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Ensuring the High Performance of Design and Engineering Firms in Mexico's Aerospace Industry: A Qualitative Comparative Analysis

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Abstract. The aerospace industry is considered strategic for economic and national security reasons because it generates short- and long-term benefits for countries, such as new investments, technology transfers, and spillover. Therefore, this research aimed to identify the necessary and sufficient conditions for guaranteeing the high performance of design and engineering firms (DEFs) in Mexico's aerospace industry. Taking a resource-based perspective enhanced by absorptive capacity and entrepreneurship approaches, this study contributes to understanding the causal ambiguity and social complexity characterizing the relationship between firms' performance and resource allocation. Additionally, this research used a fuzzy-set qualitative comparative analysis (fsQCA) method to gain insight into the configurations (i.e., sets of resources) that lead firms to achieve high performance levels (HPLs) in Mexico's aerospace industry. The results demonstrated that absorptive capacity, innovation capacity, entrepreneurial capacity, research and development activities, and specialized human resources are necessary conditions for achieving HPLs.

Keywords: Aerospace industry; Design and engineering firms; fsQCA; High performance levels; Mexico

1. Introduction

France, Germany, the United Kingdom, and the United States are global leaders in the aerospace industry. Nevertheless, new players (including research, production, and manufacturing centers) have recently emerged in Brazil, China, India, Mexico, and Singapore, lowering production costs for aircraft components and other mechanical and electronic systems through intercompany collaboration (Bédier et al., 2008; Casalet, 2013). Emerging economies aim to pursue innovation and disseminate new knowledge to reduce the technological gap between themselves and industrialized economies (Fu et al., 2011). Overall, the aerospace industry in emerging economies has focused on developing joint venture projects between foreign and local investors and other stakeholders to fulfill original equipment manufacturers' (OEMs') requirements (Bédier et al., 2008; Casalet, 2013; Deloitte, 2019).

In this regard, Mexico has engaged in successful collaboration and implemented strategic actions, such as export promotion and research and development (R&D) efforts, to develop joint ventures, which, combined with the government's promotion of technology

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transfer, have led to the growth of the country's aerospace industry (Goldstein, 2002; Goldstein, 2006; Flores and Villareal, 2017). In fact, Mexico is considered one of the most important investment locations in the aerospace industry and an example of a consolidated aerospace industry that aims to boost innovation (ProMéxico, 2016; Flores and Villareal, 2017). Typically, design and engineering firms (DEFs) have driven the aerospace industry in Mexico, and their performance relies heavily on creating and disseminating new knowledge and venturing into different innovative areas within firms to expand their client portfolios with new products, services, and technologies (FEMIA, 2015).

From a theoretical perspective, the resource-based view considers causal ambiguity and social complexity as two essential features for understanding and explaining firms' performance (Barney and Clark, 2007). Qualitative comparative analysis (QCA) deals with causal complexity by analyzing configurations (i.e., sets of resources) resulting from combinations of different conditions (i.e., resource allocations; Ragin, 2008; Mello, 2021). This paper argues that the causal ambiguity and social complexity considered by the resource-based view can be analyzed using QCA methods to investigate complex causal processes (Wagemann, 2012; Parente and Federo, 2019; Gerrits and Pagliarin, 2020). QCA approaches explain how the presence or absence of different conditions in alternative configurations can result in similar outputs (Ragin, 2008). The set-theoretic relations in QCA employ the concepts of equifinal, conjunctural, and asymmetric causation as explanations for causal complexity (Wagemann, 2012), which in this research related to Mexico's aerospace industry. The research question underpinning this study was as follows: What are the necessary and sufficient conditions that lead DEFs in Mexico's aerospace industry to achieve high performance levels (HPLs)?

The results suggest that five conditions are necessary for DEFs in Mexico's aerospace industry to achieve HPLs: R&D activities, entrepreneurial capacity (EC), absorptive capacity (AC), innovation capacity (IC), and specialized human resources (SHR). The results also suggest that R&D and EC are crucial for achieving HPLs, while AC, IC, and SHR are peripheral to the desired outcome. Finally, this study identified some configurations leading to HPLs in DEFs in Mexico's aerospace industry. In this country, small- and medium-sized companies share risk through alliances and joint research projects, mainly supported by the National Council for Science and Technology (CONACYT). The results suggest that DEFs can develop firm-level strategies for managing the resources and processes underpinning the R&D activities, entrepreneurship, and innovation that will lead to high-performing DEFs in Mexico's aerospace industry.

Besides this introduction, the paper is organized into four sections. Section 2 presents the literature review that supported the study. Section 3 discusses the fuzzy-set qualitative comparative analysis (fsQCA) model employed in the research for data collection, case selection, and analysis. Section 4 evaluates and discusses the empirical results, and Section 5 presents concluding remarks.

2. Literature Review

2.1. Firms' Performance and Strategic Management

The resource-based view uses the concepts of causal ambiguity and social complexity to explain why some firms outperform others. The approach is based on two fundamental assumptions (Barney and Clark, 2007; Barca, 2017): First, resources are heterogeneously distributed among firms, and second, resources are imperfectly mobile between firms and industries. Thus, resources are seen as valuable, rare, non-imitable, and non-substitutable, resulting in quantity and quality differences across resource allocations but essential for developing and sustaining competitive advantage (Barney and Clark, 2007; Newbert, 2007;

Barca, 2017).

Additionally, the AC model explains how firms can achieve superior performance by applying and assimilating new knowledge through a learning process (Cohen and Levinthal, 1989; 1990). In this model, AC's intangible, idiosyncratic, and cumulative nature makes it difficult to imitate, since converting knowledge is the basis for superior performance (Moon, 1999). In this research, IC and R&D were necessary conditions for DEFs to achieve superior performance (i.e., HPLs) in Mexico's aerospace industry since innovation is a fundamental source of success and survival for firms in a complex environment. Indeed, R&D influences IC, given that both activities feed a firm's internal innovation process and competitive advantage (Fosfuri and Tribó, 2008).

Finally, entrepreneurship is another condition that leads firms to achieve superior performance through the process of discovering and creating business opportunities. In this study, EC allowed for the identification and creation of profitable opportunities for firms requiring access to information and knowledge and the ability to recognize, perceive, and develop economically viable projects (Heru, 2016; Koroleva et al., 2020). The entrepreneurial approach highlights the importance of knowledge, technical ability, experience, and continuous training as sources of the valuable, rare, non-imitable, and non-substitutable SHR necessary for developing superior performance.

2.2. *The Aerospace Industry in Mexico*

Aerospace research, production, and manufacturing centers have arisen in several emerging economies in recent decades, leading to these economies being positioned in a competitive way in the global aerospace industry for several reasons. In the case of Mexico, although this industry only started developing a few decades ago, it achieved significant importance in 2004 since specialized foreign direct investment in the aerospace industry arrived in this country (ProMéxico, 2013). Since then, Mexico has introduced actions and strategies to help it succeed, such as supporting the relations between OEMs and indigenous firms, creating public research centers, promoting production and co-production agreements, establishing joint ventures and alliances, and creating links between multinational corporations and small- and medium-sized local enterprises (Flores and Villareal, 2017). Accordingly, Mexico has become one of the most important global centers for assembling aircraft parts and a key investment location in the aerospace industry (FAI, 2014; Flores and Villareal, 2017).

The literature on the aerospace industry in Mexico is limited. To our knowledge, no analysis of Mexico's aerospace industry has been conducted from a QCA perspective, although Solleiro et al. (2020) examined the innovation policy supporting foreign direct investment, firms' certification in production processes, and human resources training. Hernández and Carrillo (2018) showed that the aerospace industry in Mexico has been enhanced mainly by foreign companies contributing to the development of capabilities and certifications, whereas Muñoz et al. (2019) analyzed the structure of the aerospace industry, focusing on its stakeholders and their interrelationships.

From a different perspective, Flores et al. (2017) analyzed the spatial patterns of co-located firms and establishments in Mexico's aerospace industry. In their paper, Gomis and Carrillo (2016) investigated multinational aerospace firms' productive and organizational capabilities in the global value chain, while Luna et al. (2017) assessed the aerospace manufacturing industry in Mexico from a Porter's cluster perspective.

Finally, from an econometric perspective, Chamonica and Gómez (2017) developed a panel data model, highlighting the positive influence of R&D and foreign direct investment on technology transfer in Mexico's aerospace industry. Sandoval et al. (2019) applied graph theory to define the scope of Mexico's aerospace industry in the global value chain, while

Villarreal et al. (2016) applied quotient placement statistics to detect spatial placement patterns in agglomerations in this industry.

3. Methods

3.1. *The QCA Approach*

The QCA approach tests hypotheses based on Boolean algebra and set-theoretic relations, focusing on determining sufficient and necessary conditions for yielding a desired outcome (Ragin, 2008; Wagemann, 2012). Causal complexity is a core feature of set-theoretic analysis guided by three principles (Parente and Federo, 2019; Mello, 2021): conjunction, equifinality, and asymmetry. Conjunctural causation considers that a single condition is frequently insufficient and must be combined with another to achieve the desired outcome. Equifinality considers more than one sufficient (but not necessary) condition producing an outcome. Asymmetric causation means that knowing the causes of an outcome does not necessarily imply that the opposite outcome is equally known (Braumoeller, 2003; Morlino, 2005; Wagemann, 2012).

The QCA approach uses two parameters to measure the necessary and sufficient conditions for achieving a desired outcome (Roig-Tierno et al., 2017; Parente and Federo, 2019; Mello, 2021): consistency and coverage. Consistency measures the extent to which the terms of a solution are a subset of the result (i.e., a measure of fit among different conditions comprising a configuration yielding an outcome), and coverage indicates the proportion of cases that take a particular path to obtain a specific outcome (i.e., the empirical relevance of the configuration; Ragin, 2008; Parente and Federo, 2019; Mello, 2021).

Some variants of QCA methods are crisp-set QCA (csQCA), fsQCA, and multi-value QCA (mvQCA; Ragin, 2008). This research adopted the fsQCA approach as a research method to examine various membership set levels: a score of 1 indicated total membership, a score closes to 1 (0.8 or 0.9) indicated partial membership, a score below 0.5 but above 0 (0.2 or 0.3) indicated further out than inside the set, and a score of 0 indicated total exclusion (Ragin, 2009). Overall, fsQCA is adequate for describing conditions because it allows the results to be examined according to partial degrees of membership rather than total membership in a specific set (Ragin, 2008).

3.2. *fsQCA and Hypothesis*

The QCA approach allows for the representation of a firm's performance using certain conditions in various configurations (Ragin, 2008; 2009), thus revealing the presence (or absence) of conditions that generate a desired outcome. Each configuration has a causally complex structure since the conditions underpinning it cannot be exhaustively examined due to the complex circumstances involved in their origin (Wagemann, 2012). This approach was appropriate for understanding the causal complexity characterizing DEFs' operations in Mexico's aerospace industry.

Typically, fsQCA research is developed in four steps (Ragin, 2008; Fiss, 2011), which this research followed: First, conventional scale measures were transformed into fuzzy membership (i.e., calibration). Second, a truth table was developed to visualize all logically possible configurations. Third, cases with desired outcomes were identified (i.e., consistency analysis). Finally, causal configurations were minimized using computed solutions and model analysis.

Computed solutions may be complex, parsimonious, or intermediate. Intermediate solutions are suitable for interpreting results (Ragin, 2008), but the configurations of complex solutions are more significant than those of parsimonious solutions, and the configurations of intermediate solutions provide no logical reminder or patterns of combinations of conditions not observed empirically in counterfactual analysis (Ragin, 2008; Rihoux and Ragin, 2009; Schneider and Wagemann, 2010). The hypothesis guiding this research was as follows:

> *AC, IC, EC, SHR, and R&D activities are necessary and sufficient conditions for DEFs to achieve HPLs in Mexico's aerospace industry.*

3.3. Cases and Data Collection

Cases and conditions are crucial for a set-theoretic comparative analysis (Ragin, 2009). The cases must have a certain degree of heterogeneity to facilitate a comparison of their characteristics and define the expected result. Cases must also be sufficiently parallel to allow comparisons between specific dimensions that share similar background characteristics. In short, selected cases must present both success and failure characteristics. In this research, 17 DEFs met the validity criterion for choosing cases, which is based on firm´s annual sales identifying successful and unsuccessful cases according to the methodology applied.

Two instruments were used to collect data and information in this research: a survey and semi-structured interviews. The survey and interviews were conducted from April–May 2018 across 17 out of 40 DEFs operating in Mexico's aerospace industry. The questionnaire and interviews enquired about R&D, entrepreneurial, and innovation activities, selected AC, and SHR. When the data were collected, the model was computed according to the set-theoretic relations defined in the hypothesis using COMPASS 3.0 software.

4. Results and Discussion

4.1. Sufficiency and Necessity Analysis

A direct method was applied to calibrate the data in this research (Ragin, 2008). The five condition thresholds were 0 (total exclusion), 2 (point of indifference), and 4 (total membership), while the desired outcome thresholds were 20 (total exclusion), 500 (point of indifference), and 1,000 (full membership). The DEFs' average annual sales were used as the criterion for establishing the desired outcome (i.e., an HPL). Table 1 shows the membership values of the data in this model.

Table 1 Membership values of fuzzy sets

AC	IC	EC	SHR	R&D	HPL
0.92	0.92	0.95	0.82	0.92	0.97
0.92	0.86	0.92	0.95	0.82	0.96
0.71	0.65	0.82	0.82	0.89	0.94
0.57	0.86	0.86	0.77	0.77	0.85
0.54	0.82	0.77	0.82	0.86	0.84
0.90	0.57	0.86	0.82	0.94	0.82
0.57	0.89	0.86	0.77	0.65	0.81
0.43	0.92	0.82	0.94	0.35	0.5
0.43	0.82	0.88	0.89	0.92	0.43
0.43	0.86	0.86	0.82	0.71	0.34
0.57	0.77	0.88	0.86	0.35	0.24
0.43	0.71	0.57	0.43	0.65	0.16
0.57	0.29	0.03	0.65	0.03	0.09
0.23	0.54	0.08	0.14	0.54	0.06
0.57	0.18	0.03	0.65	0.03	0.05
0.18	0.18	0.57	0.57	0.03	0.05
0.14	0.57	0.05	0.54	0.05	0.05

Table 2 (i.e., the truth table) shows the configurations that might explain an HPL. Consistency analysis determines which configurations are consistent with the desired outcome (Ragin, 2008). Values below 0.80 in the RAW Consistency column indicated substantial inconsistency; hence, the first four configurations were considered sufficient for achieving an HPL. The complex solution did not consider the logical residuals, the intermediate solution considered only the empirically possible logical residuals, and the parsimonious solution considered any logical residual that contributed to generating the desired result (Ragin, 2008). However, parsimonious and intermediate solutions were also considered to identify central and peripheral causal conditions (Fiss, 2011). Notably, the parsimonious and intermediate solutions were used to explain the high performance values in this research.

Table 2 Estimated truth table

AC	IC	EC	SHR	R&D	Cases	HPL	RAW Consistency	PRI Consistency	SYM Consistency
1	1	1	1	1	7	1	0.927407	0.883886	0.883886
0	1	1	1	1	2	1	0.823394	0.596859	0.596859
0	1	1	0	1	1	1	0.815451	0.426667	0.426667
0	1	1	1	0	1	1	0.808917	0.387755	0.387755
1	1	1	1	0	1	0	0.793210	0.417391	0.417391
0	0	1	1	0	1	0	0.708696	0.172840	0.172840
0	1	0	0	1	1	0	0.684874	0.184783	0.184783
0	1	0	1	0	1	0	0.582192	0.0827067	0.0827067
1	0	0	1	0	2	0	0.523333	0.0714285	0.0714285

Table 3 summarizes two of the three solutions typically computed in fsQCA models. However, parsimonious and intermediate solutions are critical to analyze the results. The parsimonious solution had a consistency value of 0.7997 and a coverage value of 0.9203, while the intermediate solution had a consistency value of 0.8167 and a coverage value of 0.9203.

Table 3 Sufficiency analysis

Parsimonious Solution			
Causal Configuration	Raw Coverage	Unique Coverage	Consistency
~ AC* IC*EC	0.460784	0.0208334	0.759596
AC*R&D	0.817402	0	0.902571
EC*R&D	0.893382	0	0.838895
SHR*R&D	0.887255	0.00612748	0.848769
Solution coverage, 0.920343; solution consistency, 0.799787.			
Intermediate Solution			
Causal Configuration	Row Coverage	Unique Coverage	Consistency
IC* EC*R&D	0.841912	0.401961	0.840881
~ AC* IC* EC*SHR	0.460784	0.0208333	0.781705
Solution coverage, 0.862745; solution consistency, 0.816705.			

Four configurations were present in the parsimonious solution that explained how DEFs in Mexico's aerospace industry could achieve HPLs. Configuration 1 showed that, even in the absence of AC, the joint presence of IC and EC were sufficient conditions for DEFs to achieve the desired outcome:

$$\sim AC * IC * EC \rightarrow HPL \tag{1}$$

Configuration 2 showed that AC and R&D activities, if jointly present, were sufficient conditions for DEFs in Mexico's aerospace industry to achieve HPLs:

$$AC * R\&D \rightarrow HPL \tag{2}$$

Configuration 3 indicated that EC and R&D activities, if jointly present, were sufficient conditions for DEFs in Mexico's aerospace industry to achieve HPLs. Notably, Configuration 3 had the highest coverage value (0.8933) with acceptable consistency (0.8388; see Table 3):

$$EC * R\&D \rightarrow HPL \tag{3}$$

Finally, Configuration 4 showed that SHR and R&D activities, if jointly present, led to DEFs achieving HPLs in Mexico's aerospace industry:

$$SHR * R\&D \rightarrow HPL \tag{4}$$

Nevertheless, the intermediate solution indicated that two other configurations could enable DEFs in Mexico's aerospace industry to achieve HPLs. Configuration 5, for example, showed that IC, EC, and R&D activities, if jointly present, were sufficient conditions for achieving an HPL. Indeed, this configuration characterized a significant number of cases (84.19%), which might explain this result, since the configuration considers a result subset consistency of 0.8408 (Table 3):

$$IC * EC * R\&D \rightarrow HPL \tag{5}$$

Configuration 6 showed that, even if AC was absent (~AC), the expected result could be achieved when IC, EC, and SHR were jointly present:

$$\sim AC * IC * EC * SHR \rightarrow HPL \tag{6}$$

The results for the parsimonious and intermediate solutions implied that several configurations would allow leading firms to achieve an HPL, as the equifinality principle suggests. Finally, the necessity analysis presented in Table 4 determined the necessary conditions, producing consistency and coverage scores for individual and specified substitutable conditions. Consistency indicates the degree to which the causal condition supersets the result, while coverage indicates the empirical relevance of a consistent superset (Ragin et al., 2007); thus, the minimum consistency value of 0.80 revealed that all conditions were necessary for DEFs in Mexico's aerospace industry to achieve HPLs.

Table 4 Analysis of necessity

Condition Tested	Consistency	Coverage
AC	0.851716	0.762898
IC	0.912990	0.652936
EC	0.959559	0.724329
R&D	0.910539	0.781283
SHR	0.948529	0.631321

The parsimonious and intermediate solutions explained how the central and peripheral conditions could contribute to achieving the desired outcome. Central conditions indicated a strong relationship with the outcome, while peripheral conditions indicated only a causal or weak relationship (Fiss, 2011); for example, the intermediate solution had a configuration with EC as a central condition and AC, IC, and SHR as peripheral conditions.

These results suggest that DEFs should constantly develop projects by investing in R&D to outperform their competitors in the aerospace market. Furthermore, these companies should collaborate with universities, research centers, and other stakeholders to continuously develop innovation. Interestingly, the consolidation of high-tech industries in several emerging economies can be explained by significant government intervention (Flores and Villareal, 2017). In Mexico's aerospace industry, adequate science, technology, and innovation policies must be implemented to support DEFs (e.g., by providing financial incentives to stimulate innovation, the development of human resources, and the design and development of education and training programs involving firms and universities, among others).

Mexico has strengthened its aerospace industry by developing and promoting R&D activities and identifying and exploiting business opportunities. However, economic incentives, training, knowledge exchanges with universities and research centers, and the development of an entrepreneurial culture should be at the core of support policies for DEFs.

In emerging economies, the consolidation of high-tech industries depends largely on government policies targeting science, technology, innovation, industry, higher education, and trade (Vertesy, 2012; Flores and Villareal, 2017). Consequently, DEFs in Mexico's aerospace industry should invest in R&D to survive and be successful in the global market. However, according to data provided by our interviewees, despite Mexico being strengthened by policies promoting R&D and the detection and exploitation of business opportunities, these companies typically invest in R&D activities no more than 3% of their profits. Although this percentage is small, the strategy has positively influenced patenting activity in this industry, thus generating intellectual property relating to the design and manufacture of aircraft interiors, software for real-time assistance with aircraft operational problems, advanced manufacturing technology, computer simulation, treatment processes, and metal alloys. Patents in Mexico's aerospace industry have supported Mexican companies' science and technology development. Indeed, since R&D is an essential condition for developing companies in this industry, the government should introduce policies that stimulate the creation of new companies and support research projects to improve firms' performance through collaboration with universities and research centers. The creation of new companies, supported by financial incentives, has been a viable path for promoting the development of the aerospace industry. Also, the government should implement education and training programs to develop qualified human resources, thus contributing to the development of innovative projects and products (Boselie et al., 2005; Berawi, 2018; Hanid et al., 2019). In the case of Mexico, the interviewees recognized the need for economic incentives, training for employees, and knowledge exchanges with universities to promote an entrepreneurship culture suitable for developing new technologies.

5. Conclusions

Highly innovative industries require resources to innovate and constantly outperform their competitors, and DEFs in Mexico's aerospace industry likewise require continual innovation. In this research, AC, IC, EC, SHR, and R&D activities were all necessary conditions for achieving HPLs; however, they did not necessarily have to be present simultaneously to achieve the desired outcome. The causal complexity principle explains that DEFs in this industry may develop a sustained competitive advantage. The conditions evaluated in this study may explain the performance of firms in other countries resembling Mexico, but they may differ from the conditions in industrialized countries with different characteristics for highly innovative industries.

Nevertheless, the parsimonious and intermediate solutions suggest that R&D activities and EC are central conditions, while AC, IC, and SHR are peripheral conditions. The analysis of central and peripheral conditions allows conclusions to be drawn regarding the causal essentiality of specific combinations of causal conditions. Central conditions are critical to the survival of DEFs in Mexico's aerospace industry, and the causal complexity in this analysis revealed how DEFs can develop a sustained competitive advantage in the global aerospace industry. The results indicate that R&D activities and EC are central conditions in this process, and DEFs must constantly invest in R&D efforts to promote innovation and improve AC. Certainly, R&D activities and SHR are critical for exploiting profitable projects in Mexico's aerospace industry.

Finally, further research should consider other causal conditions in the analysis of HPLs, such as the financial strategies of DEFs in Mexico's aerospace industry that support innovation development. Indeed, the aerospace industry is high risk, requiring firms to carefully manage their financial conditions.

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