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ARTICLES

Comparative analysis of the absorptive capacity of knowledge of auto parts companies in Rio Grande do Sul

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ABSTRACT

The article analyzes auto parts companies in Rio Grande do Sul so as to understand their knowledge absorption capacities and to identify important combinations to reach Absorptive Capacity. The Absorptive Capacity is a dynamic skill, and relationships among learning, innovation and interaction may boost knowledge absorption and improve companies' innovative capabilities. Data analysis using Fuzzy Sets Qualitative Comparative Analysis revealed necessary and sufficient conditions related to the dimensions and components that shape the Absorptive Capacity. It was observed that the combinations of capabilities of the companies are sufficient to reach an average level of Absorptive Capacity.

KEYWORDS: Absorptive capacity; Fuzzy sets; Auto parts sector

1. Introduction

In order to grow and profit in the long term, and also to guarantee their survival, organizations need to introduce new goods and services to the market, as well as to look for new methods of doing business, demanding from them the ability to develop their capabilities to innovate. In this way, the absorptive capacity (AC), that is, the capacity of an organization to recognize the value of new knowledge, to assimilate it and to apply it, leads to a greater learning potential, raising the company's knowledge base, thus promoting its technological capacity (COHEN; LEVINTHAL, 1989, 1990, 1994).

Zahra and George (2002) adopt a procedural understanding of AC and show that the sharing of internal knowledge and its integration are essential elements of this capability. According to these authors, AC is a construct of multiple dimensions, obtained by a set of processes and organizational routines, where the companies produce a dynamic capacity within the organization. In order for AC, as a dynamic capability, to conceive a sustained competitive advantage, as well as to assist in the generation of innovations, there must be synergy between the company's internal resources.

A proactive approach to assimilating, distributing and using relevant knowledge about technological changes will allow companies to be better prepared to face challenges and also to identify profitable areas in their sector. In this context, the following question emerges: How to identify and characterize the composition of capabilities in auto parts companies in the State of Rio Grande do Sul that allows the identification, assimilation and exploitation of external technological knowledge, considering the four dimensions of absorptive capacity: acquisition, assimilation, transformation and exploitation?

The general objective of this research is to infer the composition of capabilities used by companies in the auto parts sector in the state of Rio Grande do Sul to develop Absorptive Capacity. In order to so, the theory of fuzzy sets was used, which allows representing and hierarchizing the different levels of absorption capacity.

Absorptive Capacity is composed of several linguistic variables, namely: ability to acquire, assimilate, transform and exploit knowledge. Fuzzy sets allow the possibility of entering membership values between '0' (no membership) and '1' (full membership) in a set, rather than being limited to binary values. This means that we may capture degrees of membership in relation to different levels of Absorptive Capacity.

This article is organized into six parts, including this introduction. In the second section, the concept of Absorptive Capacity is presented. In the third section, a description of the automotive industry and the auto parts sector is presented. In the fourth section, the methodological part is deepened, both in connection with an epistemic proposal and with a process of data collection and inference of results. In the fifth section, the results are illustrated and, in the sixth part, the final considerations are made.

2. The absorptive capacity in organizations

Studies regarding Absorptive Capacity (AC) started from the research of Cohen and Levinthal (1989, 1990, 1994). For these authors, the learning process of organizations takes place from a set of prior knowledge that influences the ability to make assessments. Cohen and Levinthal (1990) point out that companies with higher levels of AC tend to be more capable of exploring the opportunities present in the environment in which they operate. According to these authors, the ability of an organization to recognize the value of new knowledge, to assimilate it and to apply it for commercial purposes is an assessment of its innovative capacity. This ability is known as AC.

Cohen and Levinthal's research achieved great visibility, since it not only explained the definition of absorptive capacity, but it also listed, albeit theoretically, the explanatory factors for its development (LANE; KOKA; PATHAK, 2006). The literature on absorptive capacity has reached a certain degree of integration, especially with regard to the conceptual bases that determine a theoretical framework that may be investigated.

Zahra and George (2002) added another pillar to the original three-dimensional construct of Cohen and Levinthal, proposing the Acquisition, Assimilation, Transformation and Exploitation capabilities, and subdividing their elements into two subsets: Potential and Realized AC. Potential AC, integrated by Acquisition and Assimilation, was defined by Zahra and George (2002, p. 190) as that which "[…] makes the organization receptive to acquiring and assimilating external knowledge". On the other hand, Realized AC holds the transformations and exploitation, which is the one that "[…] reflects the organization's ability to capitalize on the knowledge that was absorbed".

3. The automotive industry and the auto parts sector

A concept often used to describe how companies innovate in a specific sector or industry is called the Sectoral Pattern of Tecnical Change.There are different innovative standards, which vary according to the nature of the innovation, the type of knowledge used and the way companies acquire and use this knowledge. Pavitt (1984) highlights three types of patterns 1) dominated by suppliers; 2) intensive production, which are subdivided into sectors that are intensive in economies of scale and specialized suppliers; and 3) based on science.

In this sense, the auto parts sector fits into the category of specialized suppliers, which is a subdivision of the intensive production sectors. Specialized suppliers are companies that produce parts, components and accessories, which have a strong interaction between users and producers, resulting in technological complementarity. Understanding innovative standards is important to grasp how companies compete in a given sector and how innovation might contribute to economic development (SILVA; SUZIGAN, 2014).

Ferraz, Kupfer and Haguenauer (1996) studied the competitiveness of the Brazilian industry and identified four industrial groups: commodities, diffusers, durables and traditional. Considering the auto parts sector, we will address the specificities of the competition pattern for the

Durables group. In this group, competition takes place on a global scale, with intense renewal of products and constant incorporation of technological content. The prevailing market structure is the differentiated and concentrated oligopoly, where few companies compete through the large-scale production of differentiated products. Product differentiation and high-volume production are important features. These sectors are also intensive in technology, using microelectronic equipment, automation and techniques for continuous improvement of production processes. The availability of qualified labor and training infrastructure are also considered essential. In addition, companies seek technical compliance, competitive prices and establish global sourcing systems for importing components.

The automotive industry faces challenges with technological innovations and the convergence of large-scale connectivity solutions such as the Internet of Things (IoT). These changes have had an impact from the manufacturing process to the use of vehicles by end users, bringing benefits such as reduced operating costs, greater productivity and increased safety. Digital transformation is a major challenge for the sector, influencing business models and vehicle development.

The oil shortage, with availability estimates of just 50 years, and the polluting effects of fossil fuel refining operations and shortages of combustion-powered vehicles have posed challenges for the automobile industry. Among the growing alternatives are hybrid vehicles, which combine internal combustion and electric engines, and fully electric vehicles. The high cost of batteries is an obstacle to expanding the use of electric vehicles. With the massification of production and use, a reduction in costs is expected in the near future (DOGAN; EROL, 2019). According to Bloomberg NEF (2019), the global electric car fleet surpassed 5.1 million in 2018, with an increase of 2 million compared to 2017. China is the world's biggest electric car market, followed by Europe and the United States. The Bloomberg NEF (2019) estimate is that electric vehicles will reach a 30% market share by 2030 in all means of transportation except two-wheelers.

According to Reis (2018), automakers intend to invest around BRL 36.7 billion in Brazil by 2022, with a large part of this amount directed towards the development of new vehicles and Industry 4.0, through updating and modernizing the production structure, introduction of new technologies and connectivity. This new reality of the national industry will demand professionals who are capable of adapting to the evolutions brought about by Industry 4.0 in processes and products.

In this context, it is essential for suppliers to adapt to the Industry 4.0 framework and to new technologies, such as electric and autonomous vehicles, which are disrupting the industry. This opens up opportunities to increase productivity, to reduce errors, to further customize products and to promote more sustainable solutions.

Regarding the number of auto parts companies, Brazil had around 2,800 establishments in 2018, according to data from RAIS (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2018). The products of this sector are distributed in section C - Manufacturing Industry, division 29, group 29.4 and in six classes, according to the CNAE 2.0 classification (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2020b). The sector in study is characterized by a hierarchical structure of supply, with multinational companies, usually global suppliers, and others with little technological insertion, which are normally local suppliers. The markets for these companies are those of automakers, exports, intersectoral and reposition. According to the Annual Industrial Survey (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2018), the production in the Brazilian auto parts sector grew from around 1.5 billion pieces in 2014 to more than 1.8 billion pieces, but dropped to around 1.7 billion pieces in 2017. Sales were around BRL 65 billion in 2017. The auto parts sector is important for the country's economy, but it faces challenges in terms of production and sales.

The auto parts sector has shown significant variations in the number of companies that invest in innovative activities over the years.

According to Instituto Brasileiro de Geografia e Estatística (2017), in 2008, around 30% of companies in the sector invested in innovative activities. This number increased to around 40% in 2011, but dropped to around 25% in 2014. In 2017, the percentage of companies investing in innovation was around 35%.

Furthermore, according to data from Instituto Brasileiro de Geografia e Estatística (2017), expenditures on internal research and development (R&D) activities in the auto parts sector in Rio Grande do Sul were around BRL 500,000.00 in 2008, while in 2011 this value rose to around BRL 1,000,000.00. In 2014 and 2017, the amount spent on R&D was around BRL 1,000,000.00.

In Rio Grande do Sul, the auto parts sector is diversified, with companies that manufacture everything from small incorporated auto parts to component systems for different types of vehicles. In 2018, the number of establishments manufacturing parts and accessories for motor vehicles in Rio Grande do Sul was 352 companies, and the approximately twenty thousand people employed in the auto parts sector in Rio Grande do Sul represented 3.24% of the total of employees in all industries in the state (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2020a). The total labor productivity of auto parts companies in Rio Grande do Sul in 2016 was approximately BRL 130,000.00, while the total labor productivity of auto parts companies at the national level was around BRL 115,000.00. In 2018, total labor productivity in Rio Grande do Sul was once again ahead when compared to Brazil (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2020a).

Furthermore, according to data from Instituto Brasileiro de Geografia e Estatística (2020a), in 2018, the average wage for auto parts companies in Brazil was around BRL 3,200, while in Rio Grande do Sul, it was BRL 2,800. As for the mark-up of the auto parts sector in Rio Grande do Sul, it is the highest at country level (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2020a) despite the downward trend over the years - it dropped from 0.33 to 0.25 in one decade.

4. Methodology

4.1 Diversity of evolutionary theory and comparative research

Neo-Schumpeterian design methodologies, based on Schumpeterian competition principles, have contributed to the economic analysis of industries by incorporating qualitative aspects of structural dynamics. These approaches allow cross-sectional observations and longitudinal analyzes that analyze the evolution of variables and their impact on the performance of companies and industries. The evolutionary perspective, inspired by evolutionary biology, has been an important influence on economics, going back to the work of Alfred Marshall (1988). Darwin's (2018) evolutionary theory, based on variability, heredity and natural selection, highlights the importance of organisms adapting to environmental changes for their survival. On the other hand, according to Luz and Fracalanza (2012), Herbert Spencer emphasized the notion of progress and transformation as central aspects of the evolutionary process. Whereas Darwin focuses on the adaptability of organisms, Spencer sees evolution as a transition from incoherent homogeneity to coherent heterogeneity.

From a Darwinian-inspired perspective, Nelson and Winter (1982), for example, were confident enough to describe routines with all the equivalent attributes of an evolutionary unit of analysis. Routines are understood, first, as a memory of the organization, as according to the authors: "[…] we propose that the routinization of an organization's activities constitutes the most important form of storage of specific knowledge of the organization" (NELSON; WINTER, 1982, p. 153). Learning routines, secondly, may modify existing routines, with the aim of providing greater pecuniary gain to the organization. Finally, the third characteristic of routines resides in understanding them as leading the behavior of organizations, being selected in a competitive environment.

All in all, routines might be understood as holding the basic properties of an evolutionary analysis unit, that is, they vary, are inheritable and are also selectable.

Bearing this in mind, Teixeira (2020) highlights that Nelson and Winter's (1982) discussion of routines instigated Cohen and Levinthal's (1990) discussion of the organizational characteristics of Absorptive Capacity in three topics: i) The organizational AC is greater than just the sum of individual ACs; it depends on how these are interconnected by the organizational routines of companies; ii) Previous knowledge and routines play an ambiguous role on AC: under one approach, both conduct the search process for new knowledge as well as innovations and must allow for a certain internal heterogeneity that favors this search, and also its recombination with existing knowledge; on the other hand, they contribute to a certain "selection" of internal knowledge, which benefits communication, however, it may not facilitate the identification of new external knowledge; iii) different routines are essential depending on the learning environment and on the context faced by the company.

Since knowledge is not located in a single place, cannot be divided, has a large intangible content and is valued differently, it is necessary for the company to create other heuristics, such as AC and its previous knowledge base, with the aim of exploring the external. This is consistent with the notion that companies have an idiosyncratic "menu of choices" (NELSON; WINTER, 1982), and, thus, they deal differently with the same environment and industrial structure (TEIXEIRA, 2020).

Recognizing the value of the organization and its capabilities, and knowing that different companies, with different resources and capabilities, see and explore "free and available" knowledge in different ways, it is understood that a technique that can encompass these diversities present in companies is necessary. Ragin's (1987) conception, in which a method based on Boolean algebra could combine the strengths of the qualitative and quantitative approaches, leads to the creation of a comparative method that combines elements of both, namely: the Qualitative Comparative Analysis (QCA).

Rihoux and Ragin (2009, p. 352) elucidate that, from qualitative studies, the QCA inherits the ability to transmit a holistic view, that is, each case is analyzed as a whole to be understood and that cannot be omitted throughout the search. In the QCA, the combination of conditions that guide the result is not just one. The method allows for a diversity of paths, as there are many possible condition configurations that may lead to the same result (RIHOUX; RAGIN, 2009, p. 8).

Nevertheless, the QCA also presents aspects that bring it closer to quantitative studies. The QCA may be understood as formal in the sense that it is based on the language of Boolean algebra and also on the set theory, whose norms and solutions implement and translate rules of logic. The research approach focused on diversity, developed in Ragin (2000), accompanies the study of causality. It aspires that different causal conditions relate to different results, that is, the researcher's objective when examining similarities and differences is to find causal links, how different configurations of causes generate results in the different cases under study (RAGIN, 1994, 2000). It is worth highlighting that the diversity is not only in the different types of cases in the sets portrayed by the phenomena, but also in the degree to which each unit of analysis belongs to such sets. For this reason, there was the emergence of the QCA with fuzzy sets, proposed by Ragin (2000).

The use of fuzzy sets manages to capture the second dimension of diversity, which is to consider the scale of membership of each observation unit (case) in the sets of interest (phenomena), without giving up the first dimension of diversity, which is the difference in types. In this way, fuzzy sets capture both aspects – the quantitative distinction and the qualitative distinction – in a single instrument (BETARELLI JUNIOR; FERREIRA, 2018). Hence, the QCA, and its variant fsQCA, emerge as efforts to operationalize the approach to diversity.

A dimension to achieve AC, such as the acquisition capacity, through fuzzy sets, may be expanded into high acquisition capacity and low acquisition capacity. As a category is characterized, there is increased attention to the potential diversity that is being selected. In this sense, fuzzy sets allow a much closer perception of the complexity of the studied situations (RAGIN, 2000).

The major contribution of QCA is to identify situations where there are (1) complex causality: each individual case is a combination of several properties (RIHOUX; RAGIN, 2009); (2) asymmetric causality: it exists when the occurrence of a phenomenon and its non-occurrence require separate analyzes and different explanations; (3) non-linear relationships: it is considered that the conditions are not independent variables and that the intensity of their effect depends on other relevant variables (RIHOUX; RAGIN, 2009); (4) equifinality: there are cases where different combinations of factors can generate the same phenomenon, (5) multipurpose: it exists when the same condition can generate different results in different contexts or times, that is, its result is part of contexts (GURGEL, 2011; SILVA, 2013), (6) necessity relations: condition A is necessary for outcome Y if the occurrence of Y is not possible without the presence of A (SCHNEIDER; WAGEMANN, 2012); (7) sufficiency relations: condition A is sufficient, but not necessary, if such condition is capable of producing the result, but at the same time there are other combinations also linked with the result (SCHNEIDER; WAGEMANN, 2012).

Accordingly, it is worth highlighting the measures of consistency and coverage within the scope of the fsQCA; they assess whether or not there is a predominance of some procedural combinations that link to certain outcomes. The consistency measure highlights the subset of cases related to the established condition and the result, in the context of all cases belonging to that condition. The coverage measure, in its turn, highlights a list of cases that contain the condition in the total number of cases in which the result is present, thus, these assessments are crucial since the result found may arise from different combinations, and not just a single specific causal relationship. When observing several paths to the same result found by inference, if the coverage of a given causal combination is small, its power to explain the phenomenon will be small.

Adaptation and growth of companies are linked to a diversity of ways of learning and competing selected in the market environment. Since the learning of companies to innovate is approached with theoretical constructions that rely on Darwinian evolution principles, QCA and its variant fsQCA may be more adequate vis-à-vis econometric analyzes to empirically discuss absorptive capacities.

The challenge of this research lies in translating the plurality based on auto parts companies in RS into selected causal combinations, without major loss of information or reduction of companies to a single type. The fsQCA was selected to be used, which is an instrument that works with the construction of various combinations along a scale of membership of cases to sets.

4.2 Classification and research outline

This research adopts a quali-quanti approach, combining qualitative and quantitative elements. The data for this study were obtained from two sources: *a*) the Annual List of Social Information (RAIS) for the year 2018 which contains information relevant to the proposed objectives; *b*) primary data collected through the application of a questionnaire, following a previously established script, with auto parts companies located in Rio Grande do Sul (RS), Brazil.

The selection of the universe of companies used RAIS data to calculate the locational quotient (LQ), with the intention of spatially delimiting local production systems, methodologically guiding the field research. The LQ indicates the relative concentration of a certain industry in a region or municipality compared to the participation of this same industry in the space defined as a base, in this case the state of RS. Thus, locational specialization indicates a probable productive and technological learning process, and when approaching companies that participate in these articulations, even if incipient and informal, the sample seeks to incorporate its effects for the AC of each company.

For the purposes of this research, the index presented in a previous work by Suzigan et al. (2001) was used:

$$QL_{ij} = \frac{\frac{E_{ij}}{E_i}}{\frac{E_i}{E}} \quad (1)$$

where:

$QL_{ij} = LocalQuotientij$;

E_{ij} = employment in sector i of region j;

$E_i = \sum_j E_{ij}$= employment in sector i of all regions;

$E_i = \sum_i E_{ij}$= employment in all sectors of region j;

$E = \sum_j \sum_i E_{ij}$= employment in all sectors of all regions.

It is considered that there would be specialization of activity i in region j, if its LQ was greater than one. In addition, to make the sample more comprehensive, a calculation of the proportion of employment per municipality in the auto parts sector was made compared to total employment in the sector in the state of RS. Thus, for the spatial selection of companies, there is a combination of places where there is a relative concentration of the sector in local employment (QL), with information on the gross proportion of sectoral jobs in the state. This second step strengthens the sample by including companies that have adopted other strategies to improve their AC, considering the possible relationship between the relative concentration of employment in the auto parts sector by municipality and the companies' capacity to absorb knowledge and innovation.

When employment in the auto parts sector is concentrated in certain municipalities in relation to the total employment in the sector in the state, this may indicate the existence of regions with a productive specialization in this sector. This concentration might create an environment conducive to the exchange of knowledge, collaborative interactions among companies, suppliers as well as research and development institutions, in addition to facilitating access to sector-specific resources. These factors may contribute to the development of a greater absorptive capacity in companies located in these regions.

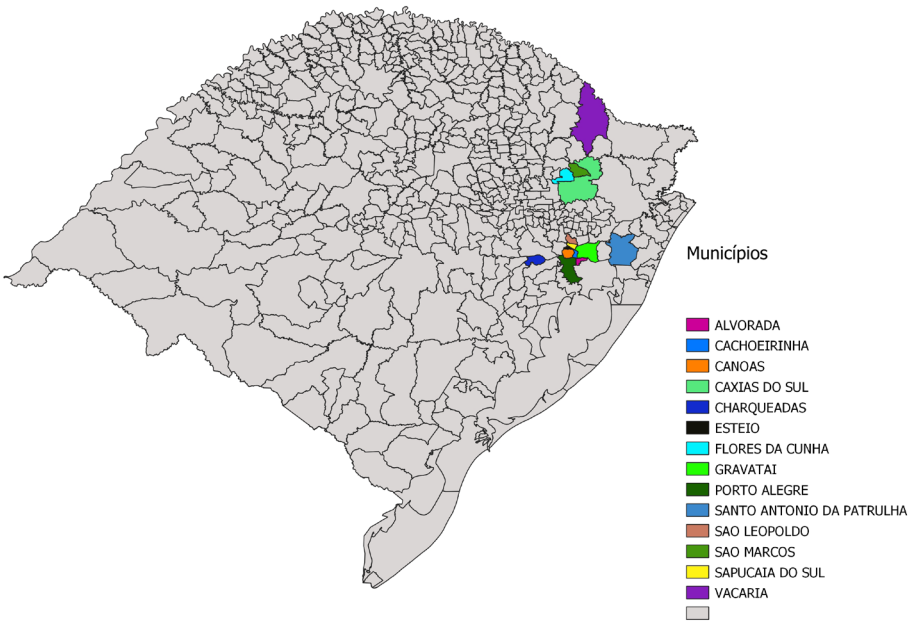
The selected sample represents approximately 96.2% of all jobs and approximately 76.9% of all establishments in the auto parts sector in Rio Grande do Sul. This suggests that the sample was selected in areas where the concentration of the auto parts sector is significant, which is important to capture the specific characteristics of this sector.

By using the LQ as a criterion for selecting the sample, it is possible to direct the research resources more efficiently, focusing on the regions or municipalities with the highest concentration of the auto parts sector.

There were 14 municipalities, which can be seen in Figure 1. After the spatial definition, the addresses of the companies in the auto parts sector belonging to the most representative municipalities were extracted from the Econodata electronic address.

The research instrument was elaborated with reference to the absorptive capacity of the companies. Thus, the indicators used to assess the absorptive capacity of the companies included items from the AC measurement structure proposed by Zahra and George (2002), which highlight four dimensions: 1) Acquisition; 2) Assimilation; 3) Transformation; 4) Exploitation. In Chart 1, it is possible to observe the dimensions selected for use in the research instrument and their respective sources.

FIGURE 1
Municipalities selected through LQ and Proportion of sectoral employment.



Source: Elaborated based on data from Instituto Brasileiro de Geografia e Estatística (2018).

CHART 1
Dimensions selected for use in the research instrument

		Items	Source
Potential Absorptive Capacity	Acquisition	The company easily identifies the technological opportunities that arise in the market.	Teixeira, Pinto and Lopes (2017)
		The search for relevant information about our sector is constant in the company's day-to-day activities.	Flatten et al. (2011)
		The company has contact with other organizations (Technological Centers, Research Institutes, Consultancies, etc.) to learn how to produce and / or innovate.	Camisón and Fóres (2010)
		The company's employees have the necessary qualifications to work on innovative projects.	Vega-Jurado, Gutiérrez-Gracia and Fernández-de-Lucio (2008)
		The company develops internal skills to acquire technological knowledge from Research and Development Centers (R&D) or from customers.	Camisón and Fóres (2010)
	Assimilation	New opportunities to serve our customers are quickly understood.	Jansen, Van den Bosch and Volberda (2005)
		The company holds periodic meetings to share information, solutions and achieved results.	Flatten et al. (2011)
		Management emphasizes cross-departmental support for problem resolution.	Flatten et al. (2011)
		The company's employees participate in training courses and professional events.	Camisón and Forés (2010)
		The company has the ability to use the level of knowledge, experience and employees' skills in the assimilation of new knowledge.	Camisón and Forés (2010)
Realized Absorptive Capacity	Transformation	Employees are able to apply new knowledge in their work practices.	Flatten et al. (2011)
		The company encourages employees to combine ideas across departments.	Flatten et al. (2011)
		In the company, there are regular meetings to discuss the consequences of market trends and the development of new products.	Jansen, Van den Bosch and Volberda (2005)
		The company recognizes the usefulness of new external knowledge for existing knowledge.	Jansen, Van den Bosch and Volberda (2005)
		The company has the ability to adapt technologies developed by others to meet its own needs.	Camisón and Forés (2010)
	Exploitation	The company's employees are used to absorbing new knowledge, as well as to preparing it for future proposals and to making it "assessable".	Flatten et al. (2011)
		The company regularly reconsiders technologies and adapts them according to the new knowledge.	Flatten et al. (2011)
		The company supports the development of prototypes (products still in the development or testing phase, not ready for commercialization).	Flatten et al. (2011)
		The company has the ability to put new knowledge into new products and processes.	Camisón and Forés (2010)
		The company is able to respond to demand requirements and competitive pressures, seeking to innovate more and more to ensure competitiveness.	Camisón and Forés (2010)

Source: Elaborated by the authors.

Information regarding absorptive capacity was captured using rulers representing linguistic variables, in which the interviewee places the ruler at the level he or she sees as the most appropriate according to his or her perception (where the left side of the ruler represented the minimum intensity of agreement and the right side the maximum intensity of agreement with the assertion presented). In this format, people can freely express their choice, without necessarily choosing a number, but a position on the ruler that expresses higher or lower levels referring to what is asked. Figure 2 illustrates the scale used.

The questionnaire was sent electronically to the companies through the "Question pro Essentials". software. The data treatment was carried out from fuzzy sets and operated by the free software fsQCA.

4.3 Inference system modeling for AC

This section addresses the analyses that were carried out, related to the necessary steps for the construction of the fuzzy inference system. The procedure combined two stages: the first uses a fuzzy Mamdani controller system, operated with two subsystems, to organize queries to companies as dimensions of the AC; the second stage uses the AC dimensions resulting from the Mamdani system to feed the inference of necessary and/or sufficient conditions for different AC intensities, processed with fsQCA. The control systems are based on concepts of fuzzy sets, in which there are the following steps: i) fuzzification (input), ii) fuzzy inferencing (evaluation of rules) and iii) defuzzification (outputs).

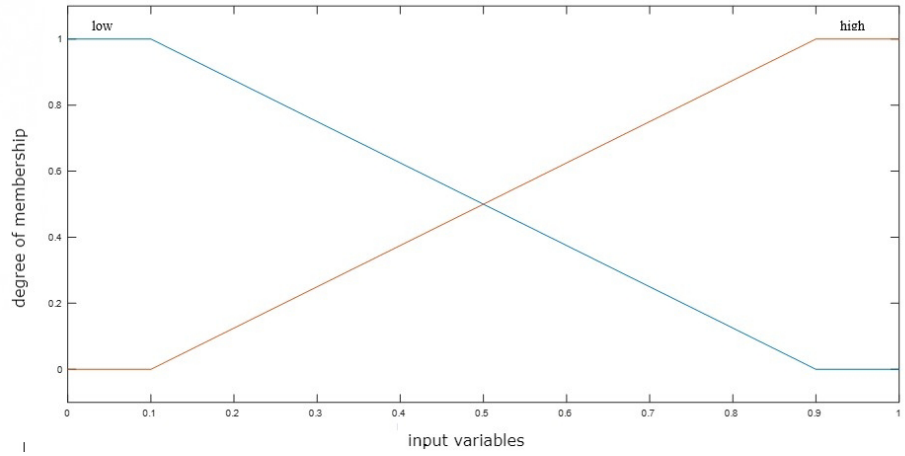
FIGURE 2
Scale used to capture the information.

Source: QuestionPro (2020).

Each AC dimension (acquisition, assimilation, transformation and exploitation) was measured from 5 questions. To analyze the responses of each item of the questionnaire, the following denominations were defined: low and high. The analyses related to the fuzzy sets are in the range between 0 and 1 so that each input and output variable of the built inference systems present standardization in their controllers. Figure 3 shows how the input variables of all dimensions (Acquisition, Assimilation, Transformation, Exploitation) were parameterized, where it is possible to associate the values to their respective degrees of pertinence.

The description of the calibration[1] of the scores for membership to the work sets is based on the way in which the data were captured. The scale used (ruler format) allowed respondents to activate the ruler according to their own perceptions, where the left side of the ruler had the minimum term (zero): indicating a lower agreement and

FIGURE 3
Composition of input variables of all dimensions.



Source: Elaborated by the authors.

[1] The calibration method used in the present work resulted from the theory of fuzzy sets and a symmetry chosen by the authors for the overlapping of the sets, without requiring pre-established anchors, according to Longest and Vaisey (2008).

consequently leading the response to a higher degree of membership to the "low" set; the right side has the maximum term (one), indicating greater agreement and consequently leading to a greater degree of membership to the "high" set; and finally, 0.5 (half of the ruler) refers to a total indecision by part of the respondents, which coincides with the 0.5 of membership and not membership together. Therefore, the calibration values, which are: 0 (limit for non-full adherence) – 0.5 (crossed point or maximum ambiguity) – 1 (limit for full adherence), are explained by the way the research responses were captured. In addition, the trapezoidal format was chosen for the representation. The term "low" corresponds to the range of [1 1 0 0] and the term "high" [0 0 1 1].

The next stage of the process is called inference and represents the junction between input variables (linguistic) and output variables through the set of If-Then rules (JANÉ, 2004) modeled by the minimal operator of the Mamdani method.

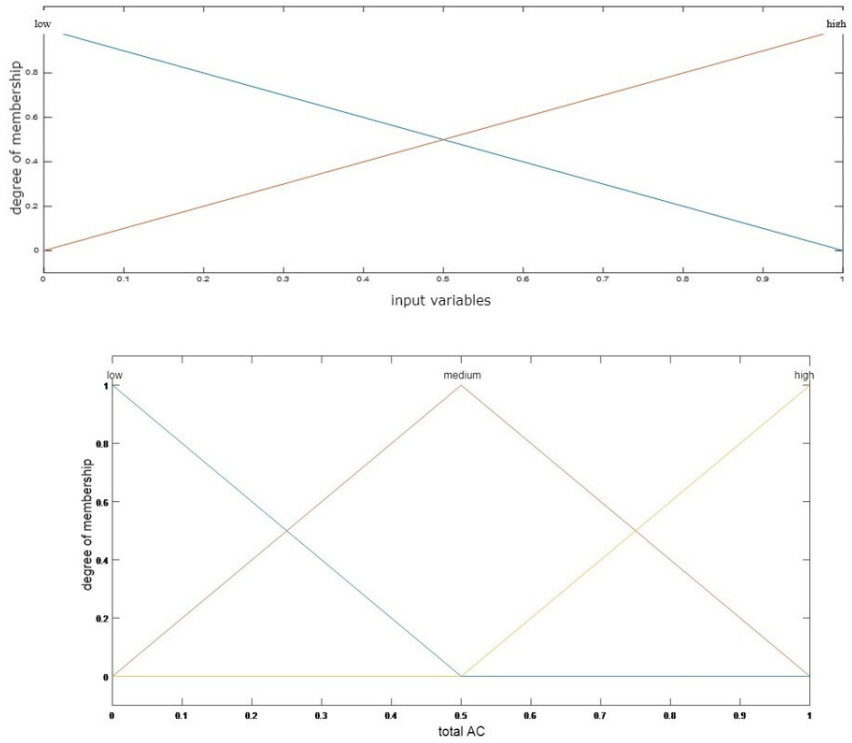
The fuzzy rules are built after formatting the linguistic variables (high, low). This procedure was repeated for 4 blocks of questions, each consisting of 5 questions, and the result was the attainment of an output set representing the four dimensions of AC proposed by Zahra and George (2002): Acquisition, Assimilation, Transformation and Exploitation.

The calculation of the rules is carried out as follows: the linguistic terms, associated with each linguistic variable, must be raised to the power of the number of inputs that the controller has (MAMDANI; ASSILIAN, 1975). In the case of the calculation related to each of the AC dimensions, the number of rules is defined by (2^5), as it represents the linguistic terms of each variable, that is, (2) representing the terms low and high; and (5) the number of variables, because for each dimension there were 5 questions to be answered, representing the input variables in the fuzzy system. In this case, the number of rules was 32 for each dimension[2].

[2] The rules adopted are equivalent for all dimensions.

To find the Total AC of the companies, a second inference system was made, where the inputs are the fuzzy outputs of each of the four dimensions (acquisition, assimilation, transformation and exploitation). The composition of input and output linguistic variables was parameterized according to Figure 4. Combinations of the antecedent sets of Acquisition Capacity (Low and High), Assimilation Capacity (Low and High), Transformation Capacity (Low and High) and Exploitation Capacity (Low and High) were explored to achieve a high Absorptive Capacity. From this perspective, the inference system is able to present the logical connectives constructed to establish the fuzzy system relationship and to establish the result (AMENDOLA; SOUZA; BARROS, 2005). The system reads the data according to the established rules and results in a fuzzy value for each company.

FIGURE 4
Composition of Input and Output variables, respectively, for Total AC.



Source: Elaborated by the authors.

As it can be observed in Figure 4, the triangular membership function was chosen, since a second level of analysis is being carried out, where there is no longer a direct connection with the responses of the respondent individuals. The triangular function, with the term "medium", seeks to enrich the classification of the inference process. The term "low" corresponds to the interval of [0 0 0.5], "medium" [0 0.5 1] and "high" [0.5 1 1]. In this sense, there is a transition area from low to medium degree in the range of 0 to 0.5. The total membership to the medium set is only one value (0.5) and the transition area between medium and advanced is 0.5 to 1. Thus, the answers will, in most cases, belong to two sets, in order to modify only the degree of pertinence in each one. The number of rules in this new system is defined by (2^4), as it represents the linguistic terms of each variable (low and high) and (4) the number of input linguistic variables for each dimension. Therefore, the number of rules was 16.

After formatting the memberships of the companies' responses to the fuzzy sets, the free software fsQCA was used to describe the necessary and sufficient conditions to achieve Absorptive Capacity. In order to carry out the fsQCA analysis, the α-cut[3] value projected on the membership function of each company was applied to the functions that make up the sets of Figure 4. Thus, there is the degree of membership of the respective α-cut to the corresponding low or high set of Acquisition Capacity, Assimilation Capacity, Transformation Capacity and Exploitation Capacity - all antecedent conditions -, and Absorptive Capacity (AC) of the company, consequent variable.

By establishing the causal combinations for AC, the result is a list of combinations to reach the AC variable. In addition to the list of possible combinations, the Consistency and Coverage of each combination is already generated.

[3] For every α value of the interval [0,1], the α-*cut* *A*α (or cut on level α) of a fuzzy set A of U as the subset is defined: Aα = {x∈U / μ A (x) ≥α. The α-*cut* can be understood as the fuzzy set that presents a restriction or a limit imposed on the domain of the set based on the value of α.

5. Results

The research was carried out with a sample of 80 companies, of which 28 companies responded it, representing 35% of the sample. The data collection took place between November and December 2020. Of the 28 companies in the sample, none is considered large; the majority (39%) is small, followed by 29% of medium-sized and 32% of micro companies. The average operating time of the companies is 21 years, ranging from 3 to 72 years. As for the origin of the capital, 46% are of national capital, 8% are of foreign capital and 46% are Ltd. Most companies (92%) are represented by headquarters, while only 8% are branches.

The research's respondents, who are the managers and directors of the companies, have mainly undergraduate (44%) and specialization/MBA (44%) backgrounds. The remaining 12% have high school, technical or master's degrees. As for supplier levels, most companies (46%) are classified as level 2, followed by 21% at level 3 and 14% at level 1.

After the data collection, the inference of the input variables was carried out, through the rules that express, in a linguistic way, the possible interrelationships of the investigated dimensions, with the objective of obtaining a defuzzified[4] number, represented by a real number. Therefore, the output of the aggregation of the five questions of each of the dimensions was obtained, as well as the output of the aggregation of the 4 dimensions that represent the total AC of the companies. The degrees of membership obtained by this process are shown in Table 1.

In order to establish sufficient combinations for the consequent variables High AC, Medium AC, Low AC, High[5] Non AC and Low[6] Non AC, the fsQCA Fuzzy Truth Table Algorithm option was activated. The resultant is a list of combinations to reach each consequent variable.

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[4] Understood as a procedure that allows understanding the distribution of the possibilities of outputs of a fuzzy linguistic model in a quantitative way (ORTEGA, 2001). In the present research, the defuzzification is done by the Center of the Area, represented by the center of gravity of the possibility distribution function of the output value (SANDRI; CORREA, 1999).

[5] The set High Non AC is established by the negation of HighAC, that is (1- degree of membership) to High AC. If HighAC is "success", the necessary and sufficient conditions for HighAC are combinations of what not to do if HighAC is the goal.

[6] The same idea applies as for High Non AC.

TABLE 1
Degree of membership of the answers obtained in the survey

Company	low aq AC	high aq AC	low as AC	high as AC	low tr AC	high tr AC	low ex AC	high ex AC	low AC	médium AC	high AC
A	0.5	0.5	0.45	0.55	0.38	0.62	0.5	0.5	0	0.98	0.02
B	0.5	0.5	0.33	0.67	0.36	0.64	0.43	0.57	0	0.94	0.06
C	0.59	0.41	0.45	0.55	0.36	0.64	0.55	0.45	0	1	0
D	0.62	0.38	0.35	0.65	0.57	0.43	0.65	0.35	0.08	0.92	0
E	0.45	0.55	0.25	0.75	0.26	0.74	0.25	0.75	0	0.82	0.18
F	0.67	0.33	0.7	0.3	0.7	0.3	0.67	0.33	0.16	0.84	0
G	0.25	0.75	0.25	0.75	0.25	0.75	0.25	0.75	0	0.76	0.24
H	0.25	0.75	0.25	0.75	0.26	0.74	0.26	0.74	0	0.76	0.24
I	0.52	0.48	0.39	0.61	0.39	0.61	0.49	0.51	0	0.96	0.04
J	0.26	0.74	0.26	0.74	0.3	0.7	0.29	0.71	0	0.8	0.2
K	0.46	0.54	0.39	0.61	0.38	0.62	0.29	0.71	0	0.92	0.08
L	0.43	0.57	0.35	0.65	0.33	0.67	0.41	0.59	0	0.9	0.1
M	0.28	0.72	0.25	0.75	0.25	0.75	0.26	0.74	0	0.76	0.24
N	0.29	0.71	0.26	0.74	0.28	0.72	0.26	0.74	0	0.78	0.22
O	0.25	0.75	0.25	0.75	0.25	0.75	0.25	0.75	0	0.76	0.24
P	0.28	0.72	0.26	0.74	0.25	0.75	0.26	0.74	0	0.78	0.22
Q	0.67	0.33	0.75	0.25	0.64	0.36	0.5	0.5	0.08	0.92	0
R	0.45	0.55	0.28	0.72	0.45	0.55	0.43	0.57	0	0.96	0.04
S	0.25	0.75	0.25	0.75	0.26	0.74	0.28	0.72	0	0.76	0.24
T	0.44	0.56	0.38	0.62	0.38	0.62	0.46	0.54	0	0.94	0.06
U	0.5	0.5	0.57	0.43	0.39	0.61	0.5	0.5	0	1	0
V	0.29	0.71	0.36	0.64	0.43	0.57	0.5	0.5	0	0.94	0.06
W	0.38	0.62	0.29	0.71	0.31	0.69	0.35	0.65	0	0.86	0.14
X	0.33	0.67	0.49	0.51	0.45	0.55	0.46	0.54	0	0.98	0.02
Y	0.26	0.74	0.3	0.7	0.28	0.72	0.29	0.71	0	0.8	0.2
Z	0.5	0.5	0.3	0.7	0.46	0.54	0.41	0.59	0	0.96	0.04
Z2	0.5	0.5	0.5	0.5	0.57	0.43	0.5	0.5	0	1	0
Z3	0.44	0.56	0.5	0.5	0.26	0.74	0.46	0.54	0	0.98	0.02

Source: Elaborated by the authors.

Considering minimum values for assessment of 0.8 for Consistency[7] and 0.5 for Coverage, there were no consistent combinations for sufficiency, not even necessary conditions with acceptable coverage for establishing High Absorptive Capacity (highAC) and Low Absorptive Capacity (lowAC). Therefore, there is not a sufficient path in the answers of the interviewees to obtain HighAC and LowAC.

The same procedure was adopted to establish necessary and sufficient conditions to obtain a Medium Absorptive Capacity (MediumAC). The Fuzzy Truth Table Algorithm, fsQCA Complex Solution option was activated. Five sufficient combinations were found. However, the comparison among them revealed that there was a sufficient, consistent and with good coverage combination (Line 5 of Chart 2) to reach Medium AC. It turns out that the combination is related to all high antecedents. Thus, so as to reach a Medium AC it is necessary that the ACacquisition, ACassimilation, ACtransformation and ACexploitation are high.

There are 16 companies compatible with sufficient causal combination to obtain Medium Absorptive Capacity. In addition, all combined background possibilities were sought (lowaqAC, highaqAC, lowasAC, highasAC, lowtrAC, hightrAC, lowexAC, highexAC), as well as in isolation, for the fsQCA necessity test. However, these combinations turned out to be inconsistent (with consistency below 0.9[8]).

For the establishment of High Non-Absorptive Capacity, there were 5 combinations again, only one being sufficient (Line 5 of Chart 3) - based on consistency and coverage values. The same 16 companies are compatible with sufficient causal combination to obtain High Non-Absorptive Capacity. Next, the model and the result of the algorithm (Chart 3).

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[7] Ragin (2006, p. 3) points out that for consistency values below 0.75 it is difficult to sustain that there is a relationship between the assessed sets, that is, that one is a subset of the other.

[8] According to Rihoux and Ragin (2009) and Schneider and Wagemann (2012), the conditions that present consistency greater than 0.9 can be considered necessary conditions. Furthermore, consistencies between 0.8 and 0.9 are considered almost always necessary conditions for the result in question.

CHART 2
Sufficient combination for Medium Absorptive Capacity[9]

TRUTH TABLE ANALYSIS			
File: C:/Users/neisa/Desktop/DADOS fsQCA.csv			
Model: mediumAC = f(lowaqAC, highaqAC, lowasAC, highasAC, lowtrAC, hightrAC, lowexAC, highexAC)			
Algorithm: Quine-McCluskey			
--- COMPLEX SOLUTION ---			
frequency cutoff: 1			
consistency cutoff: 1			
	raw coverage	unique coverage	consistency
Line 1 -	0.369249	0.0250202	1
lowaqAC*~highaqAC*lowasAC*~highasAC*lowtrAC*~hightrAC*			
lowexAC*~highexAC			
Line 2 –	0.365617	0.00564975	1
lowaqAC*~ighaqAC*~ lowasAC* highasAC* lowtrAC*~hightrAC*			
lowexAC*~highexAC			
Line 3 -	0.393462	0.00403547	1
lowaqAC*~highaqAC*~lowasAC*highasAC*lowtrAC*~hightrAC*			
lowexAC*~highexAC			
Line 4 -	0.414044	0.000807106	1
lowaqAC*~highaqAC*~lowasAC*highasAC*~lowtrAC*hightrAC* ~lowexAC*highexAC			
Line 5 -	0.627119	0.2159	1
~lowaqAC*highaqAC*~lowasAC*highasAC*~lowtrAC*hightrAC*			
~lowexAC*highexAC			
solution coverage: 0.670702			
solution consistency: 1			

Source: Elaborated by the authors.

[9] The results use the symbol "~" (tilde) to say that the variable in question is being denied (receiving a value of 0).

CHART 3
Sufficient Combination for High Non AC

TRUTH TABLE ANALYSIS			
File: C:/Users/neisa/Desktop/DADOS fsQCA.csv			
Model: ~highAC = f (lowaqAC, highaqAC, lowasAC, highasAC, lowtrAC, hightrAC, lowexAC, highexAC)			
Algorithm: Quine-McCluskey			
--- COMPLEX SOLUTION ---			
frequency cutoff: 1			
consistency cutoff: 1			
	raw coverage	unique coverage	consistency
Line 1 – lowaq	0.364542	0.0247012	1
AC*~highaqAC*lowasAC*~highasAC*lowtrAC*~hightrAC* lowexAC*~			
highexAC			
Line 2 – lowaq	0.360956	0.00557774	1
AC*~highaqAC*~lowasAC*highasAC*lowtrAC*~hightrAC* lowexAC*~			
highexAC			
Line 3 – lowaq	0.388446	0.00398409	1
AC*~highaqAC*~lowasAC*highasAC*~lowtrAC*hightrAC*lowexAC* ~highexAC			
Line 4 – lowaq	0.408765	0.000796795	1
AC*~highaqAC*~lowasAC*highasAC*~lowtrAC*hightrAC* ~lowexAC*			
highexAC			
Line 5 –	0.619124	0.213147	1
~lowaqAC*highaqAC*~lowasAC*highasAC*~lowtrAC* hightrAC*~			
lowexAC*highexAC			
solution coverage: 0.662151			
solution consistency: 1			

Source: Elaborated by the authors.

The combination, again, is related to all high antecedents. In this way, as well as for Medium AC, to reach High Non AC it is sufficient that acquisition AC, assimilation AC, transformation AC and exploitation AC are high. When analyzing the necessary conditions for High Non AC, it was found that there are no consistent conditions. For establishing Low Non AC, there was again the same consistent combination for sufficiency, that is, all high antecedents – having a consistency of 1 and coverage of 0.56 (slightly lower than the combination for High Non AC). Furthermore, the necessity was tested, with antecedent sets individually or combined with each other in all possibilities, and, again, combinations of antecedent sets were not consistently necessary.

The identification that high dimensions of Absorptive Capacity (AC), when combined, do not reflect in a high total AC. This apparently contradictory result may come from two possible explanations. Firstly, it may be considered that this result is a reflection of the more general innovative strategies adopted by the companies under study. It is possible that some companies are taking more comprehensive approaches in relation to innovation, which may influence the relationship between AC dimensions and their contribution to total AC. The incidence of such strategies on each of the AC dimensions, separately, can be perceived as high, although the combined effect between them leads to a medium-level AC. These broader strategies may generate different effects than what would be expected when considering AC dimensions individually.

Another relevant explanation to be considered is the cumulative character of AC as a whole. It could be argued that, given an initially low starting point in terms of AC, the researched companies may need to put considerable effort into building and developing AC dimensions. Nevertheless, these efforts may, at first, only result in medium ACs.

6. Final considerations

Technological progress generates diversification of economic opportunities, from the search process for technological development, which occurs in the midst of a natural trajectory of a technology and

new technological paradigms affect companies. Since the level of competition in the markets affects the search and innovation capacity of companies, in order to compete and stand out in the market, they need to improve their adaptability and absorption of technological knowledge. A high level of Absorptive Capacity enables companies to redefine their knowledge base and internal capabilities to innovate.

The instrument to measure this capacity has to be able to capture the dynamic relationships of the innovative company and the different configurations that promote a given absorption capacity. Thus, the QCA research approach, configured with fuzzy sets, becomes adequate to understand diversity.

The primary data collected from companies in the auto parts sector in Rio Grande do Sul and analyzed comparatively through the membership to qualitative sets (fuzzy sets), showed a sufficient path for companies to obtain Medium AC, High Non AC and Low Non AC. The combination sufficient for all these results had all high antecedents – High Assimilation Capacity and High Acquisition Capacity and High Transformation Capacity and High Exploitation Capacity.

The results indicate that the companies in the auto parts sector consulted in Rio Grande do Sul have a medium absorptive capacity of knowledge. Bearing in mind that the inference resulted from the consultation of companies in the sector in Rio Grande do Sul, the acquisition, assimilation, transformation and exploitation capabilities assessed by them as "high" compared to competitors in the sector are just sufficient to achieve a Medium AC. Hence, the result suggests a limitation of companies in the sector in terms of AC in general, which, consequently, reflects a difficulty in keeping up with changes in the most general sense. This picture may derive from difficulties in the joint management of all dimensions of the knowledge absorption process that imply a loss in the resultant of the combination of efforts.

The model presented organizes the conditions of necessity and sufficiency for AC and dialogues with the epistemology presented on the evolutionary theory, representing the reality of companies in the auto parts sector in Rio Grande do Sul. Furthermore, it is understood that the relevance of the proposed methodology is that it allows the

description of combinations of antecedent variables present in the literature, obtaining an assessment of the absorptive capacity (AC) of the companies and allows understanding the reality in which they are situated. Finally, the picture found indicates that companies in the auto parts sector of RS need policies that increase the synergistic effect of their efforts to build knowledge absorptive capacities, in order to be able to generate innovations and, above all, to create and to maintain competitive advantages in the face of changes in the automotive industry.

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