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Genetic algorithm modeling of European Union firms' competitive advantage

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Abstract

Purpose – This research aims to identify the optimal configuration of investment which leads firms to their best competitive positions, considering the degree of concentration in the market.

Design/methodology/approach – The methodology was quantitative and based on secondary data with samples of 124, 106 and 90 firms from competitive environment classified as perfect competition, monopolistic competition and oligopoly, respectively. Proposed models' parameters were estimated by means of genetic algorithms.

Findings – Adjustments on firm's investment are contingent on the degree of competition they face. Results are in line with existing academic research affirmation that the purpose of investments is to create and exploit opportunities for positive economic rents and that investments allow firms to protect from rivals' competitive actions and reinforce the need for investment decision makers to consider the environment in which the firm is competing, when defining the amount of investment that must be done to achieve and maintain a favorable competitive advantage position.

Originality/value – This research brings two main original contributions. The first one is the identification of the optimal amount of capital and R&D investments which leads firms to their best competitive positions, contingent to the degree of concentration of the competitive environment in which they operate, and the size of the firm. The second one is related to the use of genetic algorithms to estimate optimization models that considers the three competitive environments studied (perfect competition, monopolistic competition and oligopoly) and the investment variables in the linear and quadratic forms.

Keywords Competitive position, Investment, Competitive environment, Genetic algorithms

Paper type Research paper

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1. Introduction

The effects that firms' investment exert on firms' competitive position, considered the degree of competition, have been approached by several authors, mainly with the identification of linear effects, but none of them proposed the identification of the optimal configuration of investments that leads firms to achieve competitive advantage. 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 in the markets in which they operate.

This research brings two main contributions. The first one is the identification of the optimal amount of capital and R&D investments which lead firms to their best competitive positions, contingent to the degree of concentration of the competitive environment in which they operate, and the size of the firm (control variable). The second one is related to the use of genetic algorithms to estimate optimization models that consider the three competitive environments studied (perfect competition, monopolistic competition and oligopoly) and the investment variables in the linear and quadratic forms.

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 and Nugent, 2017; Bazoobandi and Alexander, 2020), and the greater the nation's politic and economic influence in the decisions of the economic group to which they belong (Xiaotong and Keith, 2017).

In the second one, the context of firms, which is the focus of this research, the most competitive tend to be those firms with the highest internal capacity to create value (Ma, 1999) by means of product and process-innovation (Arrow, 1962; Boone, 2000; Agustia *et al.*, 2022; O'Leary *et al.*, 2022) 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 and Rivkin, 1998), in terms of growth and profitability (Ştefan and Coca, 2011; Brito and Brito, 2014). The possibility of combining profitability and growth strategies to achieve a better competitive position means that there must be a balance between them (Dias *et al.*, 2019a, b).

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; Machokoto *et al.*, 2021; Agustia *et al.*, 2022). 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 and Tu, 2020; Dias *et al.*, 2022).

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 and Mcleod, 2016) and, to achieve the best competitive positions, firms constantly adjust their strategies, considering internal and external factors (Wilden *et al.*, 2016; Fainshmidt *et al.*, 2019; Agustia *et al.*, 2022; Dias *et al.*, 2022). These adjustments involve directing investment strategies and decisions to place greater emphasis on growth, profitability, or both (Brito and Brito, 2012, 2014; Dias *et al.*, 2019b). Thus, factors such as competitive environment, investment strategies decisions and firm's competitive position are in constant interaction (Dias *et al.*, 2020).

This study presents relevant contributions to the empirical literature. First, the analysis of the relationship between firms' investment and competitive advantage under three different competitive environments is approached by means of genetic algorithm models, using data from firms located in countries that are members from European Union. Second, the identification of different results, conditioned by degree of competition, contributes to better understanding of the dynamics of the firms' investments and its relations to competitive environments.

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 (Håkansson and 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 resource accumulation is fundamental to its existence (Håkansson and Snehota, 1989). In this context, Håkansson 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 (Stewart, 1998; Perez and Famá, 2006; Teece, 2007; Teece *et al.*, 2016; Schoemaker *et al.*, 2018; Peng *et al.*, 2021).

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 (Barney and Hesterly, 2011; Santos *et al.*, 2017; Afonso *et al.*, 2018; Karmarkar and Plassmann, 2019; Pallant *et al.*, 2020; Machokoto *et al.*, 2021).

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 (Teece *et al.*, 2016; Tell *et al.*, 2016; Pascucci, 2018; Schoemaker *et al.*, 2018; Karmarkar and Plassmann, 2019; Pallant *et al.*, 2020; Peng *et al.*, 2021). 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 capacity of firms to react or cause changes in the business environment, in search of the maintenance or acquisition of a better competitive position (Teece *et al.*, 1997; Teece, 2018).

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 (Wernerfelt, 1984; Porter, 1986, 1999; Håkansson and Snehota, 1989; Camisón *et al.*, 2016; Wilden *et al.*, 2016; Ringov, 2017; Wu *et al.*, 2017; Namada, 2018 Yuan *et al.*, 2018 Fainshmidt *et al.*, 2019). 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 and Martin, 2000; Goudarzi, 2013; Kumar and Ranjani, 2018; Machokoto *et al.*, 2021). 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 (Lampel and Shamsie, 2003; Santos *et al.*, 2017; Dias *et al.*, 2019b; Alam *et al.*, 2020; Peng *et al.*, 2021).

Thus, firms also differ in their competitive position in the market, which can not only be influenced by their own operating characteristics and internal capacity (Porter, 1980; Håkansson and Snehota, 1989; Teece *et al.*, 1997; Namada, 2018), but also by the environment in which they operate (Porter, 1980; Håkansson and Snehota, 1989; Sener, 2012; Camisón *et al.*, 2016; Wilden *et al.*, 2016; Ringov, 2017; Santos *et al.*, 2017; Wu *et al.*, 2017; Yuan *et al.*, 2018; Dias *et al.*, 2019b; Fainshmidt *et al.*, 2019; Alam *et al.*, 2020). It should be considered that the firm's competitive position, in addition to being influenced by its capabilities, is also influenced by the external competitive environment configuration, whether it is industry, country or region to which it is linked.

The effects of firms' investments on competitive position have been approached by many authors with different results. Some of them concluded that firm growth by investment positively influences firm's competitive advantage (Kulatilaka and Perotti, 1998; del Sol and Ghemawat, 1999; Tsai and Wang, 2004); that firms investment have a positive effect on firms' performance, which is commonly used as a proxy to competitive advantage (Brailsford and Yeoh, 2004; Amir *et al.*, 2007; Gupta and Banga, 2009; Fang Yang, 2014; Pandya, 2017; Zuoza and Pilinkienė, 2019; Kim *et al.*, 2021); that the effects of R&D investments on competitive advantage are contingent on the degree of competition faced by firms (Miller *et al.*, 2005; Tubbs, 2007; Ravšelj and Aristovnik, 2020), and that firms adjust their investment in R&D and in Capex when facing financial constraints in times of crisis (Flammer and Ioannou, 2021).

Based on the presented theoretical approaches, we propose that,

Proposition. Firms should increase the amount of investment in both Capex and R&D to increase the competitive position, the less concentrated the competitive environment.

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. 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.

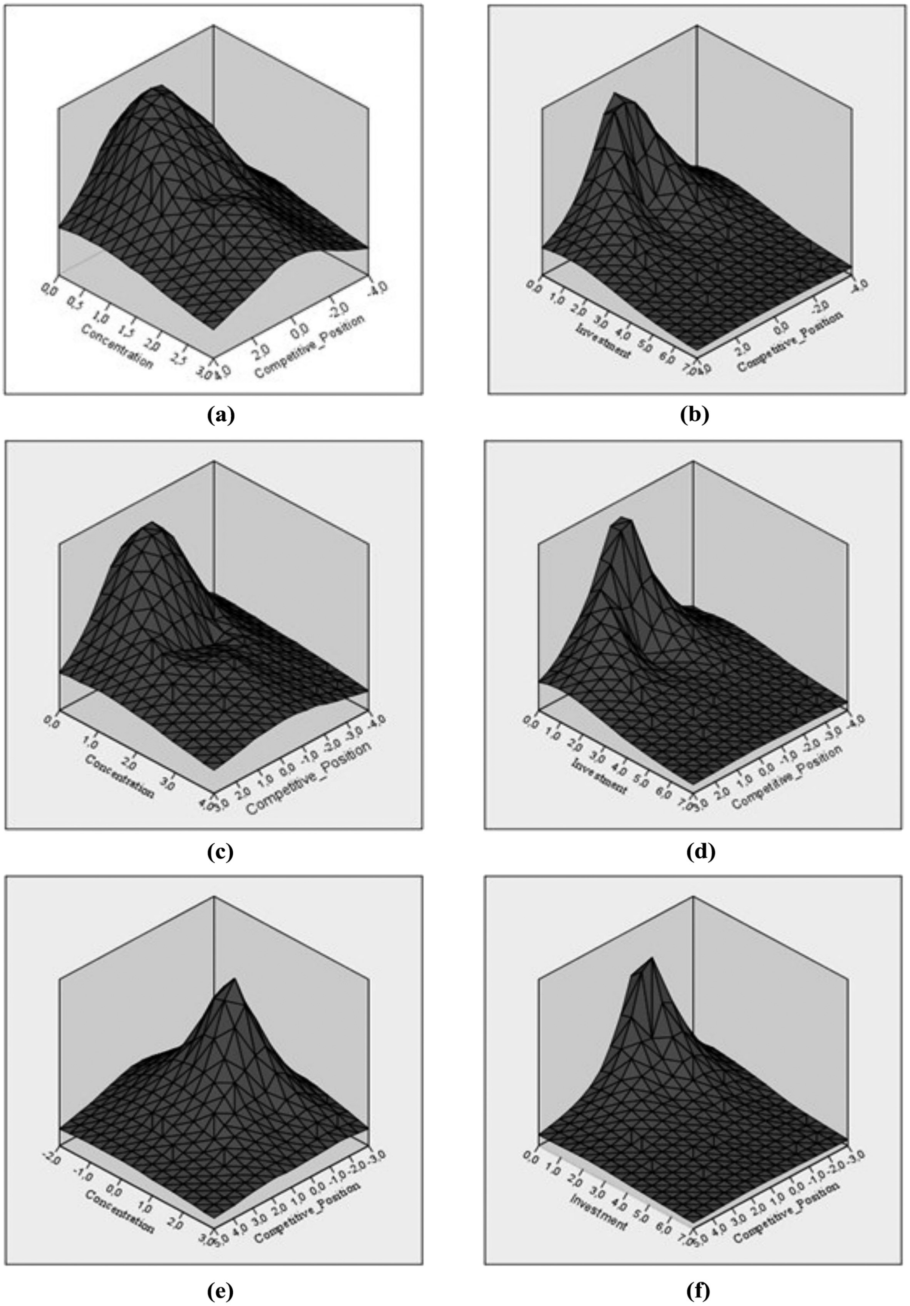

Figure 1.
Relationship between concentration, investment and competitive position

Source(s): Figure by authors

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

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 × IN = Interaction between CE and IN (moderating effect of CE on the influence of IN on CP).

SIZE × 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 Equations (1) through (3) is presented in Table 1.

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

Category	Variable	Calculation method	References
Competitive Environment (CE)			
Degree of industry concentration	Herfindahl-Hirschman (relative)	$HHIRel = (\sum_{i}^{n} S_i^2) : \frac{1}{n}$	Brezina *et al.* (2016), Dai *et al.* (2019), Jošić *et al.* (2019), Powers and Topper (2019), Zhang *et al.* (2020)
Investment (IN)			
Investment in capital	Capex	$\ln(Capex)$	Dias *et al.* (2019a), Curtis *et al.* (2020), Lai *et al.* (2020), Nguyen and Nguyen (2020)
Investment in research and development	R&D	$\ln(R\&D)$	Dias *et al.* (2019a), Rocha *et al.* (2019), Alam *et al.* (2020), Curtis *et al.* (2020)
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)	Brito and Brito (2012), Fontoura and Serôdio (2017), Aghion *et al.* (2019), Dias *et al.* (2019a), Yi *et al.* (2019), Dias *et al.* (2020), Wang (2020)
Profitability	ROA – (firm's Return on Assets (ROA) compared to the average ROA of the industry's firms)	Z-score (firm's ROA)	Brito and Brito (2012), Erica *et al.* (2018), Dias *et al.* (2019a), Zapata *et al.* (2019), Dias *et al.* (2020), Zhong and Wu (2020)
Firm Size (SIZE)			
Firm's size	SIZE – (firm's size measured with reference on total assets)	$\ln(Total\ Assets)$	Saliha and Abdessatar (2011), John and Adebayo (2013), Kartikasari and Merianti (2016), Kumar and Kaur (2016), Dinali Viglioni and Leal Calegario (2021), Wijayaningsih and Yulianto (2021)

Source(s): Table by authors (2021)

Table 1.
Operationalization of the variables

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 in the sample per industry, per competitive environment is presented in Table 3.

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.

As one can see in Table 3, 50% of the firms in perfect competition competitive environment (62 from 124) are in the top 1,000 ranking of R&D investment elaborated by the European Commission for the year of 2017, and above 29% are in the top 500 (35 from 124). A total of 59% of the firms in monopolistic competition competitive environment are in the top 1,000 (63 from 106), and 43% are in the top 500 (46 from 106). A total of 55% of the firms in oligopoly are in the top 1,000 ranking of R&D investment (50 from 90) and 28% are in the top 500 ranking (26 from 90) (European Commission, 2022).

The year of 2017 was chosen for the study because it represents the maximum growth in European Union's GDP in the after 2008 crisis and before the Brexit period (growth of 2.2% in

2010; growth of 1.9% in 2011; reduction of 0.7% in 2012; neither growth or reduction in 2013; growth of 1.6% in 2014; growth of 2.3% in 2015; growth of 2.0% in 2016, growth of 2.8% in 2017; growth of 2.1% in 2018; and growth of 1.8% in 2019) (The World Bank, 2022).

4.2 Genetic algorithms models results

Equations (4)–(6) were used as references to the estimation of the values of competitive position, for the environments perfect competition, monopolistic competition and oligopoly,

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(s): Adapted by authors from Djolov (2013)

Table 2. Economic view of HHI

Industry	Number of firms	Top 1,000	Top 500
Perfect competition			
Chemicals	27	16	11
Computer services	22	5	3
Electrical equipment	19	10	6
Electronic equipment	19	13	7
Foods	22	9	4
Telecommunication equipment	15	9	4
Total	124	62	35
Monopolistic Competition			
Industry	*Number of cases*	*Top 1,000*	*Top 500*
Biotechnology	11	9	6
Building material	17	8	3
Chemical inputs	7	4	4
Medical equipment	16	9	7
Medical supplies	8	4	3
Pharmaceuticals	25	18	16
Semiconductor	14	8	7
Storage	8	3	0
Total	106	63	46
Oligopoly			
Industry	*Number of cases*	*Top 1,000*	*Top 500*
Clothing and accessories	10	2	2
Computers	7	1	1
Heavy construction	5	3	1
Industrial products	7	4	3
Iron and steel	7	7	4
Media agencies	4	1	0
Mining	2	2	2
Personal products	4	2	2
Software	44	28	11
Total	90	50	26

Source(s): Table by authors based on data processing results and on data from European Commission (2022)

Table 3. Number of cases per industry, per competitive environment and investment ranking

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)–(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 construct's indicators are presented in Equations (10)–(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 4, 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.

	Perfect Competition			Monopolistic Competition			Oligopoly		
Variables	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

Note(s): *** significant at 5.00%
[a] –Difference = calculated mean minus original mean
Source(s): Table by authors based on data processing results

Table 4.
Differences between means

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 4. 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 4.

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 5.

For the monopolistic competition environment, as can be seen in Table 5, 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 5.

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 5. 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.

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, and firm size as control variable. For this, we built a data sample of European Union firms from several industries, that were active in three competitive environments, namely perfect competition, monopolistic competition, and oligopoly, during the 2017 year.

Overall, we show that the adjustments on firm's investment is contingent on the degree of competition they face, leading them do achieve on competitive advantage goals. Results are in line with existing academic research affirmation that the purpose of investments is to create

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(s): Table by authors based on data processing results

Table 5. Original and calculated values for Capex, R&D and competitive position

and exploit opportunities for positive economic rents and that investments allow firms to protect 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. These results are in line with the findings of Tsai and Wang (2004), Zuoza and Pilinkienė (2019), Kim *et al.* (2021), Peng *et al.* (2021), and O'Leary *et al.* (2022), who identified a positive effect of firms' investment on competitive advantage, and also with the findings of Miller *et al.* (2005), Tubbs (2007), Ravšelj and Aristovnik (2020), Machokoto *et al.* (2021), who identified that the effects of firm's investment on competitive advantage are contingent on the degree of competition faced by firms, and with the findings of Dias *et al.* (2022), who identified a positive effect of task environment on firm's competitive advantage.

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. 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.

The present study brings relevant theoretical contributions. First, previous studies have approached the effects exerted by firms' investment on performance and competitive position, and also the effects exerted by competitive environment on firms' investment. Therefore, the present study contributes to the theory field by using theories that considerers the interaction between competitive environment and firms' investments, and its relationships with firms' achievement, in terms of competitive position. Second, prior research has focused on the effects exerted by competition on firms' investment decisions and performance. This research extends this theoretical framework when fulfill the existing gap related to the identification of the optimal amount of investment that allows firms to achieve and sustain competitive advantage, considering the degree of concentration and competition in the competitive environment.

The results of the study have relevant implications for executives who decides on firm's investment to achieve a competitive position that is favorable to the firm. They show that the adjustment in the financial resources that should be allocated in R&D activities and Capex must be estimated under a nonlinear perspective instead of a predominantly linear perspective. Another contribution of the research to decision making is that managers should consider the degree of competition the firm face in the competitive environment, when forecasting the results of the implementation of resources allocation strategies, in conjunction with the firm's capacity of deploying financial resources.

Policy makers should consider the results of the study when defining programs focused on the development of a set of conditions that promotes innovation and allow firms to have access to resources to be allocated and used to achieve and keep a favorable competitive 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, and the expansion of the time length. This research presents the limitations of using only public traded firms' data to calculate industry concentration measures, and of only considering one year period.

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