster, but no state publication or presentation makes a definition of the aerospace *agrupamiento*.[88] In terms of vision, Mexican policy recognizes the importance of firms as the main carriers of technologies, but it also recognizes the need to involve more actors. However, the overall vision falls short because it does not stress the processes that should be pursued (e.g. innovation, R&D and system integration) and instead stresses the different actors as if the presence of an OEM will imply automatically the undertaking of high knowledge-content activities. Even if in some instances, the policy does mention that innovation should be achieved in the future, the steps and measures needed to achieve it are not explained.

While their definition of an aerospace cluster is quite short, what seems to be true for the four clusters (if we take Mexicali and Tijuana as one cluster) -in some way inspired by the triple helix, as the Monterrey Aerocluster suggests- is indeed the recognition of industry, academia and government as key players. Here we want to stress the actions taken by regional governments to foster the industry and academic players. Regarding industry, what governments do is participating in promotion and providing some incentives. As was mentioned in section 2.4, state governments actively participate in international aerospace fairs as part of the Mexican stand. In

---

[86] Interview with the Secretariat of Economic Development of the State of Baja California, and a document entitled "Development of the Aeronautics Industry Cluster in Baja California" elaborated by PRODUCEN.
[87] This word can be taken as a literal translation of cluster.
[88] Interview with the Secretariat of Industrial Development of the State of Chihuahua, and some PowerPoint presentations of the Secretariat.

terms of incentives, these regional promotion offices help these firms to apply for R&D support funds upon CONACYT (The National Council for Science and Technology). The support of regional governments is mainly concentrated in helping firms to meet financial needs related with labour training, certifications, and promotion issues. They also orient firms in logistic and legal issues.[89] In terms of the academia, the four clusters have worked with local universities to open four-year engineering programs in aeronautics. The public State University of Baja California in its campus of Mexicali has already opened such a program. In Chihuahua, the Autonomous University of Chihuahua located in Chihuahua City has an aeronautics program. In the case of Monterrey, the Autonomous University of Nuevo León in its Monterrey campus was one of the first to introduce the program. When it comes to Querétaro the supports has been stronger. A completely new, dedicated aeronautics university has been created with the expressed purpose to support the sector in the formation of human resources. It provides engineering and technical degrees. In addition, the well-known private higher education institution, Instituto Tecnológico de Monterrey provides a specialization in aeronautics for some of its engineering programs at its Querétaro campus. Thus, so far government support has been stronger in the Querétaro cluster, because in addition to the new dedicated aerospace university, an aerospace industrial park was built adjacent to the city's airport. In terms of creating an institutional environment akin to the aerospace sector, those have been the biggest efforts. In a way, these represent an advance in terms of the technological infrastructure. However, what is still lacking is the creation of research centres with a clear mandate and equipment to support the industry. So far, the only research centre with some impact is the CIATQ located also in Querétaro, which assisted General Electric to create its aerospace division in Mexico. As we saw in table 5.3, in general, firms do not find present-day research centres very helpful.

---

[89] Although it is not official, when firms with big investment plans come to the country, the state in question together with the national government usually offer land.

The report called "Plan de Vuelo Nacional"[90] (National Flight Plan) made by the Ministry of Economy does mention some issues of technological specialization and cluster targeting. Specifically, the report identifies the clusters of Baja California and Querétaro as Strategic Poles of Innovation. According to the report, these two clusters are under the area of influence of the aerospace corridor of western US (Washington state and California) and the aerospace corridor of eastern Canada and US (Montreal, Washington D.C. Area, Georgia, Texas, Kansas) respectively. As the report itself says, this designation is based more on the potential than the current state of technological capabilities. As was mentioned above, for some reason, Querétaro has become the de facto recipient of federal aid. The designation of Baja California seems to be due to the number of firms, that one may add, established there more because of US proximity than because of government aid. It should be acknowledged that there is indeed some sort of selection present in the Mexican policy by designating only two places as "strategic", although it seems that Querétaro has received the largest share of that support. Nevertheless, the report does not mention which special treatment and policy measures these two clusters will receive as a result of that designation.

Regarding specialization in a specific aeronautical technology area, the report mentions the following specializations for the 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 specialized suppliers) is in place to support those specializations.

---

[90] See in references: Plan de Vuelo Nacional.

Regarding ownership, there are some Mexican-owned firms, and their importance cannot be downplayed. However, at least for the Mexican firms surveyed, none of them carries on system or subsystem integration. The report also mentions FDI attraction as a way to gather a critical mass of firms. Thus, presumably the creation or the strengthening of Mexican-owned firms is not in the government priorities.

Other crucial element in the policy that seems to be lacking are financial schemes (beyond R&D support) able to provide sufficient funds to carry on important investment in these firms. Given the huge sums involved, this kind of support should come from the National government, but so far there is no indication that some sort of this support will be ready soon.

CHAPTER VI
BACK TO THEORY

Throughout the thesis we have tried to analyze the present developments and propose future venues for the Mexican aerospace sector with the aid of three main theoretical bodies within an evolutionary and innovation systems approach, including clusters theory, modularity and the PLC-ILC perspective. It is important to note that originally, none of those approaches were developed with the aerospace sector in mind; a sector which as we have seen, has several peculiarities that differentiates it from others. For that reason we have presented a debate with the theoretical foundations of those approaches, plus several contributions of different scholars using these and other approaches in order to understand the dynamics of industrial aerospace activity. Our theoretical value added is to put together these different perspectives within the evolutionary approach. Next, we summarize the main points stressed.

The ILC-PLC theory predicts that once the product (industry) stabilizes in its technical dimensions a dominant design emerges and innovation shifts from product innovation to process innovation (Abernathy and Utterback, 1978). Process innovations usually favours scale economies (Bonaccorsi and Giuri, 2000), which leads to the shakeout of the industry or in other words, to the concentration of production in just some firms (Klepper, 1996). Complete standardization in the maturity stage of this cycle opens the door to delocalization of activities to other countries (Vernon, 1966). Some have argued (Mowery and Rosenberg, 1985) that the ILC-PLC theory may not be that pertinent in the case of the aerospace industry, among other aspects, because even if there is a dominant design, innovation in product is still important (Niosi and Zhegu, 2008), and because activity is still mainly concentrated in the traditional leading countries. Niosi and Zhegu (2008) have pointed out that those divergences between what the ILC-PLC theory predicts and what is actually happening can be explained by the innovation system approach. Particularly, they have stressed that leading countries in the aircraft industry possess a rich environment in terms of R&D infrastructure and government support, while other potential countries lacked those conditions, thus reinforcing the leadership of these traditional countries and preventing the diffusion of aircraft production activity to other places. In this sense, the ILC-PLC theory is still useful if we add the notion of innovation systems. Even in the original terms of the ILC-PLC, new players are emerging and represent an important part of the aircraft activity. Moreover, contrary to the cases of Brazil and China, in which there are important local firms, we argue that the case of Mexico in which the main actors are foreign subsidiaries, represents the original Vernon (1966) concern about the best-efficient production location (from the point of view of the original producer in the developed country) according to the cycle stage of the product. However, in order to understand how the ILC-PLC can help us to understand delocalization strategies, in addition to an Innovation System perspective, we think that the recognition that the aircraft is not a simple product but instead a complex product made up of different modules is important too.

Although the model proposed by Abernathy and Utterback (1978) is very useful, the characteristics of the aircraft as a modular product make it difficult to consider it just a single product in terms of the dynamics of product and process innovation. The insight of Murmann and Frenken (2006) is very useful in the sense that different modules of a complex product may follow different life cycles of their own. Therefore, although the dominant design for subsonic civil aircraft has not changed in fundamental ways since the 1960s (Kehayas, 2007, Niosi and Zhegu, 2008), this has not prevented intense (even radical) change at the module or sub-system levels (Frigant and Talbot, 2005; Benzler and Wink, 2010; McGuire et al 2010). Those modules with the most intense technological change have acquired more prominence over others. The ever increasing costs of aircraft development, coupled with the ever increasing types of technologies applied to aerospace, favour the allocation of more responsibilities to sub-system integrators, the arrival of a handful of new sub-system integrators (which also increase competition) and specialized suppliers (Benzler and Wink, 2010) and, to a certain extent, the division of R&D and manufacturing activities (Ehret and Cooke, 2010). This trend reinforces the already modular architecture of the aircraft, in which different firms can take charge of different modules. Moreover, it seems that there is also some level of modularity at the sub-system or module level. This implies that a subsystem integrator can outsource to a third party some manufacturing work. Later, the integrator receives all the parts (some of which it produces in subsidiaries in low-cost nations) and integrates them. For an industry with tough quality and safety standards this is a huge achievement. It is important to note, that the knowledge and skills needed for the integration is what set apart these system and sub-system integrator firms from the rest (included some specialized suppliers).

Even if new technologies have been recently incorporated into new generation planes, there is a good deal of codified knowledge at the aircraft's technology knowledge base. This is the result of the industry's history and the existence of a dominant design, which is reflected in the reinforcement of the modularity trend. Therefore, on one hand, there are important technological changes within some modules, which work in favour of tacitness; one the other hand, there is a degree of maturity, which favours codification. According to the ILC-PLC, it is this maturity in terms of the product and process (Vernon, 1966) and the consolidation of leader firms (Klepper, 1996) that open the door for the delocalization of activities. Current leading firms are eager to find international partners either to share development and financial responsibilities, to seek complementary technologies, to access markets, or to lower costs (MacPherson and Pritchard, 2007; McGuire et al 2010).

Again, there are two facts that at first sight seem to contradict the ILC-PLC theory when it comes to describe delocalization of activities towards low-cost locations. The first is that sometimes delocalization of activity does not have to do much with low-cost but with market and/or technology access. This is explained by purposeful attempts by governments to foster a local aircraft industry. These governments create a series of measures (like offset agreements) and policy supports to encourage the setting up of manufacturing and R&D facilities from leading firms sometimes in the form of joint ventures with local firms. Of course, most countries willing to create an aircraft industry have not been successful. The proposition here is that some modules and activities of aircraft production are relatively easy to transfer to other locations due to the combination of two factors related with two of the approaches seen in the thesis: 1) modularity and 2) innovation systems: the first has to do with the degree of codification of some modules which makes feasible the technology transfer. In this sense, it is revealing how Chinese firms are developing the capacity to design and assembly their own planes (a capability that was developed by being in joint ventures with leader firms that did whole assembly in China), while the most technological dynamic modules like engines and avionics for those planes have to be bought from the traditional leader firms in those areas. The second element is the continued development of capabilities in the host country thanks to a steadily government support that among other things provides financial backing.

The second fact that somehow contradicts PLC-ILC delocalization has to do with a temporal dimension. As Niosi and Zhegu (2010) have pointed out, the aircraft industry in leading countries have experienced a consolidation of leading firms with few exceptions of new entrants like Embraer. According to internationalization theories, when firms consolidate their leadership in an oligopolistic structure (like the one predicted and confirmed by the ILC-PLC in the case of the aircraft industry), it is because they have developed an important advantage that few or none have. Then, according to theories like the specific-assets (Caves, 1971) firms will be willing to exploit those assets in other markets. As we saw in the above paragraph this has been one of the causes in delocalization of activity towards countries like China. However, sometimes the delocalization of activities does not seek to exploit new markets but simply to lower costs. As we saw throughout the thesis, this has been the main driver in the case of Mexico. Thus, the delocalization of activity from leading countries to low-cost countries should follow the original pattern predicted by Vernon (1966). The proposition in this thesis is that conditions to migrate to Mexico were already in place well before 2005, the year when the trend took force. We propose this because the supposedly advantages that were promoted to attract aerospace firms were the experience in the automobile, electronics and auto parts; sectors which have been in the country well positioned at least since the late 1980s. The existence of a handful aerospace manufacturing facilities in Mexicali since the 1960s-1970s reinforce this vision. We propose that the delocalization of aerospace activity for reasons of low-costs locations (like Mexico) experienced a lag in time not predicted by the ILC-PLC theory. The reasons for this lag in time can be explained in terms of evolutionary economics concepts. Contrary to the vision of rational agents with perfect information that can make cost-efficient location decisions with just second hand information, Knickerbocker (1973) explains that firms usually are reluctant to do activities in places in which they do not have experience. This implies that rationality is bounded by the experience of the firm, and that this firm learns only as it gets familiar with other settings. Since aerospace manufacturing requires stringent standards in quality and safety, the reluctance to move such activities is even bigger[91]. Thus, uncertainty about meeting those standards is the main retarder in the case of Mexico with respect to aerospace activity from foreign firms. This idea is reinforced by the fact that several foreign firms from other sectors had already facilities in

---

[91]It is interesting to note that General Electric research facility in Querétaro would be a counterexample of the uncertainty argument presented, however, the company as a corporate had already a good deal of experience in Mexico well before the opening of the turbine research facility.

Mexico for low-cost reasons (in which the market played a marginal or no role at all). Thus, when the Mexican government and Bombardier announced the opening of a plant in Querétaro, other firms might have followed by two reasons: first, the involvement of the government lowered in some way the uncertainty factor; and two, as Knickerbocker (1973) proposes, firms cannot afford to lose the advantages that first-moving competitors may be gaining by going to other locations. Of course, once the firms are in place, they gain valuable knowledge and start to accumulate capabilities which reduce their initial uncertainty. These firms may even start to do more complex activities as they learn how to develop their resources in the host country (Ronstadt, 1978)[92]

As we stressed in this thesis, aerospace activity usually takes place on clusters. Sometimes the word cluster evokes images associated with the industrial districts and often recalls Michael Porter's concept of clusters. Nevertheless, while it is true that some firms gain advantages by being located in clusters, the reasons behind those advantages vary greatly depending on the knowledge base underlying the activities of those firms. In this sense, the industrial district and Porter's cluster are not well suited to explain the realities of aerospace clusters. For instance, the image of a collection of complementary firms working in a loosely hierarchical relationship towards the same or at least similar productive goals –image that pervades the industrial district approach– does not correspond to the fact that different aircraft subsystems can be produced in different parts of the world and latter assembled by a final assembler in yet another part of the world (Niosi and Zhegu, 2005; Frigant and Talbot, 2005). For this same reason, rivalry within the cluster as proposed by Porter, is not a force in the dynamism of the region, since rivals may or may not be located in the same cluster; but more important, even if they are, their clients and main suppliers are located all

[92]To continue with the example of GE, it recently announced an extension of its research facilities in Querétaro. Milenio online. 2011. "GE invierte 24 mdd en industria aérea", Milenio online, February 18. Retrieved from: <http://impreso.milenio.com/node/8913976>

over the world. This last argument also diminishes the argument of sophisticated demand of final customers within the cluster (as stated by Porter) as an important element in the dynamism of the cluster.

Works on aerospace clusters have revealed that sometimes the mere presence of aerospace firms attracts specialized suppliers, thus the location becomes a growth pole in the sense of Perroux, because it means that it serves as an attractor of related industries. The more developed aerospace clusters usually have the presence of an anchor tenant firm that besides attracting specialized suppliers, helps to create a skilled labour pool that eventually attract other aerospace firms. These suppliers and aerospace firms may not necessarily have a direct business (or knowledge) link with the anchor tenant, yet they can instead profit from the technical and institutional infrastructure developed thanks to the anchor tenant presence in the region. In fact, a good deal of knowledge spillovers takes place through links between firms located in different clusters (Niosi and Zhegu, 2005). This anchor tenant is usually a final assembler or the system integrator of an important module. However, for a system integrator to act as an anchor tenant it should be engaged in substantial R&D activity (Agrawal and Cockburn, 2003; Niosi and Zhegu, 2010). However, for an aerospace cluster to become also an innovation system, other institutional agents like governments and education centres are usually heavily involved in the support of the industry by providing financial aid and by setting up research facilities and training programs.

The above description is not to say that all aerospace clusters are alike (even in developed countries), but to stress the elements that potential clusters should pursue in order to become a magnet for aerospace firms and for high technology activities. As the mere idea of a life cycle suggests, aerospace clusters may start as potential and productive clusters and later become consolidated clusters including sophisticated R&D activities. However, even consolidated clusters suffer changes and it seems that the steady technical change in the industry and the emergence of new countries, are critical elements to understand the opportunities and limitations of potential clusters.

Although there is not a unique way for newcomer countries to enter the industry, some strategic steps seem compulsory to be followed. In a first stage, production technology has to come from leading firms. For countries without some historic capability in the sector this is the only feasible option, and they have to rely completely on this option. This technology transfer may come in the form of manufacturing facilities. To encourage leading firms to transfer more R&D intensive activities, it is crucial to invest in developing a technological infrastructure able to provide inputs (highly skilled labour, R&D infrastructure such as wind tunnels, or public R&D in advanced materials) to those innovative activities. For these investments to be efficient, governments need to be involved and to consider two issues: the first are clusters, and the second is the type of technology to develop. Regarding clusters, it is unlikely that Mexico, with its limited financial resources, can develop many clusters of aerospace activity. Thus, it should choose among only certain localities to concentrate all the support on them. In the case of technology, the increasing importance of some aircraft sub-systems and the technology involved in them makes almost mandatory to concentrate precisely in just one or few of them. In a later moment of the strategy, the creation of a domestically-owned firm should be envisaged. As it was stated, this national firm may not be in the final aircraft assembly business, but it should certainly target to be a sub-system integrator able to carry on R&D intensive activities, or a niche within aircraft production (i.e. tiltrotors, skycars). The developing country may also consider the possibility of attracting a foreign system integrator in order to learn manufacturing processes, as China has done by attracting Embraer from Brazil to produce regional jets in that country.

CONCLUSIONS

Overall conclusions

The setting up of manufacturing facilities in Mexico by leading aerospace firms took notoriety in the press around mid 2000s. Given the still underdeveloped innovation system in Mexico, apparently there was a mismatch between the needs of the aerospace industry and what the country could provide. This phenomenon attracted our attention and raised several questions: How many firms were already there? What type of activities are they doing? In which places are they located? Why is it that until these years they start to benefit from the industrial infrastructure of Mexico, when other industries were well acquainted with it? What have been the incentives given by Mexican authorities?

In this thesis we concentrated on type of activities of aerospace firms (which are mainly subsidiaries), attraction forces of Mexican aerospace clusters, and policy measures taken by the Mexican government.

As it was explained, we thought the concepts of modularity, ILC-PLC, and clusters would be pertinent to answer those questions. The modularity concept, from the management literature, is used to stress that products made up of different parts or modules require different knowledge management strategies compared to simpler products. The revision of the concept showed that the aircraft is not only modular, but also a complex product that requires highly specific knowledge and huge financial sums to achieve its design and production. Regarding the ILC-PLC theory, we showed how the consolidation of main world players in the aerospace industry plus the maturity of some parts of the aircraft as a product, allowed us to expect delocalization of production to other places. Given that in developed countries aerospace activity tends to cluster, the assumption is that location has to some extent an influence in the type of activities that firms perform. We showed how some world aerospace clusters act as growth poles, have anchor tenant firms and institutional support for innovation activities.

With the aid of these three concepts we put forward the hypotheses that the more likely aerospace activities to be transferred to a developing country like Mexico would be manufacturing activities pertaining to the more mature parts of aircraft modules and not R&D or cutting edge activities, and for that reason, the attraction factors of Mexican localities should be more related with manufacturing advantages. In addition, we did not expect to find a solid institutional support in terms of complementary knowledge-producing organizations and/or government financial incentives dedicated to the sector. The sources of information of this thesis are a survey applied to 30 aerospace firms in Mexico, interviews with four state economic development offices, and secondary information like documents with information of the Ministry of Economy, specialized aerospace magazines and journals. The results of this thesis largely support the hypotheses put forward, although some of them require further analysis. Some unexpected results were also seen.

Regarding the type of activities, it is clear that almost all firms were devoted to manufacturing, with few firms in MRO (maintenance repair and overhaul) and few cases of R&D. To have an idea of the complexity of the manufacturing activities, we asked about innovative activities. Almost all firms in the survey declared to have introduced new products at the level of the firm, but innovation at world level was almost absent. 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. 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 manufacturer, though a good one. A methodological note is raised regarding this issue. We followed the Oslo manual convention when asking about innovation and then classify it according to three levels: firm, country, and world level. Although it is true that firms make an important effort by producing new products, the effort should be qualitatively different when the firm designed it than when it did not.

However, there are two issues that may differentiate the future path of this manufacturing activity compared to other industries like the automotive. On one hand, it is worth mentioning that innovation at the process level is present in most of the firms. This by itself is not surprising since it has been the case in other industries. What may be different is that some of the processes (and even products) are carried on for the very first time in Mexican firms at a world level. It seems that scale economies may prevent the duplicity of activities and machinery among head quarters and their subsidiaries. Although more time and evidence is needed, it appears that the high costs involved in aerospace activity that initially postponed internationalization compared to other sectors, may be also the circumstance that accelerates this same internationalization. On the other hand, most of the processes and products we are referring to are parts and not complete subsystems. In other words, all the work done in Mexican aerospace firms (with perhaps one or two exceptions) are parts that will be integrated later in a module elsewhere. This is contrary with what happens in the automotive industry in which complete systems are integrated in the country (although the original innovation comes from abroad).

The point we want to stress is that the particular characteristics of the aircraft as a product, which we illustrated with the aid of the modularity concept, will make different the transfer of activities compared to other industries. Since the inauguration of the Bombardier plant, Mexican authorities have mentioned a future day in which a complete plane will be made and assembled in the country. This discourse seems to believe that the logical forward step of manufacturing some parts is to manufacture all parts and integrate them. The proposition in this thesis 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. Therefore, local assembly would be feasible only in the medium run if Mexico is able to develop a cost-efficient aerospace manufacturing infrastructure.

By public information as well as the information we gathered in the survey, we know there are some examples of design and R&D activities that were initially not expected (for confidentiality reasons we are not too specific). Interestingly, the more advanced cases do not seem to have followed the linear logic in which the firm first do manufacturing activities and then design and R&D facilities follow. Indeed, those facilities seem not to be related to manufacturing activities in the country, instead they are part of the overall design and R&D efforts of the corporate. There are other cases in which there are design labs that help firms' efforts, but those labs stick to secondary design. Although these cases are scanty, and require further research, they seem to support the idea that leading aerospace companies will transfer several manufacturing activities including R&D, although these activities will hardly represent complete sub-systems or modules, and in the case of R&D this will be complementary to activity done elsewhere in the corporate (as the absence of patents granted for those R&D facilities suggests). Thus, the ability to developed and produce a complete module will be absent in firms located in Mexico unless strategic measures are taken.

The geographical distribution of aerospace firms in Mexico revealed that the tendency to agglomerate is present in the country. The fact is that from the 32 Mexican states, only sixteen have at least one aerospace firm, and from those sixteen, five states host 75% of the firms. The cities of Tijuana and Mexicali in the Baja California state, Querétaro in the Querétaro state, Monterrey in the Nuevo León state, and Chihuahua in the Chihuahua state were selected to do the empirical research. For the survey, 30 firms distributed in those cities participated in the study. National and regional development offices promote those localities as aerospace clusters. As it was shown in this thesis, Mexican clusters fall short of elements present in other well known world aerospace clusters. Regarding the growth pole concept, it is clear that in Mexico the activity of aerospace companies has very little driving effect on the regions they establish since an overwhelming majority of their links are done with agents outside the cluster. This is true for both, business links and knowledge links. In other words, ideas, systemic physical inputs and final products are treated with agents located abroad. In terms of the anchor tenant concept, since the activities carried on by aerospace firms in Mexico's aerospace clusters are more related with manufacturing and very little to R&D, it is very unlikely that a firm will be playing the role of anchor tenant. Therefore, it can be said that Mexican aerospace agglomerations do not fit the concepts just mentioned. Instead, the agglomeration forces found in Mexican aerospace clusters are related to manufacturing advantages, specifically, 1) the presence of an industrial infrastructure, 2) skilled industrial labour force, not necessarily in aerospace, and 3) the other low operation costs (provided in part by the *maquiladora* program).

One factor that may change the nature of agglomeration force number two in the medium or long run is the opening of technical training centres and advanced engineering degree programs in aeronautics. Thus, the experience that employees currently working in aerospace firms plus the generation of new technicians and engineers specialized in aeronautics may give rise to a stronger agglomeration force but without being as compelling as the one observed in consolidated aerospace clusters. In this sense, the word aerospace clusters could be misleading in the case of Mexico, if we compare with other world examples. Nevertheless, the fact is that firms gather in specific locations. We do not have a definitive answer to that phenomenon, since there are other cities in Mexico that could provide the advantages seen above. Tentatively, it appears that in the case of Tijuana and Mexicali, it was a spontaneous gathering that was due mainly to their closeness with California. In the case of Querétaro and Chihuahua, it seems that the strong promotion of state governments gave some trust to the firms, especially in the former city. In the case of Monterrey the story is different because although there are some foreign aerospace firms, most are national-owned firms that are suppliers (for confidentiality reasons we do not give more details). In any case, all the cities mentioned, together with some in Sonora (that was left out of this study), seem to have gained an initial advantage as attractor locations.

Some conceptual notes are pertinent regarding the clustering observed in Mexican aerospace firms. It is important to note that even if the growth pole logic was behind the development of established aerospace clusters in leading countries, the reality of Mexico and current circumstances of the aerospace industry make this not be an appropriate model to expect or follow. The growth pole logic assumes a partnership between a big firm and the government to develop a region. However, in the case of Mexico, the country does not have a local big firm able to exert a driving effect, neither the specialized supplier base that is supposed to relocate to the underdeveloped region. In this sense, in developing countries like Mexico, the localities that host aerospace manufacturing activities should be localities with an important infrastructure and not localities that are to be developed. Regarding the anchor tenant idea of a firm that does most of the activities needed to develop its products (including R&D), its applicability is also a debatable issue. Since we do not have sufficient evidence, we are only going to put forward a tentative hypothesis based on the apparent division of R&D and production in aircraft development. We found a handful of firms that were doing either complex manufacturing or R&D activities. The firms in the former case did complex manufacturing without the assistance of R&D units in site. Also, as it was pointed out, there were R&D units completely detached from manufacturing activities in the country. Therefore, tentatively, the support towards manufacturing activities, although useful, is not an automatic step towards more knowledge-content activities. In order to do so, an ambitious and strategic innovation policy should be developed to encourage aerospace firms to carry on more complex activities like integration of systems and subsystems and/or R&D. The set-up of a world-class public research infrastructure seems mandatory to this end (Benzler and Wink, 2010) given the inclusion of new technologies in new plane models. Actually, achieving proficient levels in manufacturing requires also this sort of policies given the stringent quality and safety standard. However, as we are going to see next, institutional efforts have been stronger regarding labour force formation, but limited when it comes to develop knowledge-producing organizations.

In terms of the institutional support given to the sector, we found this has been concentrated in three main areas: 1) the development of a labour force, 2) infrastructure support, and 3) support for high technology activities. Regarding the first, it is notorious that at least four universities located in four of the cities we studied, opened engineering degrees in aeronautics, standing out the brand new aeronautics university opened in Querétaro expressly to support the industry. In the same line, a training centre in the city of Chihuahua (Cenaltec) was established expressly to train technicians for aerospace companies. In addition to these education and training centres, regional development offices offer funds to help firms in the hiring and training process. In terms of infrastructure, the aerospace park in the city of Querétaro was made with the purpose to attract Bombardier and other firms to establish there. It is important to mention that in general, firms do not have problems finding industrial locations as the results of this research suggests. Perhaps this aspect of physical infrastructure is not much relevant, but we wanted to highlight it because it has received much promotion. Regarding the incentives for firms to carry on high technology activities, the new program of the Conacyt has provided 5.3 USD million for 25 projects. It is soon to know the impact of the projects, but it is true that the amount of funds should grow in the future if the program wants to really support high impact projects. In terms of complementary knowledge-producing organizations, the most salient is the CIATQ located in Querétaro, a government research lab that has experience helping out firms in aerospace, although it supports other industries as well. There are also plans to set up a new brand research centre completely devoted to aeronautics in Monterrey. With these few examples, it is clear that the support should really be expanded in this area; otherwise it would be really difficult to lure aerospace firms to carry on innovative activities in Mexico.

An interesting point is that the Ministry of Economy has identified Querétaro and Baja California as potential Strategic poles of innovation. Nevertheless, the reasons behind that identification are not well explained. As it was shown, border cities host more firms within them, but these firms do not get much support from being in a cluster. Thus, even if Baja California has been designated as a strategic cluster, firms do not feel much enthusiasm about it, as the results of co-location show (see table 5.6). The contrary is in the case of Querétaro. Whether these particular states should be the chosen ones or not, requires a more thorough evaluation. Particularly, one of the criteria should be the capacity of the location to develop an effective technological platform, and not just the number of firms in the case of Baja California, or the allegedly existence of an anchor tenant in the case of Querétaro, which as we have seen, according to the definition there are not such firms in Mexico. In any case, even for those states that have been designated, policy measures have been modest. More important, that designation does not contain a set of incentives that will encourage firms to only establish in those places. This issue is critical in the sense that a technological infrastructure dedicated to the aerospace sector will require huge amounts of financial resources, and the best way to use them will be concentrating such facilities in just two or at most three places. Given the financial limitations of the Mexican government, this concentration of resources seems mandatory.

Also, the policy should take in account possible venues regarding aeronautic specialization in some important modules of the aircraft. The profiles of the different clusters given so far, seems insufficient as a technological guide; they are the result of what firms are doing in this moment, and not the result of a technological prospective. Regarding the creation and/or support of a Mexican-owned firm (whether public or private ownership) active in the integration of an important aircraft module, it seems that it is not a priority in the policy so far.

Finally, even though advantages not related with innovation may explain the presence of firms in Mexico's aerospace clusters, these advantages should not be minimized given the tough quality standards of the aerospace industry, and if properly managed they may form the base for future development.

Limitations and further research

As it was mentioned before, one limitation of the study is the way in which innovation is measured. This is particularly challenging when dealing with subsidiaries, because even though the managers knew whether the product was produced for the very first time in the their facilities or not, their assessment about the degree of involvement of both the subsidiary and other part (or parts) of the corporation was not much clear in some cases. Therefore, in this case, knowing the qualities of the product, does not give a precise capability assessment about the people that did it. On the one hand this situation overestimates capabilities in cases of almost pure technology transfer, and on the other hand, it underestimates capabilities in cases in which firms in Mexico even rectified designs due to errors committed in the corporate design department. Knowing the frequency of these two situations is difficult.

The previous point is an inherent difficulty when dealing with subsidiaries, but a point that could have been improved upon is related with system integration. Thanks to the conceptual revision about modularity and to interviews with notable managers in Mexico, we figured out that an interesting issue that may explain differences in aerospace compared to other industries is the ability of a firm to integrate systems. By this integration we mean the ability to do all the activities and services necessary to deliver a complete module ready to be installed without further work. The feeling we have is that in aerospace this ability is harder to reach compared to other activities like automotive.

In this sense, further research on this integration ability perhaps could throw light about the difference on capabilities in different countries. For instance, as we saw in the thesis, the number of Mexican aerospace firms (even if adjusted downwards) is rather larger compared to a country like Brazil. However, the big difference is that Brazil has a firm able to integrate the whole plane and sell it. The proposition here is that asking firms about what is lacking in terms of capabilities in order to reach system integration ability could point out potential opportunity areas not seen by just asking about innovation.

The few cases of R&D found in Mexico deserve perhaps a deeper study to have a better knowledge about their presence in the country. A tentative hypothesis might be that the apparent division of manufacturing and R&D in aerospace, makes that some parts of the corporate R&D may relocate to lower-cost locations in a fashion similar to manufacturing but without being necessarily related to each other. Having a better knowledge of that phenomenon may lead to improve conditions for the migration of that type of R&D activities (and not only to manufacturing).

The current policy framework in Mexico to assist firms in high technology activities started in 2009, thus, it is relatively new, and more time and evidence is needed to assess its results, especially in the case of aerospace firms. Thus, a follow up of this policy is mandatory.

ITP proposal for Mexico's aerospace sector

With the evolutionary elements of an innovation and technology policy presented in section 1.3 together with the results of this research, we are in a position to sketch the general characteristics that an ITP should contain to foster development in the Mexican aerospace industry.

Vision

The first point has to do with the strategic vision about where the sector is supposed to be heading. Acknowledging the impossibility of planning as a substitute for setting a strategy, Lall and Teubal (1998: 1379) argue that a clear vision is essential to set the priorities for the development path of any industry or economy. For this case, this vision requires to acknowledge at least two issues. First, that the initial transferring of manufacturing activities by foreign firms is far from being an automatic migration process, given the stringent quality standards of the industry. It was just until this decade that the number of aerospace companies in Mexico experienced an upward shift, while other sectors with less stringent (although complex) manufacturing process had already been present in the country since at least three decades ago. Therefore, an ITP should recognize that the labour cost differential (between Mexico and developed countries) and the already manufacturing capacity are necessary but not sufficient factors for an effective transferring of complex aerospace manufacturing activities. A lot of measures should be in place to encourage that kind of transfer. The second issue has to do with the transfer of R&D activities in a subsequent phase. If the transfer of complex manufacturing activities is difficult, the transfer of R&D activities is even more. But more important than that, is the recognition that R&D activities should be a fundamental part of the strategy for the country to be a relevant player in aerospace. These activities must not be left aside no matter how difficult they may seem. This is a very important issue for Mexico. As Mexican industrialization history shows, the lack of ambitious goals (whether due to conservative approaches, international pressures or for underdeveloped policy capabilities) and an excessive reliance on market forces has resulted in limited development in terms of technological capabilities and moreover innovation, for once taught very dynamic technological sectors like the automobile.

Summarizing, the policy vision should include 1) the deployment of different measures to effectively transfer complex R&D and manufacturing activities of foreign firms towards their subsidiaries, and 2) a comprehensive set of policies and infrastructure to encourage the undertaking of R&D activities and eventually the creation of locally-owned firms (in a first moment state owned, at least partially).

Horizontal policies

Given the still underdeveloped state of industrial R&D in the Mexican economy, a great deal of horizontal policies needs to be in place. These horizontal policies should give incentives to domestic and foreign firms to carry on R&D activities and thus initiating a virtuous learning process. To this matter, Teubal (1996: 454, 459) differentiates between grants/loans and R&D tax credits. Teubal (1996) argues that firms that do not have well developed R&D routines would be better aided by grants or loans. Since those firms are just beginning to handle those kinds of projects, they have a lot of incertitude as to what the final outcome would be, and as such they need to feel supported in order to undertake the project. Moreover, those kinds of aids such be heavily promoted upon the firms and not to expect they will approach the government agency. This is especially important for small firms and for large firms that have not yet developed R&D capabilities. On the contrary, R&D tax credits are a good instrument for firms that have already a good experience in R&D activities, such as foreign corporations.

For the aerospace sector in Mexico the situation is somehow complex. Given that the majority of the firms are foreign subsidiaries, it can be argued that those firms know for sure that R&D is a crucial activity. However, the subsidiary in particular does not carry on R&D activities (the majority of these firms function as manufacturing firms). Thus, on the one hand, the firm is aware of the advantages of R&D, but on the other hand it does not have the capabilities to do that kind of activities in Mexico. Moreover, their mandate in most of the cases is related to manufacturing and production, and as such they might be more interested in being efficient at those activities, instead of trying to develop more complex capabilities at the risk of losing relevance to the eyes of the headquarters. Therefore, offices in charge of administering those programs should be in very close relation with firms either to show them the importance to set up R&D routines or to back the subsidiaries in their attempts to gain more freedom to pursue other activities.

If, as Teubal (2002) argues, an ITP should move the economy, or for that matter a sector, from a low technology to a high technology path development, the question is how high high-technology should be. Should an ITP foster technology adoption, innovation or both? A reasonable answer is that in a first stage an ITP would be centred on improving the knowledge content of the manufacturing activities of the subsidiaries, thus measures to facilitate the transfer of advanced manufacturing techniques should be adopted. This improvement in the manufacturing activities may be conductive to process-innovation, not necessarily new to the world, but new to the subsidiary. This would be an important learning process, and it would become more relevant as the process-innovation cases multiply and go from new to the subsidiary to new to the world (or at least new to the corporation).

For practical ends, the last two paragraphs imply that policy measures should include both, support for technology transfer activities -from parents to subsidiaries- (like training, credits for machinery, legal advice on imports), and for encouraging those firms to improve their technological capabilities through policies aimed at the adoption of advanced technology.

Market-building and technology infrastructure policies

If the ITP path of action is something like the scenario just described, market-building policies and technology infrastructure policies are important.

A strong signalling by the government is also crucial. Heavy promotion of the benefits that Mexico offers is mandatory. To some degree, the inauguration of Bombardier's Querétaro plant was an important signal. However, the promotion should be accompanied with equally strong steps towards providing an advanced technological infrastructure that actually could fulfil those promises. The set-up of training and education programs with a technical profile is a central element of this infrastructure[93]. Given the unlikely event of attracting foreign personnel in important numbers, the local environment should provide the majority of skilled workers[94]. As we saw, Mexican authorities have been active in this sense by setting up different education and training programs in aerospace, and providing financial support for training needs. Nevertheless it should be kept in mind that much of the experience in this industry is acquired in the shop floor. For this reason, the subsidiaries play a crucial role in the first stages of an ITP. They are the agents with the main source of

[93] The degree of specialization in aeronautic technology is a matter of some dispute. According to some personal information, trying to offer top aeronautic engineering formation may not be a good idea at the beginning of the development of the sector. This is because activities that require that kind of formation are not expected to be transferred to Mexico in the short and medium run

[94] It seems that the option of attracting foreign workers is not a significant one. Wage differentials and the tendency of these kinds of workers to remain in just one place, makes this option not feasible. On the contrary, people in managerial positions obey to a different logic, which allows them to be transferred with similar wages.

knowledge in the whole host-country system. They should participate in the set-up of the education and training programs.

Another important element in the technological infrastructure is to set-up of laboratories that could help firms in their technical and management problems. According to Justman and Teubal (1995) this kind of infrastructure should be oriented in a first stage to provide services that have been proven elsewhere. It will be on a later stage that this infrastructure should invest in creating cutting edge knowledge. To complement this infrastructure, the existence of specialized suppliers is mandatory. In this sector these suppliers are related to heating treatments, precision machining, aerodynamic tests, electronic components and instrumentation, software, etc. Nevertheless the whole idea of an advanced infrastructure on aeronautic technology entails one problem. Contrary to the relative immobility (from other countries towards Mexico) of skilled human resources in this sector, specialized infrastructure and services might exhibit some kind of mobility besides their apparent sticking to some locations. In a sector in which quality and precision are crucial, and in which transportation costs represent a minor fraction of total costs and in which development and production takes longer (when compared to other sectors), firms usually seek for the best possible option when it comes to a specialized service. This implies that it is easier for Mexican subsidiaries to seek those services in the US, Canada or even Europe. In this sense, the challenge of an ITP in this area is twofold; to provide incentives for specialized suppliers to establish in the country and to give massive support for the developing of local ones. Tentatively Monterrey could become an important location to develop local suppliers since it already has some of them. In order to be effective in this attempt, a critical mass of aerospace firms should be attracted to the country.

Targeted policies

A critical issue that was explained in **Chapter I** is the cluster. As it has been explained, a comprehensive ITP towards the aerospace sector requires an enormous effort and huge investments. Deployment of those policy measures and funds could have better results when applied to only certain clusters. Trying to develop various aerospace clusters throughout Mexico does not seem a good idea. Beyond the agglomeration economies in terms of human resources and suppliers explained in **Chapter I**, the huge sums of public and private investment needed to mount the required infrastructure (i.e. academic, public laboratories) makes almost mandatory to chose only two or maximum three places as designed aerospace clusters. The problem in this aspect has to do with the agglomeration forces and actual infrastructure present in the potential clusters. Given that this first moment of the internationalization trend is based on the low-costs advantages of Mexico coupled with some manufacturing capacity existing in some places of the country, the result is that foreign subsidiaries are establishing their subsidiaries in places with those characteristics. The first option would be to choose among those places according to the number and importance of the firms located. Although surely this is important, the selection of the clusters should also take into account the potential of that locality to provide all the ingredients of an ITP mentioned so far, if the objective is to have clusters with high technology and innovative activity in the near future.

Another important topic on targeted policies is the eventual development of a nationally-owned aerospace firm which in a first time should be government property. Although at this moment is difficult to make assertions about what kind of technological activity, alliances, organizational scheme, and supports this firm should have, it is certainly important to put it as a medium to long term policy objective. After some time of the beginning of the ITP, it should be more or less clear in which modules or modules of the aircraft, it is more likely to obtain better technological results given the learning path of the available human resources. Negotiations with foreign firms to form joint-ventures might be necessary. Searching for available niches would also be required.

Although the Mexican market is not large enough to provide room to immediately start with a national-owned firm, it can be certainly used to some extent to that end. It is important to recall that airline firms in Mexico are privately owned. In principle the government cannot enforce local airlines to buy planes with local content. Nevertheless, acknowledging that at some point the creation of a local-owned firm (beyond suppliers) is a crucial step to further the development of the sector, the Mexican government must to some degree use two instruments to support such firms, namely the use of offset agreements (similar to the ones used by Asian countries), and exerting influence in the buying choice of Mexican airline firms

ANNEXES

Annex 1 presents the English version of the questionnaire in which the survey upon Mexican aerospace firms is based. Annex 2 is the Spanish version of the questionnaire. Both versions were used as requested by the interviewee, being the Spanish version the most used.

ANNEX 1

QUESTIONNAIRE IN ENGLISH

UNIVERSITÉ DU QUÉBEC À MONTRÉAL
DEPARTMENT OF MANAGEMENT OF TECHNOLOGY

CANADA RESEARCH CHAIR ON THE MANAGEMENT OF TECHNOLOGY

RESEARCH TEAM:
Jorge Niosi, Ph.D. (professor and research director)
Majlinda Zhegu, Ph.D. (professor)
Javier Martínez Romero (Ph.D student)

"GLOBAL OUTSOURCING AND R&D BEST PRACTICES IN THE AEROSPACE INDUSTRY QUESTIONNAIRE IN THE DEVELOPMENT OF THE AEROSPACE INDUSTRY IN MEXICO"

Statement of Confidentiality

All responses to this questionnaire will be kept confidential and secure and will be made available only to the research team, all of whom will be bound by this statement of confidentially. All reports of this work will refer only to aggregate statistics and will not refer to any companies by name, products or people.

I agree to abide by the above Statement of Confidentiality______________________
Interviewer signature on behalf of the research team

I have read the above Statement of Confidentiality and find it acceptable______________________
Respondent signature on behalf of his/her firm

N.B. The interviewer is free to sign any non-disclosure agreement the respondent finds appropriate and the signature of the interviewer on such an agreement will bind the entire research team to its terms and conditions.

GLOBAL OUTSOURCING AND R&D BEST PRACTICES IN THE AEROSPACE INDUSTRY

QUESTIONNAIRE

PART I. Firm's characteristics

Section I.1: Respondent

Name:

Position:

Company:

Location:

Telephone:

Fax:

E-mail:

Web site:

Section I.2: Data on the company

- **Year founded: ________**
- **Ownership and control**
  ___Public or; ___Private
  ___Foreign or; ___Domestic
- **Role in the corporate structure**
  Headquarter or; ___subsidiary (branch)
- **Total sales 2005, 2008__________________;____________________**
- **Total employees by the end 2005, 2008**
  Total number___,___
  Engineering and technicians___,___
  Management and administration___,___
- **Three main products or services**

- **Three main markets**

  ____

  ____

  ____
- **% of sales exported:**______________________________________
- **What percent of your establishment's sales are in the following markets:**
  Local: ____________________
  Rest of your country: __________
  Other, please specify: __________
- **What percent of your establishment's imports come from:**
  Local: ____________________
  Rest of your country: __________
  Other, please specify: __________
- **R&D expenditures (as percentage of sales) 2005, 2008:**
  __________;____________
- **Other locations where the company has establishments**
  -In this country:
  ____
  - Abroad:

____

PART II R&D

Section II.1: R&D Strategy and Innovation

- **During the last three years, did your company offer new or significantly improved products (goods or services), or introduce new or significantly improved manufacturing processes?**
  Yes___, No___
- **Your major innovations are:**
  World novelty: __
  Novelty in your Country: __
  Novelty in your firm: __
- **What is the relative importance of your internal sources of innovation:**
  (where 1 is less important and 5 is more important)
  R&D unit (in-house) 1 2 3 4 5
  Marketing department 1 2 3 4 5
  Production engineering staff 1 2 3 4 5
  Management 1 2 3 4 5

- **Are your sources of innovative ideas:**
(where 1 is less important and 5 is more important)

Local __

Parent or affiliated companies	1 2 3 4 5
Customers	1 2 3 4 5
Governmental agencies or research institutes	1 2 3 4 5
Consultants (academic or professional)	1 2 3 4 5
Suppliers	1 2 3 4 5
Competitors' products	1 2 3 4 5
University researchers	1 2 3 4 5

National__

Parent or affiliated companies	1 2 3 4 5
Customers	1 2 3 4 5
Governmental agencies or research institutes	1 2 3 4 5
Consultants (academic or professional)	1 2 3 4 5
Suppliers	1 2 3 4 5
Competitors' products	1 2 3 4 5
University researchers	1 2 3 4 5

Global __

Parent or affiliated companies	1 2 3 4 5
Customers	1 2 3 4 5
Foreign governmental agencies or research institutes	1 2 3 4 5
Consultants (academic or professional)	1 2 3 4 5
Suppliers	1 2 3 4 5
Competitors	1 2 3 4 5
University researchers	1 2 3 4 5

Section II.2: Local cluster characteristics

- **Why do you think your company has chosen this location to establish your plant?**

....

....

- **What are the specific advantages that this location procures to your firm?**

_Local labour pool _Collocation with other firms in the same industry
_Land facilities _Physical infrastructure (transportation, communication)
_Large suppliers _Specialized research institutions and universities
_Large customers _Financial inducements

_Government policies/grants _Government incentives:
_Other (please specify) -policies
-grants

- **In case you need to invest in a new plant, would you locate it in?**
  The same region__
  The same country__
  Another country__

Section II.3: Government support (local and national)

- **In what way does national government policy helps your company?**
  __Tax credits for R&D
  __Other tax credits
  __Direct subsidies
  __Labour training
  __Other (please explain)
  __None
- **In what way does the policy of the state/province help the company?**
  __Tax credits for R&D
  __Other tax credits
  __Direct subsidies
  __Labour training
  __Other (please explain)
  __None
- **In what way does the local science, technology, industrial park or city government help the company?**
  __Land
  __Building construction
  __Direct subsidies
  __Labour training
  __Other (please explain)
  __None

PART III: OUTSOURCING AND R&D INTERNATIONALIZATION

Section III.1 Firm's role in the industry

- **Please describe your firm's role in its industry**
  a) We are responsible for marketing, sales, and distribution activities
  b) We are responsible for product design or manufacture
  c) We provide a service or tools for firms that are involved in product design or manufacture
  d) Other, please specify:______________________________

- **If you answered b) in Question 10 above, please describe your firm's customers**
  a) Our customers are firms or individuals outside our industry (i.e. service providers or end-users)
  b) Our customers are the final systems integrators within our industry (i.e. the firms that sell to firms or final customers)
  c) Our customers are intermediate systems integrators or subsystem suppliers within our industry

- **If you answered b) in Question 10 above, please describe your firm's suppliers**
- Our suppliers consist of generic suppliers outside our industry and (possibly) a single foundry within our industry (i.e. we are a component supplier)
- Our suppliers consist of multiple specialized component suppliers within our industry (i.e. we are a subsystem supplier)
- Our suppliers consist of multiple component and subsystem suppliers within our industry (i.e. we are a systems integrator)
- Other, please specify:____

Section III.2 Learning and International Knowledge Spillovers

- **By which means do you receive specifications for new products? (please, order them by importance)**

__Internet/intranet/e-mail
__phone
__postal mail/delivery service
__personal contact
__other, please specify:___________

- **How do you receive specifications for new products? (please order them by importance)**

__physical piece or prototype
__drawings
__computer drawings
__other, please specify:___________

- **Describe your implication in the development of new products**

You receive a complete set of technical specifications and:
-just follow them__
-propose improvements__

- **Did one or more of your employees have to take special training for a specific new product development project?**

Yes__; No__

- **Did you have to ask your customer for further information regarding some technical specification?**
  Yes__; No__
- **Did you or your clients have to visit each other in order to solve technical problems regarding new products?**
  Yes__; No__
- **Did you have to communicate periodically the advances to your customer as part of an information system (supply management)?**
  Yes__; No__
- **Regarding the price for the new products or services?**
  __there was a fixed price established from the beginning, or
  __it was negotiated throughout the development process
- **How do you finance the new products?**
  ____
  ____
- **How do you protect your novelty?**
  ____
  ____
  ____

Section III.3 R&D International management practices

- **What part of your R&D activity is conducted abroad? (% of R&D budget)**______________________________
- **Has the share of international R&D activity grown since the year 2005?**
  Why?______________________________
  ____
- **What type of international R&D activity are you involved in:**
  __Formal collaborative research projects
  __Participation in research consortia
  __Licensing or adoption of private or public inventions
  __Collaboration with research laboratories or universities.
- **Please give an example of one of your successful international R&D management practice?**
  ____
  ____
  ____
- **Please give an example of one of your unsuccessful international R&D management practice?**
  ____
  ____
  ____

- **What primary benefits do you derive from these relationships?**

__Leveraging R&D expenditures __Lower R&D costs
__Access to technical expertise __Government incentives
__Source of new product ideas __Problem solving capacities
__Access to equipment, material, research infrastructure

- **What are the risks from your international R&D activity?**

 __Quality of local R&D practices
 __Transactions cost
 __Intellectual property protection
 __The presence of other international competitors
 __The formation of local competitors

- **How do you protect your core competences while developing your R&D activity globally?**

 ____
 ____

- **Has your global R&D activity affected firm's relationships within your domestic location?**

 ____
 ____

- **What will be the major trends of your international R&D activity in the next five (or ten) years?**____

 ____
 ____
 ____

ANNEX 2

QUESTIONNAIRE IN SPANISH

UNIVERSITÉ DU QUÉBEC À MONTRÉAL
DEPARTMENT OF MANAGEMENT OF TECHNOLOGY

CANADA RESEARCH CHAIR ON THE MANAGEMENT OF TECHNOLOGY

RESEARCH TEAM:
Jorge Niosi, Ph.D. (professor and research director)
Majlinda Zhegu, Ph.D. (professor)
Javier Martínez Romero (Ph.D student)

"CUESTIONARIO ACERCA DE LAS PRÁCTICAS DE SUBCONTRATACIÓN E INVESTIGACIÓN Y DESARROLLO EN LA INDUSTRIA AEROESPACIAL EN MÉXICO"

Cláusula de Confidencialidad

Todas las respuestas a este cuestionario serán manejadas de forma confidencial y segura. Solo el equipo de investigación tendrá acceso a ellas, y se compromete a respetar esta cláusula de confidencialidad. Todos los reportes surgidos de este trabajo de investigación mostrarán estadísticas agregadas y no harán referencia a ninguna empresa por su nombre, productos o personas.

Me comprometo a respetar esta cláusula de confidencialidad

____

Firma del entrevistador en nombre de todo el equipo de investigación

He leído la cláusula de confidencialidad y estoy de acuerdo con ella_________________________

Firma del entrevistado en nombre de su empresa

Nota. El entrevistador tiene la facultad de firmar cualquier acuerdo de confidencialidad que el entrevistado juzgue pertinente, y la firma del entrevistador compromete a todo el equipo de investigación a respetar los términos y condiciones de dicho acuerdo.

PRÁCTICAS DE SUBCONTRATACIÓN E I&D GLOBAL EN LA INDUSTRIA AEROESPACIAL

CUESTIONARIO

PARTE I. Características de la empresa

Sección I.1: Entrevistado

Nombre:

____

Puesto:

____

Compañía:

____

Ubicación:______________________________

____

Teléfono:

____

Fax:

____

E-mail:______________________________

Sitio Web:

Sección I.2: Datos generales de la empresa

- **Año de fundación:**_________
- **Propiedad y control**
  ___Pública o; ___Privada
  ___Extranjera o; ___Nacional
- **Papel que juega en la estructura corporativa**
  ___Casa matriz (Headquarter) o; ___subsidiaria (branch)
- **Ventas totales 2005, 2008** _______________;_________________
- **Empleados totales al final de 2005, 2008**
  Total _____, _____
  -Ingenieros y técnicos_____, _____
  -Gestión y administración____, _____
- **Sus tres principales productos o servicios**

____

____

____

____

- **Sus tres principales mercados**

  ____

  ____

  ____

- **% de ventas exportadas:____**
- **¿Qué porcentaje de las ventas de la empresa están dirigidas a los siguientes mercados?:**

  Estado______________

  Resto del país________

  Otro, especifique:

  ____

  ____

- **¿Qué porcentaje de sus insumos vienen de los siguientes lugares?:**

  Estado_____________

  Resto del país________

  Otro, especifique:

  ____

  ____

- **Gasto en I&D (como porcentaje de ventas) 2005, 2008:_____________;__________**
- **Otros sitios en donde la compañía tenga establecimientos**

  -En México____

  -En el extranjero_______________________________________

PARTE II I&D

Sección II.1: Estrategia de I&D e Innovación

- **Durante los últimos tres años, ¿su empresa introdujo productos nuevos o significativamente mejorados (bienes o servicios), o introdujo procesos de manufactura nuevos o significativamente mejorados?**

  Si___, No___

- **Sus innovaciones más importantes tienen el carácter de:**

  Novedad a nivel mundial: ___

  Novedad en el país: ___

  Novedad en la empresa: ___

- **¿Cuál es la importancia relativa de sus fuentes internas de innovación?:**

  (en donde 1 es menos importante y 5 más importante)

Unidad de I&D (interna)	1 2 3 4 5
Departamento de Mercadotecnia	1 2 3 4 5
Personal de ingeniería y producción	1 2 3 4 5
Gestión	1 2 3 4 5

- **Importancia de sus fuentes externas de innovación:**
  (en donde 1 es menos importante y 5 más importante)

Local (Estado)__

Casa Matriz o Empresas del Corporativo	1 2 3 4 5
Clientes	1 2 3 4 5
Agencias gubernamentales o institutos de investigación	1 2 3 4 5
Consultores (académicos o profesionales)	1 2 3 4 5
Proveedores	1 2 3 4 5
Productos de competidores	1 2 3 4 5
Investigadores universitarios	1 2 3 4 5

Nacional__

Casa Matriz o Empresas del Corporativo	1 2 3 4 5
Clientes	1 2 3 4 5
Agencias gubernamentales o institutos de investigación	1 2 3 4 5
Consultores (académicos o profesionales)	1 2 3 4 5
Proveedores	1 2 3 4 5
Productos de competidores	1 2 3 4 5
Investigadores universitarios	1 2 3 4 5

Global __

Casa Matriz o Empresas del Corporativo	1 2 3 4 5
Clientes	1 2 3 4 5
Agencias gubernamentales o institutos de investigación	1 2 3 4 5
Consultores (académicos o profesionales)	1 2 3 4 5
Proveedores	1 2 3 4 5
Productos de competidores	1 2 3 4 5
Investigadores universitarios	1 2 3 4 5

Sección II.2: Características del cluster local

¿Por qué cree usted que su compañía escogió esta localidad para establecer la planta?

....

....

¿Cuáles son las ventajas específicas que tiene su planta al estar ubicada en esta localidad?

__Abundante mano de obra
__Co-locación con otras empresas del sector
__Disponibilidad de áreas industriales
__Infraestructura física (transporte, comunicaciones)
__Grandes proveedores
__Institutos de investigación especializados y universidades
__Grandes clientes
__Ventajas financieras

__Políticas gubernamentales (leyes, reglamentos, etc)

__Otras (por favor especifique):

__Incentivos gubernamentales:
-políticas
-fondos

____

____

____

En caso de necesitar invertir en una nueva planta, ¿en dónde se localizaría?

En la misma región___
En el país___
Otro país___

Sección II.3: Apoyo gubernamental (Estatal y Nacional)

- **¿En qué forma la política del gobierno federal apoya a su empresa?**
  ___Exención de impuestos para I&D
  ___Otros créditos fiscales
  ___Subsidios directos
  ___Capacitación laboral
  ___Otro (por favor explique)
  ___De ninguna forma
- **¿En qué forma la política del gobierno estatal apoya a su empresa?**
  ___Exención de impuestos para I&D
  ___Otros créditos fiscales
  ___Subsidios directos
  ___Capacitación laboral
  ___Otro (por favor explique)
  ___De ninguna forma
- **¿En qué forma el entorno local (científico y tecnológico, parques industriales y el gobierno municipal) ayuda a la empresa?**
  ___Tierra
  ___Construcción de edificios
  ___Subsidios directos
  ___Capacitación laboral
  ___Otros (Por favor, explique)
  ___De ninguna forma

PARTE III: SUBCONTRATACIÓN E I&D INTERNACIONAL

Sección III.1 Rol de la empresa en la industria

- **Por favor, indique el rol de su empresa en la industria**

a) Somos responsables de mercadotecnia, ventas, y actividades de distribución
b) Somos responsables de diseño de producto o manufactura
c) Proveemos servicios o herramientas para empresas que están involucradas en diseño de producto o manufactura
d) Otro, por favor especifique:

- **Si contestó b) en la pregunta 23 (arriba), indique el tipo de clientes de su empresa:**

a) Nuestros clientes son empresas o individuos fuera de nuestra industria o giro.
b) Nuestros clientes son los integradores de sistema dentro de nuestra industria. (i.e. empresas que venden a otras empresas o a clientes finales)
c) Nuestros clientes son integradores de sistema intermedios o proveedores de subsistemas dentro de nuestra industria.

- **Si contestó b) en la pregunta 23 (arriba), describa el tipo de proveedores de su empresa:**

a) Nuestros proveedores son proveedores genéricos fuera de nuestra industria (i.e. nosotros somos proveedores de componentes)
b) Tenemos múltiples proveedores de componentes especializados dentro de nuestra industria (i.e. nosotros somos proveedores de subsistema)
c) Tenemos múltiples proveedores especializados tanto en componentes como en subsistemas dentro de nuestra industria (i.e. nosotros somos integradores de sistema)
d) Otro, por favor especifique:_______________________________________

Sección III.2 Aprendizaje y derramas internacionales de conocimiento

- **¿Por que medios recibe usted las especificaciones para nuevos productos (o servicios)?**

(favor de ordenar en orden de importancia)
___Internet/intranet/e-mail
___Teléfono
___Correo postal/Servicio de paquetería o mensajería
___En persona
___Otro, por favor especifique:

- **¿Cómo recibe usted las especificaciones para nuevos productos (o servicios)?**

(favor de ordenar en orden de importancia)
___Pieza física o prototipo
___Planos

___Planos por computadora
___Otro, por favor especifique:

____

____

- **Describa su implicación en el desarrollo de nuevos productos (o servicios)**
  Recibe una serie de especificaciones técnicas y:
  -Las reproduce___
  -Propone mejoras___

- **¿Alguno(s) de sus empleados tuvo que recibir capacitación especial con motivo de nuevos productos (o servicios) o proyectos?**
  Si___; No___
- **¿Tuvo usted que solicitar información adicional a su cliente relacionada con especificaciones técnicas?**
  Si___; No___
- **¿Ya sea usted o su cliente, tuvieron que enviar personal para resolver problemas técnicos relacionados nuevos productos (o servicios)?**
  Si___; No___
- **¿Tuvo usted que comunicar periódicamente sus avances a su cliente como parte de un sistema de información (supply management)?**
  Si___; No___
- **En cuanto al precio de sus nuevos productos o servicios:**
  ___Tuvo usted un precio fijo desde el principio, o
  ___Fue negociado durante el proceso de desarrollo del mismo.
- **¿Cómo financia usted sus nuevos productos?**
  ____
  ____
- **¿Cómo protege usted sus innovaciones?**
  ____
  ____

Sección III.3 Practicas de gestión de la I&D internacional

- **¿Qué parte de su actividad de I&D se lleva a cabo en otros países (% de su presupuesto de I&D)? [o en su caso, su actividad de I&D ¿qué parte representa de la I&D del corporativo?]______________________________**
- **¿El porcentaje de su actividad internacional de I&D ha crecido desde el 2005? [o en su caso, ¿la proporción de su actividad de I&D con respecto a la del corporativo ha crecido desde el 2005?]**
  Si___; No___

Por qué?

___
___
___
___

- **En qué tipo de I&D internacional está su empresa involucrada:**

___Proyectos formales de colaboración conjunta
___Participación en consorcios de investigación
___Licenciamiento o adopción de invenciones privadas o públicas
___Colaboración con laboratorios de investigación o universidades

- **Por favor, de un ejemplo de alguna práctica o experiencia de gestión de I&D internacional en el que su empresa haya participado que haya resultado exitosa:**

___
___
___
___
___

- **Por favor, de un ejemplo de alguna práctica o experiencia de gestión de I&D internacional en el que su empresa haya participado que NO haya sido exitosa:**

___
___
___
___
___

- **¿Cuáles son los principales beneficios que la empresa obtiene de este tipo de prácticas?**

___Optimización de su gasto en I&D
___Disminuir costos de I&D
___Acceso a "know how" técnico
___Incentivos gubernamentales
___Fuente de ideas para nuevos productos
___Capacidades para resolver problemas
___Acceso a equipo, materiales, infraestructura de investigación

- **¿Cuáles son los riesgos para su empresa de su actividad de I&D internacional?**

___Falta de calidad de las prácticas locales de I&D
___Costos de transacción
___Falta de protección de la propiedad intelectual
___La presencia de otros competidores internacionales
___La generación o formación de competidores locales

- **¿Cómo protege usted sus competencias centrales (core competences) cuando desarrolla I&D internacionalmente?**

- **¿Su actividad global de I&D ha afectado su relación con su entorno local?**

- **¿Cuáles son los principales aspectos de la trayectoria de su actividad de I&D internacional en los próximos cinco (o diez) años?**

REFERENCES

Abernathy, W.J., and Utterback, J. 1978. "Patterns of industrial innovation", *Technology Review,* 50: 41–47.

Acha, V., Davies, A., Hobday, M., and Salter, A. 2004. "Exploring the capital goods economy: complex product systems in the UK". *Industrial and Corporate Change.* 13 (3): 505-529.

Audretsch, D. B., and Maryann, P. F. 1995. *Innovative clusters and the industry life cycle*. London: Centre for Economic Policy Research.

Agrawal, A., and Cockburn, I. M. 2002. *University research, industrial R&D, and the anchor tenant hypothesis*, Cambridge, Mass.: NBER.

Agrawal, A., and Cockburn, I. M. 2003. "The anchor tenant hypothesis: exploring the role of large, local R&D-intensive firms in regional innovation systems", *International journal of industrial organization,* 21(9): 1227.

Alexander, C. 1964. *Notes on the synthesis of form.* Cambridge: Harvard University Press.

Amsden, A. 2001. *The Rise of the Rest: Challenges to the West from Late-Industrializing Economies*. New York: Oxford University Press.

Arrow, K. J. 1959. *Economic welfare and the allocation of resources for invention.* Santa Monica, CA: Rand Corp.

Arthur, W. B. 1989. "Competing Technologies, Increasing Returns, and Lock-In by Historical Events", *The Economic Journal,* 99(394): 116-131.

Arthur, W. B. 1994. "Positive feedbacks in the economy", *The McKinsey Quarterly.* (1): 81.

Asheim, B. T. 2000. "Industrial Districts: The Contributions of Marshall and Beyond" in Clark, G. L., Feldman, M. P., and Gertler, M. S. 2000. *The Oxford handbook of economic geography.* Oxford, England; New York: Oxford University Press. pp. 413-431.

Avnimelech, G., and Teubal, M. 2008. "Evolutionary targeting", *Journal of Evolutionary Economics,* 18(2): 151-166.

Bagley, J. A. (1990). "Aeronautics", in McNeil, I. 1990. *An encyclopaedia of the history of technology*. London: Routledge. pp. 609-664.

Bair, J., and Gereffi, G. 2001. "Local clusters in global chains: the causes and consequences of export dynamism in Torreon's blue jeans industry", *World Development,* 29(11): 1886-1903.

Bair, J., and Dussel-Peters, E. 2006. "Global commodity chains and endogenous growth: Export dynamism and development in Mexico and Honduras", *World Development,* 34(2): 203-221.

Baldwin, C. Y., and Clark, K. B. 2000. *Design rules. Vol.1 Power of modularity*. Cambridge, Mass.; London: MIT Press.

Beaudry, C. 2001. "Entry, Growth and Patenting in Industrial Clusters: A Study of the Aerospace Industry in the UK", *International Journal of the Economics of Business,* 8(3): 405-436.

Becattini, G. 1990. "The Marshallian industrial district as a socioeconomic notion," in Pyke, F., Becatini, G., and Sengenberger, W. (Eds.). Industrial districts and inter-firm co-operation in Italy, Geneva: International Institute for Labour Studies, pp. 37-51.

Bennett, D., and Sharpe, K. E. 1979. "Transnational Corporations and the Political Economy of Export Promotion: The Case of the Mexican Automobile Industry", *International Organization*, 33(2): 177-201.

Benzler, G. and Wink, R. 2010. "From agglomerations to technology- and knowledge driven clusters: aeronautics cluster policies in Europe", *International Journal Technology of Management,* 50(3/4): 318-336.

Bernardes, R., and Guilherme de Oliveira, L. 2003. "Building up complex productive systems in developing countries: the Embraer experience" in Cassiolato, J. E., Lastres, H. M. M., and Maciel, M.L. *Systems of innovation and development: evidence from Brazil*. Cheltenham, UK: Edward Elgar. pp. 499-524.

Boschma, R. A. and Lamboy, J. G. 2002. "Knowledge, Market Structure, and Economic Coordination: Dynamics of Industrial Districts", *Growth and Change*, 33(3): 291-311.

Bonaccorsi, A., and Giuri, P. 2000. "When shakeout doesn't occur", *Research Policy,* 29 (7-8): 847-870.

Breschi, S., and Lissoni, F. 2001. "Knowledge Spillovers and Local Innovation

Systems: A Critical Survey", *Industrial and Corporate Change*, 10(4), 975-1005.

Brusco, S. 1990. "The idea of the Industrial District: its genesis," in Pyke, F., Becatini, G., and Sengenberger, W. (Eds.) *Industrial districts and inter-firm co-operation in Italy*. Geneva: International Institute for Labour Studies, pp. 10-19.

Brusoni, S., and Prencipe, A. 2001. "Unpacking the Black Box of Modularity: Technologies, Products and Organizations", *Industrial and Corporate Change*, 10(1): 179-205.

Cabral, L. 1995. "Sunk Costs, Firm Size and Firm Growth", *The Journal of Industrial Economics*, 43 (2):161-172.

Cantwell, J. 1995. "The Globalization of Technology: What Remains of the Product-Cycle Model?" in Chandler, A. D., Hagström, P., and Sölvell, O. 1998. *The dynamic firm: the role of technology, strategy, organization and regions*. Oxford: Oxford University Press. pp. 263-288.

Carrillo, J. V. 1995. "Flexible Production in the Auto Sector: Industrial Reorganization at Ford-Mexico", *World development*, 23(1), 87-101.

Carrillo, J., and Lara, A. 2005. "Mexican Maquiladoras. New Capabilities of Coordination and the Emergence of New Generation of Companies", *Innovation: Management, Policy & Practice,* 7(2).

Casas, R. 2005. "Exchange and knowledge flows between large firms and research institutions", *Innovation: Management, Policy & Practice*, 7(2/3), 188-199.

Casas, R., de Gortari, R., and Santos, M. J. 2000. "The building of knowledge spaces in Mexico: a regional approach to networking", *Research Policy,* 29(2), 225-241.

Caves, R. E. 1971. "International Corporations: The industrial Economics of Foreing Investment", in Dunning, J. H. (1993). *The Theory of transnational corporations*. International Business and the World Economy, set A, v. 1. London: Routledge, pp. 61-88.

Caves, R. E. 1982. *Multinational enterprise and economic analysis*. Cambridge surveys of economic literature. Cambridge: Cambridge University Press.

Cimoli, M. 2000. *Developing innovation systems: Mexico in a global context*. London; New York: Continuum.

Cimoli, M., and Katz, J. 2003. “Structural reforms, technological gaps and economic development: a Latin American perspective”, *Industrial and Corporate Change*, 12(2), 387-411.

Cimoli, M., Dosi, G., and Stiglitz, J. E. 2009. *Industrial policy and development: the political economy of capabilities accumulation.* Oxford; Toronto: Oxford University Press.

Cohen, W. M., and Levinthal, D. A. 1989. “Innovation and Learning: The Two Faces of R & D”, *The Economic Journal*, 99(397): 569-596.

Cohen, W. M., and Levinthal, D. A. 1990. “Absorptive Capacity: A New Perspective on Learning and Innovation”, *Administrative Science Quarterly*, 35(1): 128-152.

Cooke, P. 2001. “Regional Innovation Systems, Clusters, and the Knowledge Economy”, *Industrial and Corporate Change*, 10(4): 945-974.

Cooke, P., and Ehret, O. 2009. “Proximity and Procurement: A Study of Agglomeration in the Welsh Aerospace Industry”, *European Planning Studies*, 17(4): 549-567.

Cooke, P., and Morgan, K. 1998. *The associational economy: firms, regions, and innovation.* Oxford [England]; New York: Oxford University Press.

Cooke, P., Heidenreich, M., and Braczyk, H.-J. 2004. *Regional innovation systems the role of governance in a globalized world.* New York: Routledge.

Cooke, P., Uranga, M. G., and Etxebarria, G. 1997. “Regional innovation systems: Institutional and organisational dimensions”, *Research policy*, 26(4-5): 475-491.

David, Paul A. 1985. "Clio and the Economics of QWERTY", *The American Economic Review*, 75 (2): 332-337.

Dosi, G. 1982. “Technological paradigms and technological trajectories : A suggested interpretation of the determinants and directions of technical change”, *Research Policy,* 11 (3): 147-162.

Dunning, J. H. 1980. “Toward an Eclectic Theory of International Production: Some Empirical Tests”, *Journal of International Business Studies*, 11(1): 9-31.

Dunning, J. H. 1981. *International production and the multinational enterprise.* London: Allen & Unwin.

Dunning, J. H. 2000. "The eclectic paradigm as an envelope for economic and business theories of MNE activity", *International Business Review*, 9(2): 163-190.

Dussel- Peters, E. 2000. *Polarizing Mexico: the impact of liberalization strategy*. Boulder: L. Rienner Publishers.

Dutrénit. G. 2000. "Strategies and Technological Capabilities in a Multinational Mexican Firm", in Cimoli, M. (Ed.) 2000. *Developing innovation systems: Mexico in a global context*. New York: Continuum, pp. 226-242.

Dutrénit, G. 2009. "Premises and instruments of innovation policy: a reflection from the Mexican case", in Martínez Piva, J. M. (Ed) *Knowledge generation and protection intellectual property, innovation and economic development*. New York: Springer. pp. 235-261.

Dutrénit, G., and Katz, J. 2005. "Innovation, growth and development in Latin America: Stylized facts and a policy agenda". *Innovation: Management, Policy & Practice*, 7(2/3): 105-130.

Dutrénit, G., Capdeville, M., Corona Alcantar, J. M., Puchet Anyul, M., Santiago, F. and Vera-Cruz, A. O. 2010. *El Sistema Nacional Mexicano: Instituciones, Políticas, Desempeño y Desafíos*. Mexico: UAM-Xochimilco.

Ehret, O. and Cooke, P. 2010 "Conceptualizing aerospace outsourcing: Airbus UK and the lean supply approach", *Int. Journal of Technology Management*, 50(3/4): 300-317.

Esposito, E. 2004. "Strategic alliances and internationalisation in the aircraft manufacturing industry", *Technological forecasting and social change*, 71(5): 443.

Fagre, N., and Wells, L. T. 1982. "Bargaining Power of Multinations and Host Governments", *Journal of International Business Studies*, 13(2): 9-23.

Feldman, M. 2003. "The Locational Dynamics of the US Biotech Industry: Knowledge Externalities and the Anchor Hypothesis", *Industry and Innovation*, 10(3): 311-329.

FEMIA (2009), Foro Internacional Clusters 2009, PowerPoint presented in Reynosa-McAllen, August 13, 2009.

Foro Consultivo Científico y Tecnológico. 2006. "Diagnóstico de la política científica, tecnológica y de fomento a la innovación en México (2000-2006)", Octubre 2006. Retreived from: <www.foroconsultivo.org.mx/libros_editados/diagnostico.pdf>

Freeman, C. 1987. *Technology, policy, and economic performance: lessons from Japan*. London; New York: Pinter Publishers.

Frigant, V., and Talbot, D. 2005. "Technological Determinism and Modularity: Lessons from a Comparison between Aircraft and Auto Industries in Europe", *Industry and Innovation*, 12(3): 337-355.

Gallagher, K. P., Moreno-Brid, J. C., and Porzecanski, R. 2008. "The Dynamism of Mexican Exports: Lost in (Chinese) Translation?" *World Development*, 36(8): 1365-1380.

Gallagher, K., and Zarsky, L. 2007. *The enclave economy: foreign investment and sustainable development in Mexico's Silicon Valley*. Cambridge, Mass.: MIT Press.

Gereffi, G. 1996. "Mexico's 'Old' and 'New' Maquiladora Industries: Contrasting Approaches to North American Integration", in Otero, G. *Neoliberalism revisited: economic restructuring and Mexico's political future*. Boulder, Colo.: Westview Press. pp. 85-105.

Giuliani, E. 2007. "The selective nature of knowledge networks in clusters: evidence from the wine industry", *Journal of Economic Geography*, 7: 139-168.

Giuliani, E., and Bell, M. 2005. "The micro-determinants of meso-level learning and innovation: evidence from a Chilean wine cluster", *Research Policy*, 34(1): 47-68.

Goldstein, A. 2002. "The political economy of high-tech industries in developing countries: aerospace in Brazil, Indonesia and South Africa", *Cambridge Journal of Economics*, 26(40): 521-538.

Goldstein, A. 2005. "Lead Firms and Clusters in the North and in the South: A comparison of the Aerospace Industry in Montreal and São José dos Campos", In Giuliani, E., Rabellotti, R., and Dijk, M. P. 2005. *Clusters facing competition: the importance of external linkages*. Burlington, VT: Ashgate. pp. 135-153.

Hanel, P., and St-Pierre, M. 2006. "Industry-University Collaboration by Canadian Manufacturing Firms", *The Journal of Technology Transfer*, 31(4): 485-499.

Harrison, B. 1992. "Industrial Districts: Old Wine in New Bottles?" *Regional Studies*, 26(5): 469-483.

Henderson, R. M., and Clark, K. B. 1990. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms", *Administrative Science Quarterly*, 35(1): 9-30.

Hira, A., and de Oliveira, L. G. 2007. "Take Off and Crash: Lessons from the Diverging Fates of the Brazilian and Argentine Aircraft Industries", *Competition and Change*, 11(4): 329-347.

Hobday, M. 1998. "Product complexity, innovation and industrial organisation", *Research Policy*, 26(6): 689-710.

Hymer, S. 1976. "On Multinational Corporations and Foreing Direct Investment", in Dunning, J. H. 1993. *The Theory of transnational corporations*. International Business and the World Economy, set A, v. 1. London: Routledge. pp. 23-43.

Jáuregui, L. 2004. *Los transportes, siglos XVI al XX*. Océano, México.

Jin, C., Liand, T., Jianzhang, H., and Yongquing, Z. 2004. *The framework for innovation of complex product systems-a case study of ZDZK*. Paper presented at the 13th International Conference on Management of Technology, International Association for Management of Technology, Washington DC, United States, April.

Justman, M., and Teubal, M. 1995. "Technological infrastructure policy (TIP): creating capabilities and building markets", *Research Policy*, 24: 259-281.

Kehayas, N. 2007. "Aeronautical technology for future subsonic civil transport aircraft", *Aircraft Engineering and Aerospace Technology*, 79(6): 600-610.

Khan, M. H., and Blankenburg, S. 2009. "The Political Economy of Industrial Policy in Asia and Latin America", in Cimoli, M., Dosi, G., and Stiglitz, J. E. (Eds.), *Industrial Policy and Development: The Political Economy of Capabilities Accumulation*. Oxford: Oxford University Press. pp. 336-377.

Klepper, S. 1996. "Entry, Exit, Growth, and Innovation over the Product Life Cycle", *The American Economic Review*, 86(3): 562-583.

Klepper, S. 1997. "Industry Life Cycles", *Industrial Corporate Change*, 6(1): 145-182.

Knickerbocker, F. T. 1973. *Oligopolistic reaction and multinational enterprise*. Boston: Division of Research, Graduate School of Business Administration, Harvard University.

Krugman, P. 1986. *Strategic trade policy and the new international economics.* Cambridge, Mass: MIT Press.

Krugman, P. 1991. "Increasing Returns and Economic Geography". *Journal of Political Economy,* 99(3): 483-499.

Kuemmerle, W. 1997. "Building effective R&D capabilities abroad", *Harvard Business Review*, 75(2).

Lall, S., and Teubal, M. 1998. "Market-Stimulating" Technology Policies in Developing Countries: A framework with Examples from East Asia", *World Development*, 26(8): 1369-1385.

Langlois, R. N. 2002. "Modularity in technology and organization", *Journal of Economic Behavior & Organization*, 49 (1): 19.

Leibenstein, H. 1996. "Allocative Efficiency vs. "X-Efficiency", *The American Economic Review*, 56 (3): 392-415.

Lowe, E. A. 1997. "Creating by-product resource exchanges: Strategies for eco-industrial parks", *Journal of Cleaner Production*, 5(1-2): 57-65.

Lundvall, B.-A. 1988. "Innovation as an interactive process: from user-producer interaction to the national system of innovation", in Dosi, G. *Technical change and economic theory.* London: Pinter Publishers. pp. 349-369.

Lundvall, B.-A. 1992. *National systems of innovation: towards a theory of innovation and interactive learning.* London; New York: Pinter Publishers ; Distributed exclusively in the USA and Canada by St. Martin's Press.

MacPherson, A., and Pritchard, D. 2007. "Boeing's Diffusion of Commercial Aircraft Technology to Japan: Surrendering the U.S. Industry for Foreign Financial Support", *Journal of Labor Research*, 28(3): 552-566.

Maculan, A.-M. 2010. *The growth of the Brazilian aircraft industry and the Embraer's ups and downs*. Working paper presented at the Montreal meeting of the international research group of the aerospace industry, August, Montreal, Canada.

Malerba, F. 2002. "Sectoral Systems of Innovation and Production", *Research Policy*, 31: 247-264.

Malerba, F., and Orsenigo, L. 1997. "Technological Regimes and Sectoral Patterns of Innovative Activities", *Industrial and Corporate Change*, 6(1): 83-118.

Mani, S. 2010. *The flight from defence to civilian space: evolution of the sectoral system of innovation of India's aerospace industry.*Working paper 428, Centre for development studies, Trivandrum, Kerala, India.

Mariani, M. 2002. "Next to Production or to Technological Clusters? The Economics and Management of R&D Location", *Journal of Management & Governance*, 6 (2): 131-152.

Markusen, A. 1996. "Sticky Places in Slippery Space: A Typology of Industrial Districts", *Economic Geography*, 72(3): 293.

Marshall, A. 1986. *Principles of Economics* (8th edition originally published in 1890). Macmillan, Basingstoke, Hants.

Martin, R., and Sunley, P. 2003. "Deconstructing clusters: chaotic concept or policy panacea?" *Journal of Economic Geography*, 3(1): 5-35.

McGuire, S., Fai, F. and Ozaki, T. 2010. "Path dependence as a political construct, the disruptive influence of technology and Japanese aerospace", *Int. Journal of Technology Management*, 50(3/4): 367-379.

McKendrick, D. 1992. "Obstacles to 'Catch-Up': The Case of the Indonesian Aircraft Industry", *Bulletin of Indonesian Economic Studies*, 28(1): 39-66.

Metcalfe, J. S. 1994. "Evolutionary Economics and Technology Policy", *The Economic Journal*, 104(425): 931-944.

Moreno-Brid, J. C., Santamaría, J., and Rivas Valdivia, J. C. 2005. "Industrialization and Economic Growth in Mexico after NAFTA: The Road Travelled", *Development and Change*, 36 (6): 1095-1119.

Mowery, D. C., and Rosenberg, N. 1985. "Commercial aircraft: cooperation and competition between the U.S. and Japan", *California Management Review*, 27(4).

Mowery, D. C., & Rosenberg, N. 1995. *Technology and the pursuit of economic growth*. Cambridge [u.a.]: Cambridge Univ. Press.

Murmann, J. P., and Frenken, K. 2006. "Toward a systematic framework for research on dominant designs, technological innovations, and industrial change", *Research Policy*, 35(7): 925-952.

Nelson, R. R. 1993. *National Innovation Systems: a comparative analysis*. New York: Oxford University Press.

Nelson, R. R., and Winter, S. G. 1982. *An evolutionary theory of economic change*. Cambridge, Mass.: Belknap Press of Harvard University Press.

Niosi, J. 1999. "The internationalization of Industrial R&D, from technology transfer to the learning organization", *Research Policy*, 28: 107-117.

Niosi, J. 2002a. "National systems of innovations are "x-efficient" (and x-effective): Why some are slow learners", *Research Policy*, 31(2): 291-302.

Niosi, J. 2002b. "Regional systems of innovation: market pull and government push", in Holbrook, J. A., and Wolfe, D. (Eds.), *Knowledge, Clusters and Regional Innovation*. Montreal: McGill-Queen's University Press. pp. 39-57.

Niosi, J., and Bourassa, M. 2008. "L'innovation dans les villes canadiennes" in *Compendium d'indicateurs de l'activité scientifique et technologique au Québec*, Institut de la statistique du Québec: Canada. pp 61-70.

Niosi, J., and Zhegu, M. 2005. "Aerospace Clusters: Local or Global Knowledge Spillovers?" *Industry & Innovation*, 12(1): 5-29.

Niosi, J., and Zhegu, M. 2008. *Innovation System Lifecycle in the Aircraft Sector*. Paper presented at the Entrepreneurship and Innovation - Organizations, Institutions, Systems and Regions. DRUID, Copenhagen, CBS, Denmark.

Niosi, J., and Zhegu, M. 2010. "Anchor tenants and regional innovation systems: the aircraft industry", *Int. Journal of Technology Management,* 50(3/4): 263-284.

Niosi, J., Bas, T. G., and Zhegu, M. 2005. *Canada's regional innovation systems: the science-based industries*. Montreal: McGill-Queen's University Press.

Organisation for Economic, Cooperation & Development (2009). *15 Mexican States*. Paris: OECD.

Palma, J. G. 2009. "Flying Geese and Waddling Ducks: The Different Capabilities of East Asia and Latin America to 'Demand-Adapt' and 'Supply-Upgrade' their Export Productive Capacity", in M. Cimoli, G. Dosi & J. E. Stiglitz (Eds.), *Industrial Policy and Development: The Political Economy of Capabilities Accumulation.* Oxford; Toronto: Oxford University Press. pp. 203-238.

Patel, P. and Pavitt, K. 1997. "The technological competences of the world's largest firms: complex and path-dependent, but not much variety", *Research Policy*, 26 (2): 141-156.

Peres, W. 2009. "The (Slow) Return of Industrial Policies in Latin America and the Caribbean", in Cimoli, M., Dosi, G., and Stiglitz, J. E. (Eds.), *Industrial Policy and Development: The Political Economy of Capabilities Accumulation*. Oxford; Toronto: Oxford University Press. pp. 175-200.

Perroux, F. 1982. *Dialogue des monopoles et des nations : "équilibre" ou dynamique des unités actives*. Grenoble: Presses universitaires de Grenoble.

Perroux, F. 1955. "Note sur la notion de 'pôle de croissance,'" Économie appliquée, Vol. 7 pp 307-320; English translation: "Note on the concept of 'Growth Poles'" in Livingstone, Ian. 1971. *Economic policy for development; selected readings*. [Harmondsworth, Eng.]: Penguin Books. pp. 278-289.

Phillips, R. G. 2002. "Technology business incubators: how effective as technology transfer mechanisms?" *Technology in Society*, 24(3): 299-316.

Piore, M. J., and Sabel, C. F. 1984. *The second industrial divide: possibilities for prosperity*. New York: Basic Books.

Plan de Vuelo Nacional. 2010. Ministry of Economy (Secretaría de Economía): *www.promexico.gob.mx/work/sites/.../2/**PlanVueloNacional**.pdf*

Porter, M. E. 1990. *The competitive advantage of nations*. New York: Free Press.

Porter, M. E. 2000. "Locations, Clusters, and Company Strategy", in Clark, G. L., Feldman, M. P., and Gertler., M. S. *The Oxford handbook of economic geography*. Oxford, England; New York: Oxford University Press, pp 253-274.

Prencipe, A. 1997. "Technological competencies and product's evolutionary dynamics a case study from the aero-engine industry", *Research Policy*, 25(8): 1261-1276.

Programa Sectorial de Economía. 2007-2012. Ministry of Economy (Secretaría de Economía)

Pyke, F. S., and Sengenberger, W. 1990. "Introduction", in Pyke, F. S., Becattini, G, and Sengenberger, W. (Eds). *Industrial districts and inter-firm co-operation in Italy*. Geneva: International Institute for Labour Studies.

Rabellotti, R. 1995. "Is There an "Industrial District Model"? Footwear Districts in Italy and Mexico Compared", *World Development*, 23(1): 29.

Ramamurti, R. 2001. "The Obsolescing 'Bargaining Model'? MNC-Host Developing Country Relations Revisited", *Journal of International Business Studies*, 32 (1): 23-39.

Reinert, E. S. 2007. *How rich countries got rich-- and why poor countries stay poor*. New York: Carroll & Graf.

Reinhardt, N., and Peres, W. 2000. "Latin America's New Economic Model: Micro Responses and Economic Restructuring", *World development*, 28(9): 1543.

Ronstadt, R. C. 1978. "International R&D: The Establishment and Evolution of Research and Development Abroad by Seven U. S. Multinationals", *Journal of International Business Studies*, 9(1): 7-24.

Sabel, C. F. 1989. "Flexible specialization and the re-emergence of regional economies", in Hirst P. and Zeitlin J. (Eds) Reversing Industrial Decline? Berg. Oxford. pp. 17-70

Sanchez, R., and Mahoney, J. T. 1997. "Modularity, Flexibility, and Knowledge Management in Product and Organization Design", *Strategic Management Journal*, 17: 63.

Schilling, M. A. 2000. "Toward a General Modular Systems Theory and Its Application to Inter-firm Product Modularity", *The Academy of Management Review*, 25(2): 312-334.

Scitovsky, T. 1954. "Two Concepts of External Economies", *The Journal of Political Economy,* 62 (2): 143-151.

Scott, A. J. 1993. *Technopolis: High-technology industry and regional development in southern California*. Berkeley: University of California Press.

Semlinger K. 2008. "Cooperation and competition in network governance: Regional networks in a globalised economy", *Entrepreneurship and Regional Development,* 20 (6): 547-560

Simon, H. A. 1962. "The Architecture of Complexity", *Proceedings of the American Philosophical Society*, 106(6): 467-482.

Smith, D., and Ibrahim, G. 2006. "Cluster Dynamics: Corporate Strategy, Industry Evolution and Technology Trajectories - A Case Study of the East Midlands

Aerospace Cluster", *Local Economy*, 21(4): 362-377.

Steenhuis, H.-J., and de Bruijn, E. J. 2001. "Developing countries and the aircraft industry: match or mismatch?" *Technology in Society*, 23(4): 551-562.

Teubal, M. 1996. "R&D and technology policy in NICs as learning processes", *World Development*, 24(3): 449-460.

Teubal, M. 1997. "A catalytic and evolutionary approach to horizontal technology policies (HTPs)", *Research Policy*, 25 (8): 1161-1188.

Teubal, M. 2002. "What is the systems perspective to Innovation and Technology Policy(ITP) and how can we apply it to developing and newly industrialized economies?" *Journal of Evolutionary Economics*, 12(1): 233-257.

Thomas, Morgan D. 1975. "Growth pole theory, technological change, and regional economic growth", *Papers of the regional science association,* 34: 3-25.

Torres, A., and Jasso, J. 2005. "Cross border acquisitions and mergers: Learning processes of Mexican corporative groups", *Innovation: Management, Policy & Practice*, 7(2/3): 240-255.

Tushman, M. L., and Anderson, P. 1986. "Technological Discontinuities and Organizational Environments", *Administrative Science Quarterly*, 31(3): 439-465.

Ulrich, K. 1995. "The role of product architecture in the manufacturing firm", *Research Policy*, 24(3): 419-440.

Vernon, R. 1966. "International Investment and International Trade in the Product Cycle", *The Quarterly Journal of Economics*, 80(2): 190-207.

Verzani, J. 2005. *Using R for introductory statistics*. Boca Raton: Chapman & Hall/CRC.

Zhegu, M. 2007. *La coévolution des industries et des systèmes d'innovation: l'industrie aéronautique*. Ph.D. Thesis. Université du Québec à Montréal: Canada.