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Assessment of an emerging aerospace manufacturing cluster and its dependence on the mature global clusters

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Abstract

This study assesses the aerospace manufacturing industry of an emerging cluster by using Porter's Diamond model. The assessment is used to identify its dependence from mature global markets and the elements that are behind its dependence. In the first part of the paper, an introduction to the current landscape, the market trends and challenges of the aerospace industry is presented. Then, a case study of an emerging aerospace manufacturing cluster is undertaken: the case of Mexico. The results indicated that the aerospace industry in this country has positively developed, however, it is still highly dependent on mature global markets. Recently launched strategies and programs from the government, evidence that it is aiming to impulse the growth of the aerospace industry and to reduce its dependence on foreign markets.

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Keywords: Manufacturing network; Evaluation; Reconfiguration.

1. Introduction

The aerospace industry is predicted for continued future growth. By 2035, it is estimated that the number of passengers will increase up to 7.2 billion, compared with the 3.5 billion passengers in 2015 [1]. The largest market demand will swing to the Asia-Pacific region, where China is expected to turn into the major aviation market, taking

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the United States (US) position [1]. The backlog for the aeroplanes' manufacturers has maintained its upward trend. By 2004, the commercial aeroplanes' arrears consisted of about 2,500 aeroplanes from 2 Prime Manufacturers (PM), representing more than 4 years of production. By 2015, the backlog raised up to more than 13,000 aeroplanes from 5 PM, representing more than 9 years of work [2]. New entrants to the aerospace manufacturing industry, like the Commercial Aircraft Corporation of China (Comac) and emerging aerospace manufacturing clusters, are poisoning the current aerospace manufacturing supply chain configuration to adapt to challenges never faced before.

After evidencing that the current aerospace manufacturing supply chain configuration needs to adapt to cope with the foreseen challenges, the question now turns towards the needed reconfiguration. To answer that question, a deep analysis covering all the different aspects of a supply chain should be undertaken. The intention of this work is to try to answer part of that question, by evaluating an emerging aerospace manufacturing cluster and its dependence on mature global clusters. In the first part of the paper, a brief introduction to the current landscape, the market trends and challenges of the aerospace industry is presented. Then, a case study of an emerging aerospace manufacturing cluster will be undertaken: the assessment of the current supply chain configuration of the Mexican aerospace manufacturing industry using Porter's Diamond model.

2. Methodology and data

In the literature, there are many approaches available for assessing a single manufacturing plant, an entire organisation's supply chain and industrial clusters. One of the most used models for cluster's assessment is the Porter's Diamond model, which was developed by the Harvard Business School economist Michael Porter in his work 'The Competitive Advantage of Nations' [3]. This model is based on the statement that the competitiveness of a nation or an industrial sector is determined and can be evaluated by the interaction of four elements: *factor conditions, demand conditions, related and supporting industries, and firm strategy, structure and rivalry. Chance* and *government* are considered also as determining factors for the competitiveness, but extrinsic to business [4]. *Factor conditions* refer to the position of a nation in regards necessary attributes for production, such as infrastructure or labour force. *Demand conditions* refer to the nature of the market demand. The *related and supporting industries* element makes reference to the presence in the nation of industries related to the one subject to evaluation and the availability of suppliers. Finally, the element *firm strategy, structure and rivalry* is related to the conditions about how companies are created, organised and managed, and the nature of the competition within domestic firms. Although Porter's diamond has some flaws, it has been widely used to analyse the competitiveness of a nation and many different types of industrial clusters [4]–[8]. For instance, Kuchiki (2007) used Porter's model as a base to analyse China's automobile industry; Paone and Sasanelli (2016) used the model to compare aerospace clusters around the world in order to identify elements that could be applied for the development of an aerospace cluster in South Australia. For the sake of this study, Porter's Diamond model will be used as a base to assess the Aerospace Industries agglomerated in Mexico, with the special focus of identifying its dependence from mature aerospace clusters.

There are limitations to this study regarding the data gathered. Firstly, data were obtained from sources available to the public. Most of the information was gathered from recognised organisations such as consultancy firms and states agencies. In addition, data were gathered from February to July 2017. Hence, considering also the changing aspects of a supply chain, it can be assumed that data are not exhaustive. As a consequence, conclusions from this study should be taken as suggestive and not absolute. Although the mentioned limitations, the data gathered is a complete data set reported to date and noteworthy conclusions can be obtained.

3. Current landscape

Nowadays, the aerospace industry is dominated by 20 companies that hold around 80% of the civil and defence market. According to PwC (2014) and Thisdell (2013), North America owns 60% of the market, with the American companies Boeing for Civil and Lockheed Martin for Defence as major contributors. Europe possesses around 30% of the market, with France, United Kingdom and Netherlands as key players. Asia currently owns only 4% of the market, where Japan has the first place, followed by China and India [9], [10].

Regarding the Civil Aerospace, Boeing and Airbus are the biggest players owning half of the market. In the Defense sector, the American companies Lockheed Martin, Boeing and Northrop Grumman are the major providers.

According to the position in the market, the main mature aerospace manufacturing clusters are located in USA, Canada, France, Germany, United Kingdom, Spain and Japan. Where the main emerging aerospace clusters are located in Mexico, Brazil, China, India, Mexico, Malaysia, UAE, Russia and Singapore [6], [11]–[13].

Table 1 - Top Civil Aerospace Companies by Region (data obtained from [9], [10])

Region	Market Share	Headquarters Location	Main Firms
North America	60%	Canada	Bombardier CAE
		USA	Boeing General Dynamics Honeywell International United Technologies Corporation
Europe	36%	France	Dassault Aviation SAFRAN Thales Zodiac
		Germany	Diehl Aerosystems FACC AG MTU Aero Engines
		Italy	Elettronica Finmeccanica
		Netherlands	Airbus
		Spain	ITP
		Sweden	SAAB SKF
		UK	BAE SYSTEMS GKN Meggitt Rolls-Royce
South America	3%	Brazil	Embraer
Asia	<1%	China	AVIC
		India	Hindustan Aeronautics
		Japan	Kawasaki Heavy Industries Mitsubishi Heavy Industries
		Singapore	Singapore Technologies Engineer
		South Korea	Korean Aerospace Industries
Middle East	<1%	Israel	Elbit Systems Israel Aircraft Industries
Africa	<1%	South Africa	Denel

3.1. Market trends

Concerning the expectations for the future air traffic demand, recent market analysis from the International Air Transport Association (IATA) suggests that the aerospace industry is predicted for continued future growth. Official Airlines' reports evidence that in 2015, around 3.5 billion people and 51 million metric tonnes of cargo were transported, with a fleet of 26,000 aeroplanes averaging 100,000 flights a day. It is estimated that in 2015, the aerospace industry supported around 63 million jobs and $2.7 trillion of GDP. The prediction for the following years is that these numbers will continue growing. By 2035 the number of commuters will be doubled up to nearly 7.2 billion, based on a 3.7% annual Compound Average Growth Rate (CAGR)[1].

Asia-Pacific region is expected to become the major driver of demand in the upcoming years. The major aviation market will be China replacing the US, India will be the third place after taking UK's position, and Indonesia is predicted to enter into the top ten aviation markets [1], [2], [14]. Revenues for the aerospace industry are also growing. A revenue growth of around 2% is expected for 2017. In 2015, the airlines reported record levels of return on capital to investors: nearly $35 billion net profit on revenues of $718 billion. As fuel represents around 27% of airlines operational cost, the biggest factor that influenced a significant rise in profitability was a considerable drop in average price of a barrel of jet fuel (42% drop in 2015, compared to previous year). However, an uneven distribution of profitability characterises the aerospace supply chain, where manufacturers are the main profited. As a consequence, airlines are trying to reduce costs from PM and airport charges [14]–[16].

3.2. Aerospace industry challenges

As evidenced by the market trends and the emergence of new manufacturing clusters, the aerospace manufacturing industry is being threatened by challenges never faced before. Evidence suggests that one of the main challenges for the aerospace industry is the need to increase the production capacity in order to fulfil the rise in demand. In 2015, the estimation is that a fleet of around 26,000 aeroplanes was in service. By 2034, the forecast is that this number will grow to reach more than 37,500 aeroplanes [14], [16], [17]. Furthermore, evidence shows that biggest aerospace manufacturers are experiencing increased customer orders' backlogs [17]–[24]. By 2004, the commercial aeroplane backlog consisted of about 2,500 aeroplanes from 2 PM, with 49 major customers, representing more than 4 years of production. By 2015, the commercial aeroplane backlog raised up to 13,467 aeroplanes from 5 PM, with 233 major customers, representing more than 9.6 years of backlog [2].

Another challenge that the aerospace manufacturing companies are facing is the introduction of new players to the aerospace manufacturing industry, like the Comac and emerging aerospace manufacturing clusters in low-cost countries. These new entrants are conditioning the current aerospace manufacturers and leading a reconfiguration of the aerospace supply network [23], [25], [26]. For instance, aerospace companies are following internationalisation strategies of their manufacturing plants in new clusters, helping with this the emerging of new aerospace clusters.

Within the main reasons behind the creation of new aerospace clusters are a potential low labour and operating cost, an increase of production capacity, an expansion of their market access, and an increase in market share, as it helps to meet industrial offset obligations derived from political reasons. It is relevant to remember that as the aerospace industry is not mass production, the transportation cost is not considered as an impediment for its internationalisation [13], [26], [27].

Moreover, market demand is pushing manufacturers to adopt new manufacturing practices to enhance their manufacturing capabilities. For instance, Boeing announced in 2014, that in response to strong commercial aeroplane demand from customers worldwide and the need to replace older aeroplanes, they will increase the 737 production rate from 42 to 52 aeroplanes per month by 2018 [25]. Improved efficiencies achieved through manufacturing innovation are helping Boeing to raise their production rates [28]. Likewise, Airbus expects to raise A320 production rates from 42 aeroplanes a month to 50 units, also by 2018 [24]. To achieve this, Airbus implemented a new production organisation in 2013 to manage the industrial activities required to meet continued strong demand, while also achieving higher performance levels across the company's series and development programmes [29]. In addition, Airbus also created a new Operational Excellence Centre of Competence to define and deploy Airbus' industrial strategy, to support its long-term "Vision 2020" and to ensure "best-in-class" industrial standards for the company [29].

To sum up, evidence suggests that the main challenges that the aerospace industry is facing, such as the market trends and pressures of new entrants to the aerospace manufacturing industry, are leading the supply network to adapt and go through a reconfiguration.

3.3. Emerging aerospace manufacturing clusters

At the beginning of this century, Jim O'Neill (a chief economist at Goldman Sachs), introduced the term "BRICs" to describe the countries that he predicted to become the economic giants: Brazil, Russia, India and China [30]. More recently, O'Neill predicted that four new emerging economies could become part of the ten largest economies in the next 30 years: the "MINTs" – Mexico, Indonesia, Nigeria and Turkey [30]–[33]. In the recent years, these countries have had macroeconomic indicators that illustrate their potential, such as a real GDP variation above 3.5% [32]. In addition to the facts that position these countries as the next key locations on the world for industries' expansion [31], there is strong evidence to assume that some of these countries could also become crucial locations for the aerospace industry. For instance, Turkey has the Turkish Airlines as the fastest growing airline in the world [33]; Indonesia is predicted to become the sixth biggest customer market regarding number of passengers in the next 20 years [34]; in recent years, Mexico has been one of the countries with highest foreign investments in manufacturing for the aerospace industry in the world. The latter one has been used as a case study and the results of the assessment are presented next.

4. Supply chain analysis

4.1. Background of the aerospace industry in Mexico

The Aerospace Industry in Mexico started during the World War I, when in 1915 designed and manufactured the propeller named 'Anahuac', used to reach a record in flying height (19,700ft) for the American continent [35]. In the following years, Mexico designed and manufactured its own aeroplanes. However, the manufacturing volume was in low-scale and aeroplanes were mainly used for its national agricultural and defence sector [36]. By the end of the 1900s, this country stopped the manufacture and design of its own aeroplanes and started a new approach by attracting investment from foreign companies; firms like General Electric and Safran Group started to open facilities [37], [38].

4.2. Assessment of the Mexican aerospace industry using Porter's Diamond

According to Porter's Diamond model, there are four elements that condition the national competitive advantage. These elements are *factor conditions, demand conditions, firm strategy, structure and rivalry, and related and supporting industries.* Each element will be assessed from the Aerospace Industry located in Mexico.

4.2.1. Factor conditions

According to the Global Enabling Trade Report 2016, published by the World Economic Forum (WEF) and the Global Alliance for Trade Facilitation, Mexico is one of the countries in the world that has improved the most regarding the Enabling Trade Index 2016, as it climbed 11 places from 2015 to 2016, and is positioned now in the 51st place. In 2016, its GDP was equivalent to US$ 1144.3 billion; the GDP per capita was US$ 9009.3 and it had a 2.37% share of world trade with a negative US$ 24.51 billion merchandise trade balance. Its domestic market access is considered as one of the world's most open, which is ranked in the 10th place. 93% of the imports enter to Mexico without duty. Its geographical location and internal connectivity to sea and airports help this country to be considered with a relatively high rate of infrastructure [39]. At the beginning of the 2000s, there were only 61 companies related to the Aerospace Industry. The conditions mentioned previously and the following ones contributed to increasing the number of companies through foreign investment [13], [40]–[44]: low manufacturing costs; skilled labour - according to Hernandez Martinez et al [45], the highest demand (46%) for human capital is for operators, technicians and inspectors. Education institutions, as the Aeronautical University of Queretaro (UNAQ) and many others, have helped to fulfil the requirements -; proximity to prime manufacturers in the US; duty-free access with 45 nations; a bilateral aviation safety agreement (BASA) with the US signed in 2007, which allows manufacturers to certify aerospace designs and components directly from Mexican facilities; and the Wassenaar Arrangement on Controls of Dual-Use goods and technologies.

The evolution regarding the number of companies and trade balance is shown in *Figure 1 (a)*. Although the factor conditions have helped in increasing the number of companies in more than 300% since 2006, the trade balance hasn't considerably improved. Previous numbers lead to a conclusion that the trade balance could be improved if more suppliers are developed. Further analysis on specific needs of already established companies could help to identify the specific kind of suppliers that are needed.

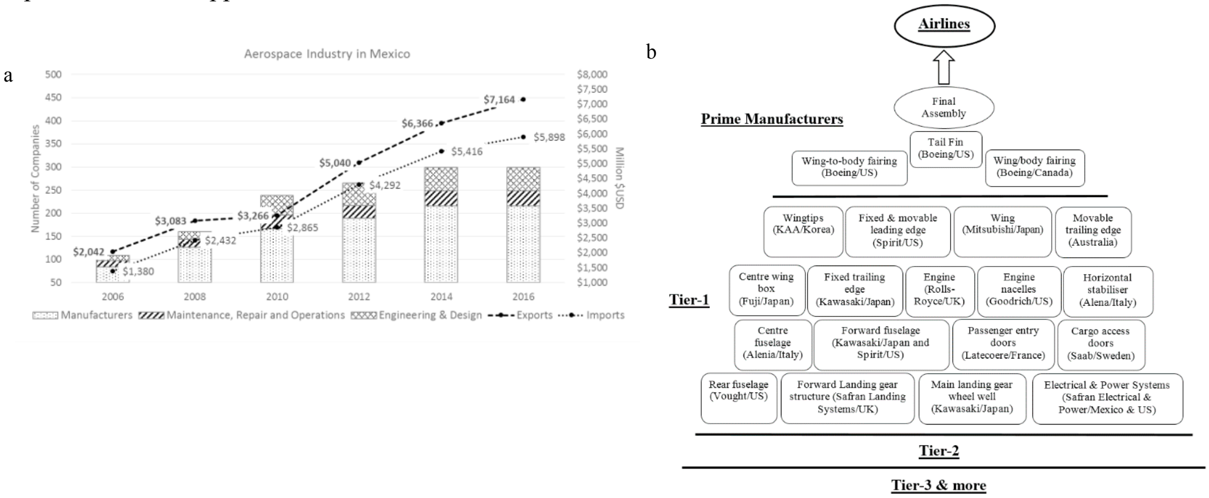

Figure 1 – (a) Aerospace Industry in Mexico (data obtained from [46]); (b) Supply Chain Structure for Boeing 787 (data obtained from [47])

4.2.2. Demand conditions

In the commercial aerospace industry, the end customers are the airlines. Prime manufacturers, as Boeing and Airbus, are the head of the manufacturing supply chain and are responsible for delivering the final product to the customer. An example of the supply chain structure of Boeing 787 is illustrated in *Figure 1 (b)*. Normally, PM have a manufacturing location that assembles components manufactured by other owned manufacturing locations and by components from Tier-1 suppliers. Taking Boeing 787 as an example, the final assembly is executed in Boeing Everett Factory and Boeing South Carolina; it assembles components from other Boeing's manufacturing locations as the wing-to-body fairing and tail fin, and it also assembles components from Tier-1 suppliers as the engines from Rolls-Royce manufactured in the UK [47].

Evidence shows that the nature of the demand in the Aerospace Industry located in Mexico is dominated by foreign customers [45], [46]. For instance, in 2014, the North American Free Trade Agreement (NAFTA), between Canada, Mexico and the US, represented 53% imports and 79% of exports for Mexico [39]. Nowadays, Mexican aerospace manufacturing is spread mainly in 5 sub-clusters: *Baja California, Queretaro, Chihuahua, Nuevo Leon and Sonora*. There are four prime manufacturers in the country, where Oaxaca Aerospace is the only Mexican. This company manufactures the aeroplane 'Pegasus PE-210A' for the Mexican army. *Baja California* is the sub-cluster that exports the most. This region is focused mainly in high-value knowledge process outsourcing, precision machinery, electric and power systems, hydraulic and interior systems. It has Honeywell Aerospace as tier-1 company and more than 60 >tier-1 firms. *Queretaro* is specialised in the assembly and manufacture of aeroplanes and helicopter parts, turbines, landing gear and MRO. It has Bombardier Aerospace and Airbus Helicopters as prime manufacturers; Safran Aircraft Engines, Safran Landing Systems, TechOps and ITP as MRO; Safran Aircraft Engines, Safran Landing Systems, Meggitt Aircraft Braking Systems and Aernnova as tier-1 firms and has more than 15 >tier-1 companies. *Chihuahua* is focused on wiring, composite materials and aerostructures. It has Cessna Aircraft as prime manufacturer; it has Safran Electrical & Power (Labinal Power Systems – which is the largest wiring plant in the world), Honeywell Aerospace, Beechcraft, EZAIR Interior Limited and Textron International as tier-1 companies; there are more than 30 companies as part of >tier-1 level. *Nuevo Leon* is dedicated to MRO of regional aeroplanes with more than 30 companies. *Sonora* region produces mainly turbine's components with more than 50 companies as part of >tier-1 level [45], [46]. The source of the demand and the destination of the manufactured products also evidence that the demand conditions are tied-up to foreign markets. The exports destinations of the country are mainly the US, Canada and France. The PM supply components to final assembly plants located mainly in the US and Canada; the tier-1 companies supply their products to the PM located in Mexico and in foreign markets. The rest of the tier levels depend directly from the upper levels, meaning that are also tied-up to foreign markets [45], [46].

4.2.3. Related and supporting industries

Mexico is a country that has been characterised by a relatively high foreign investment for manufacturing plants. The factor conditions have positioned Mexico as one of the countries in the world that have improved the most regarding the Enabling Tarde Index 2016 [39]. For this reason, there are related industries that help the development of the aerospace manufacturing industry. For instance, one of the most important industries in the country is the automobile sector. In 1985, Mexico's automobile industry had only 400,000 units per year, exporting only 20% of them. In 2002, this industry was positioned the 9th largest in the world with 2 million units per year, exporting 75% of them [46]. Thus, this kind of related industries, that have been established in the country for many years, have helped the development of the aerospace industry and are a potential opportunity area for enhancing future development.

With regards to the supporting industries, the government has launched programs and developed supporting institutions for the aerospace industry. Some examples are summarised below [45]:

- Joint supplier's development model. Created by the Ministry of Economy in cooperation with the United Nations Program for Development, aiming to train consultants to improve the supply chain.
- The methodology of the Transnational Corporations Partnerships. The main goal is to integrate the aerospace sector to already established supply chains from other sectors, as the automobile sector. Domestic suppliers will try to be integrated and foreign companies are expected to be attracted to fulfil missing capabilities.
- A Sourcing Council. Developed by the Mexican government as part of its National Flight Plan (NFP) in conjunction with Eaton, Safran Group, Bombardier, Honeywell, Bell Helicopter and Rockwell Collins. Its main goal is to identify the missing links in the supply chain, qualify domestic suppliers and attract foreign investments.

To sum-up, evidence shows that Mexico has related industries that have helped with the development of the aerospace industry, but needs to increase the availability of supporting industries in order to boost its development. Strategies recently developed reveal that Mexican government is willing to cope with this opportunity area.

4.2.4. Firm strategy, structure and rivalry

According to Porter (1998), the way in which firms are created, organised and managed and the domestic rivalry are part of the fourth element to determine the national competitive advantage of a sector [3]. The intrinsic factor conditions of the country and the benefits that the government gives to foreign companies to attract investment are the main reasons why industries of the aerospace sector in Mexico are created mainly as a result of foreign investment [41], [45], [46]. These companies are organised and managed following the guidelines established by their home-country management. The main difference relies on the people, as they take advantage of low wages in the country to hire domestic skilled labour force [46]. Concerning the domestic rivalry, it is relevant to mention that the aerospace sector is characterised by fragmenting the market rather than competing for increasing its market share. Considering the previous condition, and that the aerospace industry in Mexico is in a developing phase, the domestic rivalry is nearly non-existent in this country. However, new entrants to the aerospace manufacturing sector and emerging aerospace manufacturing clusters, are likely to lead a change to the current configuration [8], [44], [46], [48].

5. Conclusions

The Mexican aerospace manufacturing industry was assessed by analysing each of the elements described in Porter's diamond model. As an outcome of the analysis, it could be concluded that factor conditions, such as duty-free with 45 nations and a Bilateral Aviation Safety Agreement with the US have helped the development of the aerospace industry in this nation. In addition, demand conditions, referring to the source of the demand and the destination of the manufactured products, demonstrates that the nature of the demand is tied-up to foreign markets. On the other hand, analysis of the related and supporting industries suggests that the aerospace industry in Mexico needs to increase the availability of supporting industries in order to increase its development. Finally, the analysis of firm strategy, structure and rivalry show a lack of domestic rivalry in the country. All these elements triggered the conclusion that the aerospace manufacturing industry in Mexico is highly dependent on mature clusters, and that recently launched strategies and programs from the government, indicates that this nation is willing to impulse the development of its aerospace manufacturing industry and to reduce its dependence on mature global clusters. Further analysis on specific needs of already established companies is recommended to identify the actions needed to reduce its dependence.

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