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GENETIC ALGORITHM MODELLING OF EUROPEAN UNION FIRMS' COMPETITIVE ADVANTAGE

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1 INTRODUCTION

Competition could be approached under two contexts. The first one, worldwide economics, considers that countries and economic groups compete for greater capacity to accumulate resources, to generate jobs and to have access to technologies. The best the nation's economy competitive position, the best the population quality of life (Bazoobandi & Alexander, 2020; Bazoobandi & Nugent, 2017), and the greater the nation's politic and economic influence in the decisions of the economic group to which they belong (Xiaotong & Keith, 2017).

In the second one, the context of firms, the most competitive tend to be those firms with the highest internal capacity to create value (Ma, 1999) and those located in industries, countries, or regions with competitive environments conducive to good results (Peneder, 2009; Wu et al., 2017). Thus, competitive advantage is built through the interaction between internal and environmental factors (Ringov, 2017), and firms are considered effective and competitive when they manage to create superior value to their competitors (Ghemawat & Rivkim, 1998), in terms of growth and profitability (Brito & Brito, 2014; Ştefan & Coca, 2011). The possibility of combining profitability and growth strategies to achieve a better competitive position means that there must have a balance between them (Dias, Souza, et al., 2019; Dias, Rossi, et al., 2019).

Thus, a firm is competitive when it optimizes its resources and opportunities to gain a medium and long-term advantage over its rivals (Gradinaru et al., 2017). Therefore, expertise is needed to realize that efforts to use high technologies could create competitive advantages in environments where technology evolves rapidly, but not in environments where technology is slowly advancing. In circumstances where resources are limited, managers should consider the influence of environmental contexts. Therefore, they should consider the competitive position of the firm in the market, in the process of resources allocation (Yang & Tu, 2020).

The competitive advantage needs to be sustained for the perpetuation of firms in the market. However, the context of competition is characterized by transitory competitive advantages (Kanuri & Mcleod, 2016) and, to achieve the best competitive positions, firms constantly adjust their strategies, considering internal and external factors (Fainshmidt et al., 2019; Wilden et al., 2016). These adjustments involve directing investment strategies and decisions to place greater emphasis on growth, profitability, or both (Brito & Brito, 2012, 2014; Dias, Souza, et al., 2019). Thus, factors such as competitive environment, investment strategies decisions, and firm's competitive position are in constant interaction (Dias et al., 2020).

This research aims to identify the optimal configuration of CAPEX and R&D investments which leads firms to the best competitive positions, considering the degree of concentration of the markets in which they operate. In line with Rindova and Fombrun (1999) proposition that firms construct their distinctive positions through three generic processes (strategic investments, strategic projections, and strategic plot development), this research brings two main contributions. The first one is the identification of the optimal amount of capital and R&D (research and development) investments which leads firms to their best competitive positions, considering the degree of concentration of the markets in which they operate and the size of the firm. The second one is related application of genetic algorithms to estimate optimization models.

2 THEORY

Research on business strategies focuses mainly on understanding the factors that make a firm most competitive in the environment in which it operates, as well as the processes responsible for achieving this competitive position (Hâkansson & Snehota, 1989). Generally, firms are considered effective and competitive when they accumulate resources throughout their existence, interacting with the environment in which they compete, and the resources accumulation is fundamental to its existence (Hâkansson & Snehota, 1989). In this context, Hâkansson and Snehota (1989) stated that "[n]o business is an island", suggesting that every organization needs to consider the business environment where it is inserted, because, regardless of its location, most businesses are affected by global competition.

Investments made by firms may focus on the creation, extension, upgrade, protection, or maintenance of the firm's unique asset base. Investment decision-making is related to the ability to detect opportunities and threats, seize opportunities, and maintain competitiveness through improvement, combination, protection and, when necessary, reconfiguration of the firm's assets. However, detecting opportunities and threats astutely is necessary, but not enough, to succeed when surprises occur in a business environment. The firm should also seize opportunities in a timely manner by successfully innovating and implementing new systems that take advantage of external changes (Schoemaker et al., 2018; Stewart, 1998; Perez & Famá, 2006; Teece, 2007; Teece et al., 2016).

Firms that have the greatest capacity to generate economic value tend to gain competitive advantage over their competitors. Thus, the competitive advantage of a firm corresponds to the economic value that it can create, through its investments (Afonso et al., 2018; Barney & Hesterly, 2011; Karmarkar & Plassmann, 2019; Santos et al., 2017; Pallant et al., 2020).

The investment decision-making capacity is necessary to promote the organizational agility necessary to deal with the uncertainties and demands imposed by innovation and dynamic competition, associated with the context of the organizational environment (Karmarkar & Plassmann, 2019; Schoemaker et al., 2018; Pallant et al., 2020; Pascucci, 2018; Teece et al., 2016; Tell et al., 2016). Innovation is considered a strategic factor for the survival and growth of firms, especially in the face of great competitive pressure, directly affecting their competitive position (Pascucci, 2018). This capacity for innovation refers to the firm's ability to integrate, build and reconfigure internal competencies, through its investments, in order to react or cause changes in the business environment, in search of the maintenance or acquisition of a better competitive position (Teece, 2018; Teece et al., 1997).

The more competitive and dominant the firm, the more value it will offer to the market, compared to its competitors, through the transformation of raw materials into products and services (Camisón et al., 2016; Fainshmidt et al., 2019; Hâkansson & Snehota, 1989; Porter, 1999, 1986; Namada, 2018; Ringov, 2017; Wilden et al., 2016; Wernerfelt, 1984; Wu et al., 2017; Yuan et al., 2018). In this sense, firms seek to increase their competitive position, but can converge to a position of parity, due to restrictions imposed by technology, economy, regulations, labor processes, market concentration and other characteristic factors of the industry where they are in (Eisenhardt & Martin, 2000; Goudarzi, 2013; Kumar & Ranjani, 2018). Industry also affects the firm's competitive position through the ability of other competitors, as the industry operates with a constant cycle of innovation and imitation, in which firms seek innovative capabilities to gain an advantage over the firms that are in the same industry. To the extent that they are successful, other firms follow suit, adapting and improving what their competitors are doing (Alam et al., 2020; Dias, Souza, et al., 2019; Lampel & Shamsie, 2003; Santos et al., 2017).

Thus, firms also differ in their competitive position in the market, which can be influenced by their own operating characteristics and internal capacity (Hâkansson & Snehota, 1989; Namada, 2018; Porter, 1980; Teece et al., 1997), but also by the environment in which they operate (Alam et al., 2020; Camisón et al., 2016; Dias, Souza, et al., 2019; Fainshmidt et al., 2019; Hâkansson & Snehota, 1989; Porter, 1980; Ringov, 2017; Santos et al., 2017; Sener, 2012; Wilden et al., 2016; Wu et al., 2017; Yuan et al., 2018). Thus, it should be considered that the firm's competitive position, in addition to being influenced by its capabilities, is also influenced by the external environment configuration, whether it is industry, country or region to which it is linked.

3 METHODS

In this section we present the path and procedures chosen to carry out the research, as well as the variables that were used to measure the constructs that make up the model and its operationalization for data generation.

The Genetic Algorithms method was used to identify the optimal configuration of strategic factors (investments in Capex and R&D) that leads to the best competitive position of firms, considered the degree of concentration in the industry. According to Lee et al. (2002) the Genetic Algorithm is a computational tool that provides mechanisms to understand competition from the evolutionary perspective. One of these mechanisms is known as selection, and it can identify winners and losers over time (Lee et al., 2002). In this way, Lee et al. (2002) points out that Genetic Algorithms are composed of mathematical structures and therefore allow the conduction of an economic analysis without the need to resort to assumption.

3.1 Research model

When processing genetic algorithms through Evolver software®, version 7.5, values were estimated for the construct Competitive Position, according to Equation 1, elaborated with reference in the hypothetical model that was tested through the processing of a structural equation model. The parameters of the model were established as: population size equal to the number of cases in each competitive environment; crossover rate of 0.500; and mutation rate equal to 0.100.

$$CP = \beta_1 CE + \beta_2 CE^2 + \beta_3 IN + \beta_4 IN^2 + \beta_5 SIZE + \beta_6 (CExIN) + \beta_7 (SIZExIN) + \varepsilon \quad (1)$$

Where:

CP = Competitive position.
CE = Competitive environment.
CE^2 = Squared Competitive environment.
IN = Investment.
IN^2 = Squared investment.
SIZE = Firm's size (control variable);
CE x IN = Interaction between CE and IN (moderating effect of CE on the influence of IN on CP).
SIZE x IN = Interaction between SIZE and IN (moderating effect of SIZE on the influence of IN on CP).

The genetic algorithm model was elaborated with the objective of identifying which amount of Investment (Capex and R&D - Equation 2) maximize the mean value of the estimated Competitive Position. The indicators' coefficients were estimated by structural equations modeling, for each one of the three competitive environments considered in the analysis and for the most recent available year (2017) in the samples.

$$IN = \beta_3 Capex + \beta_4 R\&D + \varepsilon \quad (2)$$

Where:

IN = Investment.
Capex = Investment in capital.
R&D = Investment in research and development.

The increase in firms' Competitive Position that will be achieved as a consequence of the increase or the decrease on Capex and R&D investments, is obtained by the difference between Competitive Position estimated (Equation 1), and the original Competitive Position values (Equation 3), for each one of the firms in the samples.

$$CPo = \beta_5 MS + \beta_6 ROA + \varepsilon \quad (3)$$

Where:

CPo = Competitive position - original.
MS = Market share.
ROA = Return on Assets.

The operationalization of the dependent and independent variables in the Equations 1 through 3 is presented in Table 1.

Table 1 – Operationalization of the variables.

Category	Variable	Calculation method
Competitive Environment (CE)		
Degree of industry concentration	Herfindahl-Hirschman (relative)	$HHIRel = \left(\sum_{i}^{n} S_i^2\right) : \frac{1}{n}$
Investment (IN)		
Investment in capital	Capex	$\ln(Capex)$
Investment in research and development	R&D	$\ln(R\&D)$
Competitive Position (CP)		
Market Share	MS - (firm's market share compared to the average market share of the industry's firms)	Z-score (firm's market share)
Profitability	ROA – (firm's Return on Assets (ROA) compared to the average ROA of the industry's firms)	Z-score (firm's ROA)
Firm Size (SIZE)		
Firm's size	SIZE – (firm's size measured with reference on total assets)	$\ln(Total\ Assets)$

Source: authors (2021).

4. RESULTS

4.1 Samples

Data was collected from Thomson Reuters Datastream®, and samples are composed of 124 cases representing firms in competitive environment classified as Perfect Competition, at the year of 2017, 106 cases representing firms in competitive environment classified as Monopolistic Competition, and 90 cases representing firms in competitive environment classified as Oligopoly, according to the classification presented by Djolov (2013), presented in Table 2. The number of firms per industry, per competitive environment are presented in Table 3.

Table 2 – Economic view of HHI.

HHI in percentage range	Concentration	Competitive Environment
0.00 < HHI =< 0.20	Low	Perfect competition
0.20 < HHI =< 0.40	Slight	Monopolistic competition
0.40 < HHI =< 0.70	Elevated	Oligopoly

Source: adapted from Djolov (2013).

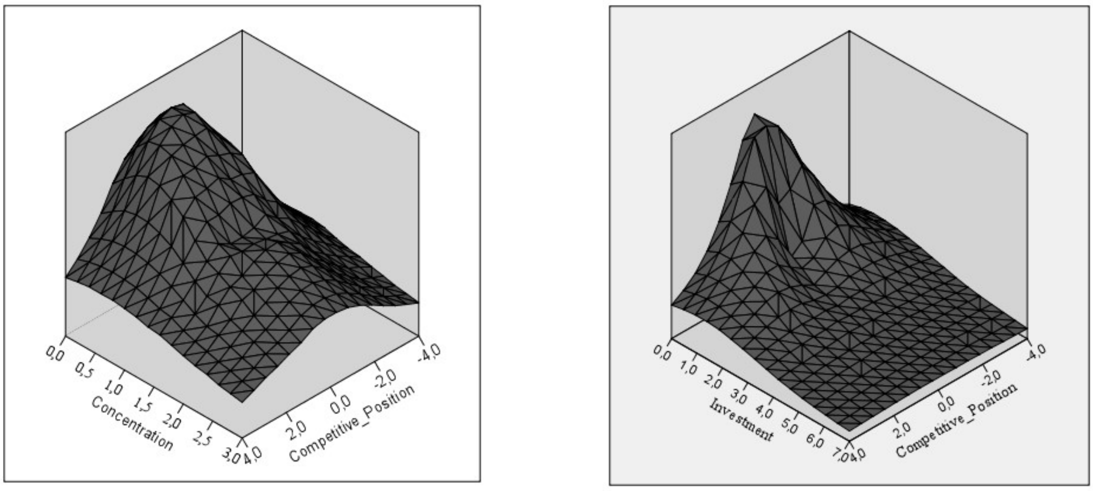
The samples were above the minimum of 57 cases estimated for a test power of 0.950, effect size of 0.500 and significance bi-caudal test at 5% for the verification of differences between the means of paired groups, through the Wilcoxon test. G*Power 3.1.9.2 software (Faul *et al.*, 2009) was used to calculate the minimum sample size. Squared effects of Competitive Environment (Concentration) and Investment were included in the model after the analysis of the graphs presented in Figure 1, which represents the relationships between competitive environment's degree of Concentration and firms Competitive Position, and between firms Investments and firms Competitive Position.

Table 3 – Number of cases per industry, per competitive environment.

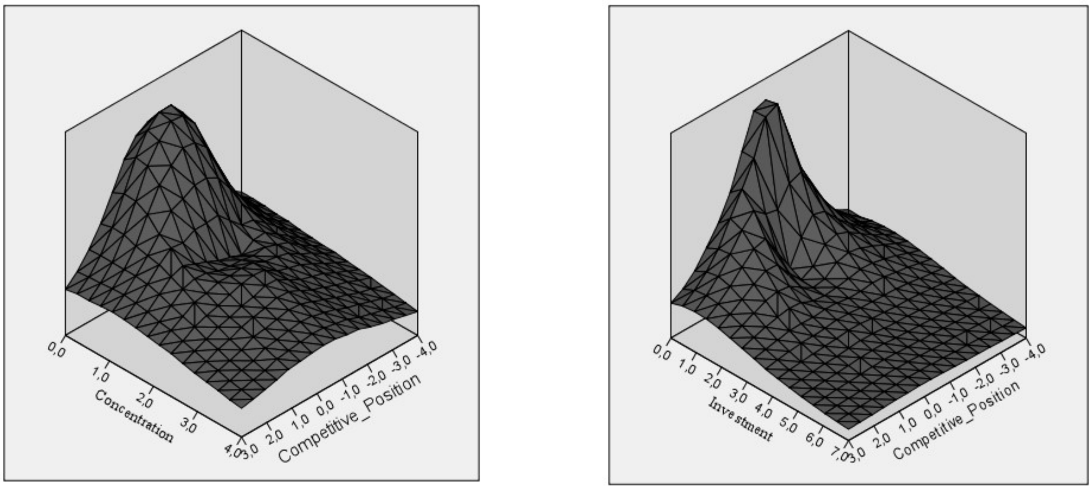
Perfec Competition	
Industry	Number of firms
Chemicals	27
Computer services	22
Electrical equipment	19
Electronic equipment	19
Foods	22
Telecommunication equipment	15
Total	124
Monopolistic Competition	
Industry	Number of cases
Biotechnology	11
Building material	17
Chemical inputs	7
Medical equipment	16
Medical supplies	8
Pharmaceuticals	25
Semiconductor	14
Storage	8
Total	106
Oligopoly	
Industry	Number of cases
Clothing and accessories	10
Computers	7
Heavy construction	5
Industrial products	7
Iron and steel	7
Media agencies	4
Mining	2
Personal products	4
Software	44
Total	90

Source: data processing.

Perfect Competition



Monopolistic Competition



Oligopoly

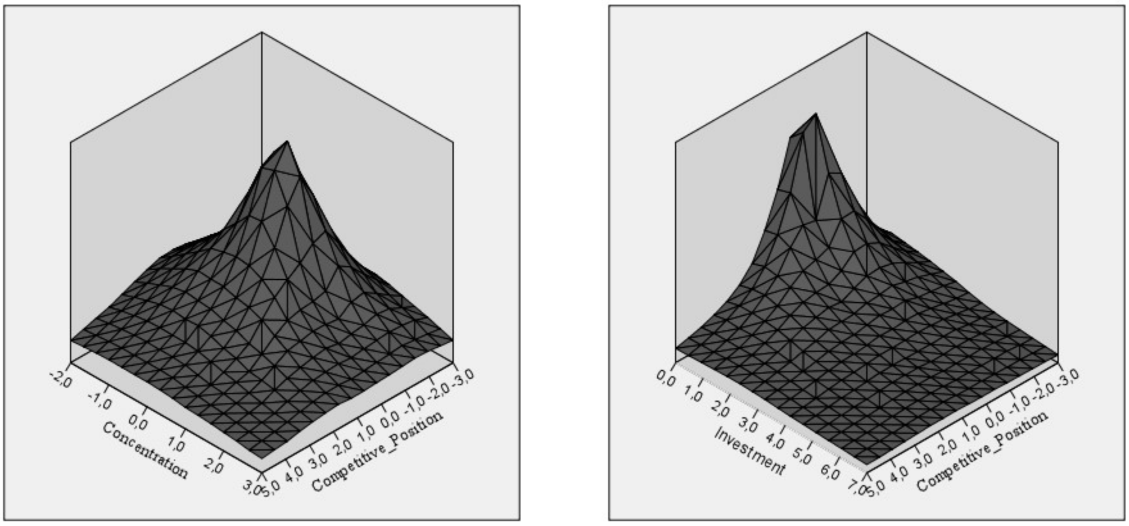


Figure 1 – Relationship between concentration, investment, and competitive position.

4.2 Genetic Algorithms models results

Equations 4, 5 and 6 were used as references to the estimation of the values of Competitive Position, for the environments Perfect Competition, Monopolistic Competition and Oligopoly, respectively. All the coefficients were obtained with reference in a hypothetical model that was tested through the processing of a structural equation model.

$$CPe = 0.058CE + 0.218CE^2 + 0.530IN - 0.041IN^2 + 0.918SIZE - 0.064(CExIN) - 0.036(SIZExIN) \quad (4)$$

$$CPe = 0.146CE - 0.340CE^2 + 0.324IN - 0.006IN^2 + 0.988SIZE - 0.074(CExIN) + 0.074(SIZExIN) \quad (5)$$

$$CPe = 0.656CE - 0.471CE^2 + 0.288IN + 0.060IN^2 + 1.105SIZE + 0.116(CExIN) + 0.176(SIZExIN) \quad (6)$$

Taking Equation 2 as reference, the coefficients of the Investment construct's indicators are presented in Equations 7, 8 and 9, for Perfect Competition, Monopolistic Competition and Oligopoly competitive environments, respectively. All the weights were obtained with reference in a measurement model that was tested through the processing of a structural equation model.

$$IN = 0.600Capex + 0.490R\&D \quad (7)$$

$$IN = 0.689Capex + 0.360R\&D \quad (8)$$

$$IN = 0.538Capex + 0.566R\&D \quad (9)$$

The original Competitive Position of the firm was calculated with reference on Equation 3, and the weights of the Investment construct's indicators are presented in Equations 10, 11 and 12, for Perfect Competition, Monopolistic Competition and Oligopoly competitive environments, respectively. All the weights were obtained with reference in a measurement model that was tested through the processing of a structural equation model.

$$CPo = 0.999MS - 0.021ROA \quad (10)$$

$$CPo = 1.000MS - 0.024ROA \quad (11)$$

$$CPo = 1.011MS - 0.058ROA \quad (12)$$

As can be seen in Table 3, the differences between means for the Competitive Position construct, in the three competitive environments addressed in the research, are statistically significant, as well as the differences between the means for the Capex and R&D indicators, which were used to measure the Investment construct. The significance of the difference between means was ascertained by Wilcoxon's nonparametric test.

Table 3 – Diferences between means.

Variables	*Perfect Competition*			*Monopolistic Competition*			*Oligopoly*		
	Difference [a]		Std Deviation	Difference [a]		Std Deviation	Difference [a]		Std Deviation
CP	0.926	***	0.745	-0.287	***	0.449	0.880	***	0.472
Capex	1.734	***	1.425	2.447	***	1.081	1.531	***	1.274
R&D	1.763	***	1.419	2.304	***	1.142	2.200	***	1.768

*** significant at 5,00%

[a] –Difference = calculated mean minus original mean

Source: data processing.

The positive value of the difference and the standard deviation values lower than the differences point to the increase in competitive position, with a tendency to the position of competitive advantage, due to the variation in investment in capital (Capex) and research and development (R&D), for the Perfect Competition and Oligopoly competitive environments, according to the data presented in Table 3. As for the monopolistic competition environment, for the firms in the sample to achieve an advantageous competitive position, it will be necessary to avoid the negative variation of the competitive position by up to about 50.00% of a standard deviation, ideally the variation of the competitive position above a standard deviation – Table 3.

In fulfillment of the objective established for this research, was identified the optimal investment configuration in Capex equal to 1.790 and R&D of 1.990, both expressed in their logarithmic form, to obtain a value of competitive position equal to a maximum of 1.892, in the perfect competition environment. These figures represent a 147.66% increase in Capex investment and 101.19% in R&D investment, leading to 50.81% increase in the competitive position – Table 4.

For the monopolistic competition environment, as can be seen in Table 4, the optimal configuration of Capex investment equal to 1.068 and R&D of -0.095 was identified, both expressed in their logarithmic form, to obtain a Competitive Position equal to the maximum of 2.796. These figures represent a 56.97% reduction in Capex investments and a 104.03% reduction in R&D investment, leading to a 32.78% increase in the competitive position – Table 4.

As for the oligopoly environment, the optimal configuration of Capex investment equal to 1.856 and R&D of 2.030 was identified, both expressed in their logarithmic form, for the competitive position range equal to 3.199 - Table 4. These values would be achieved with an increase of 174.31% of investments in Capex and of 16.76% in R&D, leading to a 24.51% increase in the competitive position.

Table 4 – Original and calculated values for Capex, R&D and Competitive Position

Original Value			Calculated Value		
Capex	R&D	Competitive Position	Capex	R&D	Competitive Position
Perfect Competition					
0.723	-0.190	1.255	1.790	1.990	1.892
Monopolistic Competition					
2.481	2.360	2.106	1.068	-0.095	2.796
Oligopoly					
0.676	1.738	2.569	1.856	2.030	3.199

Source: data processing.

5 CONCLUSIONS

This research aims to identify the optimal configuration of CAPEX and R&D investments which leads firms to the best competitive positions, considering the degree of concentration of the markets in which they operate.

Based on the results obtained by genetic algorithms models processing, it is possible to conclude that firms in the Perfect Competition environment operate with values below the ideal investment in both Capex and R&D. This investment behavior indicates a tendency to risk avoiding by firms that faces low degree of market concentration and, consequently, higher levels of competition, leading to a less than ideal competitive position of competitive parity. Efforts must be made to increase the competitive capacity of the firms that are aimed in achieving and maintaining market leadership, by increasing investments in Capex and R&D.

The model estimation results for firms in the Monopolistic Competition environment, point to the need for reduction in both Capex and R&D investments, which means that firms invest above the ideal to increase their competitive advantage. These results could be counterintuitive, but one must consider the negative effect of the degree of market concentration on the competitive position of the firms, leading firms that are not in a competitive advantage position to make investments with the objective of creating barriers to avoid aggressive behavior by powerful firms.

Firms in the Oligopoly environment operate with R&D investments close to the ideal, while there is a greater discrepancy in relation to investment in Capex. In order to face the degree of concentration in the industry and to achieve a favorable competitive position (i. e. competitive advantage), firms must increase their investment in Capex, expanding the capacity of production and creating scale conditions to attend customers and, thus, increasing their market share.

These results are in line with Rindova and Fombrun (1999) affirmation that 'the fundamental purpose of strategic investments is to create and exploit opportunities for positive economic rents' and that investments allow firms to secure more favorable configurations of industry factors and protect them from rivals competitive actions, and reinforce the need for investment decision makers to consider the environment in which the firm is competing, in terms of degree of concentration and investment capacity of competitors, when defining the amount of investment that must be done to achieve and maintain a favorable competitive advantage position.

We suggest considering the inclusion of proxies that represents dimensions of firms' sustainability, mainly under the economic, financial, and social dimensions, in the model. This research presents the limitation of using only public firms' data to calculate industry concentration measures.

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