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ABSORPTIVE CAPACITY, INNOVATION, AND EXTERNAL SOURCES OF KNOWLEDGE: THE BRAZILIAN POWER SECTOR[1]

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ABSTRACT

Purpose: This paper discusses the relationship between absorptive capacity, external sources of knowledge, and innovation in the context of the power sector. In doing so, we follow the theoretical debate over absorptive capacity dimensions. We focus on the statistical testing of Zahra and George's (2002) absorptive capacity construct to identify whether their dimensions find support in reality. We consider that the external environment encompasses both scientific and industrial sources of knowledge, which influence absorptive capacity.

Originality/value: Zahra and George's (2002) model initiated the debate of the absorptive capacity dimensions, and it is disseminated in literature. However, it is poorly tested. There is still a research gap related to the empirical validation stage of the absorptive capacity construct itself. Our research tries to decrease this gap, testing Zahra and George's (2002) absorptive capacity construct in a Brazilian company's context.

Design/methodology/approach: The research design was quantitative. A survey was applied to 402 industrial firms. We used multivariate statistical techniques and the structural models were tested by Partial Least Squares (PLS).

Findings: Zahra and George's (2002) construct of absorptive capacity was proved, and innovation, as well as the external sources types of knowledge, are related to it. The absorptive capacity is contingent on types of external knowledge.

KEYWORDS

Absorptive capacity. Innovation. External sources of knowledge. Scientific and industrial knowledge. Power sector.

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1. INTRODUCTION

Research on innovation has increased in the scholarly field of management studies which focus on learning processes and dynamic capabilities (Horvat, Dreher, & Som, 2019). These studies recognize firms like knowledge-creating entities, wherein the determinants of companies' boundaries (Tortoriello, 2015), their internal assets, and mechanisms influence innovation (Jeong-Duk & Ji-Hoon, 2017). The most usual statement is that innovation development is related to absorptive capacity (Acap) (Limaj & Bernroider, 2019).

The notion of absorptive capacity has been widespread since Cohen and Levinthal's papers (1990) when they had defined Acap as a firm's ability to absorb new external knowledge and apply it to commercial ends. Not only did this idea burst into the foreign literature, but it was also incorporated into the national academic environment (Rossetto, Carvalho, Ferreira, & Pery, 2019). The different research streams embrace the Acap concept (Song, Gnyawali, Srivastava, & Asgari, 2018). Consequently, contrasting theoretical absorptive capacity models have been competing among themselves for the best position of scientific rationality and accuracy (Maldonado, Salaiz, Vera, & Keller, 2018).

If, on the one hand, the model's varieties enriched the discussion, on the other hand, they did also create obstacles to accumulate knowledge in the academic domain (Volberda, Foss, & Lyles, 2010). Different theoretical models make it difficult to understand how literature evolves over time and what is more suitable to be applied in management settlements. In particular, two interdependent aspects lack a little understanding. One is related to the dimension or the processes that comprise the absorptive capacity models (Patterson & Ambrosini, 2015), whilst the other refers to how interchangeable their antecedents, mechanisms, and outcomes are (Chaudhary & Batra, 2018).

At least two pairs of authors represent the Acap dimension's controversy. One is Zahra and George (2002), and the other one is Todorova and Durisin (2007). The firsts authors, Zahra and George (2002), propose that absorptive capacity comprises the potential (Pacap) and realized (Racap) dimensions, while Todorova and Durisin (2007) reject this distinction. In a thought-provoking way, they advocate that such detachment is far-fetched. Against Zahra and George (2002), Todorova and Durisin (2007) stated that the transformation processes are an alternative to assimilation. It is because

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new cognitive structures appear only when ideas cannot be able to adjust to the existing ones. According to Todorova and Durisin (2007, p. 778), "firms transform their knowledge when knowledge cannot be assimilated". In such a view, the potential dimension is a conceptual mistake because when knowledge is absorbed, it is not transformed and vice-versa. Both of them are alternatives to each other.

Although this debate is well-recognized by the literature (Ebers & Maurer, 2014), hardly do we find studies that address empirical tests of absorptive capacity dimensions' validity (Chaudhary & Batra, 2018). Besides, Acap measurements do not take into account such different dimensions (Flatten, Engelen, Zahra, & Brettel, 2011). At the theoretical level, such ambiguities can lead to tautologies. Provided that the measurements of Acap remain fuzzy, we are not able to gauge it (Mikhailov & Reichert, 2019). Hence, at the practical level, we cannot either diagnose companies' absorptive capacity or come up with interventions to reach it. In this respect, Acap's theories become doubtful, and companies are vulnerable to manage their capabilities (Maldonado et al., 2018).

Taking these shortcomings into account, some scholars try to overcome them as well as advocate for the development of an integrated theoretical framework. Lane, Koka, and Pathak (2006) retrieve Acap's meaning by focusing on the construct itself. Yet, Volberda et al. (2010) point out how the underlying theories are embedded in Acap's organizational field. Despite such efforts to accumulate knowledge in Acap's theoretical domain, there is still a research gap related to the empirical validation of the absorptive capacity construct itself (Apriliyanti & Alon, 2017). Our research is an attempt to fulfill this gap.

We argue that the more one construct is validated, the more powerful it is. So, it is best to explain the reality. The literature goes forward as long as we increase the number of Acap's empirical tests. In this respect, we follow the empirical validating of Acap's models and their relation to the sources of knowledge. Particularly, we focus on the statistical testing of Zahra and George's Acap construct itself (2002) in order to identify whether their processes find support in reality innovation development and how they are measured. We choose Zahra and George's Acap view (2002) for three reasons. First, this model is a landmark in the discussion of absorptive capacity since they propose it as processes that mean the dynamic view (Horvat et al., 2019). Second, Zahra and George's ideas (2002) have inspired a vibrant research stream aiming to increase our understanding of how firms use external knowledge to innovate (Jiménez-Barrionuevo, García-Morales,

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& Molina, 2011). Third, there is a paucity of research that tests it in different institutional contexts (Adams, Flatten, Brinkmann, & Brettel, 2016).

Following this further, we consider that the external environment encompasses both scientific and industrial sources of knowledge, which influences absorptive capacity (Vega-Jurado, Gutiérrez-Gracia, & Fernández-de-Lucio, 2008). Notably, the absorptive capacity develops itself according to the type of knowledge (Murovec & Prodan, 2009). Our research questions are twofold as follow:

- To what extent is Zahra and George's (2002) construct of Acap valid in the context of the Brazilian power sector?
- Is this Acap related to external scientific and industrial knowledge?

To answer the above questions, we consider the empirical research foregoing the contributions from Zahra and George (2002), and we identify four hypotheses poorly testified in relation to the construct of Acap and external knowledge sources. The results show that there are specific dimensions of absorptive capacity that should be measured by differentiating Acap 's resources from mechanisms. Our main contribution is to show how the literature has evolved in order to develop an integrated background about absorptive capacity. We also show the adherence of Zahra and George's theoretical Acap construct (2002) to a specific economic sector as well as the influences of external sources of knowledge on it.

We organized our paper into six sections. After this introduction, the second section introduces the theoretical background. Firstly, we examine those studies that focus on a conceptual discussion as well as in those that validated measurements of the Acap construct. Secondly, based on this review, we pick up a theoretical framework of absorptive capacity that distinguishes potential from the realized absorptive capacity and identify their antecedents, mechanisms, and results. In addition, we focus on the sources of knowledge to be absorbed. In the third section, we detail the methodology as well as the test of hypotheses in the Brazilian power sector context. The fourth and the fifth sections present our data and discuss the results. Finally, we conclude and suggest new avenues for enriching the debate about Acap.

2. THEORETICAL OVERVIEW AND HYPOTHESES

Knowledge has been considered as one of the most important resources in innovation. This simple, powerful idea comes from research, which

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suggests that innovation is related to organizational learning. In this regard, the concept of absorptive capacity stands out from the crowd (Apriliyanti & Alon, 2017). Cohen and Levinthal (1990) defined Acap as the ability of firms to recognize, assimilate and apply new external knowledge to commercial ends. They have compared this ability to the cognitive structure of individuals that underlies learning (Aribi & Dupoüet, 2015).

Learning performance is associated with what individuals already know. The higher the level of education, technical training, and experience acquired in a specific knowledge domain, the easier new knowledge will be assimilated and transformed (Tian & Soo, 2018). In other words, the more individuals know, the more they are prepared to absorb new knowledge. In that discussion, learning by doing is not a sufficient condition for creating something new (Aribi & Dupoüet, 2015). Relevant knowledge includes not only technical tasks but also relates to how individuals meet people and discover complementary new sources of information (Kim, Lee, & Kang, 2018). The prior organizational knowledge comes from their employees, and it is the first antecedent directly associated with the development of organizational absorptive capacity. The other antecedents are the research and development (R&D) ongoing activities (Cohen & Levinthal, 1990). Usually, these activities increase the experience of individuals to deal with technological development, launching new products, and applying for patents. Therefore, firms create new knowledge directly from their own R&D activities (Bagchi-Sen & Smith, 2014; Camisón & Forés, 2010). Here we have two aspects of absorptive capacity. The first is the workforce traits, and the second is the organizational structure.

Internal mechanisms have also influenced the organizational absorptive capacity. Generally, they care about communication structures (Ben-Menahem, Krogh, Erden, & Schneider, 2016). In order to develop organizational absorptive capacity, it is suggested that internal channels should capture and disseminate relevant information within the firm (Zhang, Zhao, & Lyles, 2018). Language and symbols have to be shared among individuals to ensure that knowledge is clearly distributed (Tian & Soo, 2018). Other important mechanisms are cross-functional interfaces (Robertson, Casali, & Jacobson, 2012), redundancy in people's expertise, and intensive communication across different organizational units (Ben-Menahem et al., 2016).

Therefore, Cohen and Levinthal (1990) have acknowledged the importance of two absorptive capacity antecedents (employee traits and R&D structure), and they have pointed out organizational practices which concern internal organizational mechanisms (internal channels and communi-

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cation). However, they did not go into them in any depth. They have narrowed absorptive capacity to R&D expenditures. Then, their perspective has been criticized because they focused on absorptive capacity as a static resource (Lane et al., 2006). This weakness has been overcome since Zahra and George (2002) proposed that absorptive capacity was a dynamic capability formed by two different dimensions: Pacap and Racap. These two distinct dimensions are complementary in that they inform a model of absorptive capacity, which, in turn, is described by four processes or capabilities (Zahra & George, 2002).

Pacap is seen as a rule and process of acquisition and assimilation of new external knowledge (Zahra & George, 2002). While the acquisition has a role in obtaining external critical information for operations, assimilation makes external knowledge understandable. After that, it needs to be transformed and exploited. Racap is another dimension, which entails transformation and exploitation processes. Nevertheless, the disentangling between Pacap and Racap has been theoretically criticized. For example, Todorova and Durisin (2007) suggest that assimilation and transformation are alternative processes. They argue that assimilation happens when new external knowledge is closer to the firm's cognitive frame. Yet, the transformation implies that new information does not suit existing knowledge. In such a case, the companies' knowledge frame should be altered.

Although this questioning is important, it should be taken cautiously. It is because both the arguments deal with different stances of absorptive capacities. While Todorova and Durisin (2007) highlight the degree of knowledge change and the combination of existing knowledge in relation to the new external knowledge, Zahra and George (2002) emphasize knowledge conversion. Transformation concerns about either adding or deleting existing knowledge as firms face new information. In this sense, the distinction between Pacap and Racap is conducive, as firms can understand complex problems but are not able to apply knowledge to innovation.

The literature shows that Zahra and George's idea (2002) was first tested by Jansen, Bosch, and Volberda (2005). They distinguished between Pacap and Racap by examining how organizational mechanisms affect each dimension (Jansen et al., 2005). They divided Acap's mechanisms into three types: coordination, systematization, and socialization. The first, coordination, enables knowledge exchange, *i.e.*, cross-function interfaces, participation in decision-making processes, and job rotation. The second provides program behavior such as formalization and routinization. Finally, the mechanism of socialization is defined as the density of linkages and shared social expe-

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riences. The authors propose that the coordination mechanisms improve Pacap while the other two are concerned with Racap. This idea may seem trivial nowadays. However, since Jansen et al. (2005), the distinction between Pacap and Racap remained poorly tested (Bagchi-Sen & Smith, 2014). These relationships mean that there are ties between Pacap and Racap. Pacap is an antecedent of Racap, and their associations should be explicitly assumed. Thus, we argue that the relation between Acap and Racap deserves further testing (Costa & Monteiro, 2018). Our first hypothesis is related to Zahra and George's model (2002), which pointed out the relation between Pacap and Racap.

- H1: Pacap is positively related to Racap.

Although they consider Acap to be a set of potential and realized dimensions, their model suggests that Racap is directly related to innovation, while Pacap is responsible for strategic choice. The subsets coexist, but a higher Pacap does not mean outcomes in terms of innovation. The experience and the external knowledge sources, as well as the search for knowledge, increase Pacap (Kim et al., 2018). Yet, experience with the search for knowledge is concerned with accumulated learning related to innovation activities. The idea is that the greater the experience with data collection, the better the new search and analysis (Jeong-Duk & Ji-Hoon, 2017).

The statistical tests have proved that interaction with external knowledge through R&D cooperation has a more positive impact at the level of Pacap than contracting. It is also demonstrated that the relationship of experience with the knowledge that was measured by non-expired patents also has a positive impact (Tortoriello, 2015). Provided that the firms recognize the importance of external knowledge, they will have some degree of Pacap which should be transformed to be applied (Fosfuri & Tribó, 2008).

Therefore, Pacap is an antecedent of Racap, which, in turn, mediates Pacap and innovation. This means that Pacap has no direct effects on the innovation's outcomes (Murovec & Prodan, 2009). Researchers have made explicit the importance of internal information flows for innovation activities (Jeong-Duk & Ji-Hoon, 2017). External knowledge follows innovation through Racap (Tortoriello, 2015). Theoretically, Racap is recognized as an important process to promote innovation (Arbussà & Coenders, 2007). However, the relationship between Racap and innovation is still poorly tested (Adams et al., 2016). Based on this line of reasoning, we retrieve Zahra and George's idea (2002), and we posit the second hypothesis.

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- H2: Racap is positively related to innovation.

The last two hypotheses are concerned with sources of knowledge and their relations to Acap. Each level of Acap identified by Zahra and George (2002) is associated with the type of knowledge to be absorbed (scientific or industrial) and their internal factors, respectively. Three internal factors were considered, namely, organizational knowledge (set of skills and experience of the firm), formalization (extent of procedures and rules that underpin organizational processes), and integration (practices to reduce barriers of information exchange) (Tortoriello, 2015). The results show that organizational knowledge, measured by education as well as by development activities of R&D, has a positive effect on both Pacap and Racap (Vega-Jurado et al., 2008). However, the educational level of the workforce is positively related to the acquisition and exploitation of scientific knowledge, but not to industrial knowledge.

It means that scientific knowledge requires higher technical capacities than industrial knowledge to develop absorptive capacity (Vega-Jurado et al., 2008). Similarly, R&D activities are more efficient if the knowledge is scientific, just to acquire and exploit it (Bagchi-Sen & Smith, 2014). We can say the same about formalization. It is positively associated with acquiring and exploiting scientific knowledge, but it is not significant for industrial knowledge (Vega-Jurado et al., 2008).

Absorptive capacity is composed of two-factor structures. One is science-push capacity, which is based on scientific information. The other one is market information, which is named demand-pull absorptive capacity (Bagchi-Sen & Smith, 2014). Both internal R&D and the training of personnel are positively related to industrial and scientific capacity. However, the importance of each one is different for demand-pull and science-push. For instance, training of personnel related to innovation projects is more important to demand-pull than to science-push. Similarly, cooperation is positively and significantly related to science-push, but not to demand-pull. The external sources of knowledge reframed the rules of Racap. Exploitation practices emerge for each type of knowledge. The source of external knowledge results in different types of innovation (product or processes). In this sense, firms with higher a Racap innovate more easily. We can conclude that the search for knowledge should take into account learning from either the market or the science (Kim et al., 2018). The literature shows that the sources of knowledge remain untested, mainly related to Racap. Therefore, we propose hypotheses 3a and 3b.

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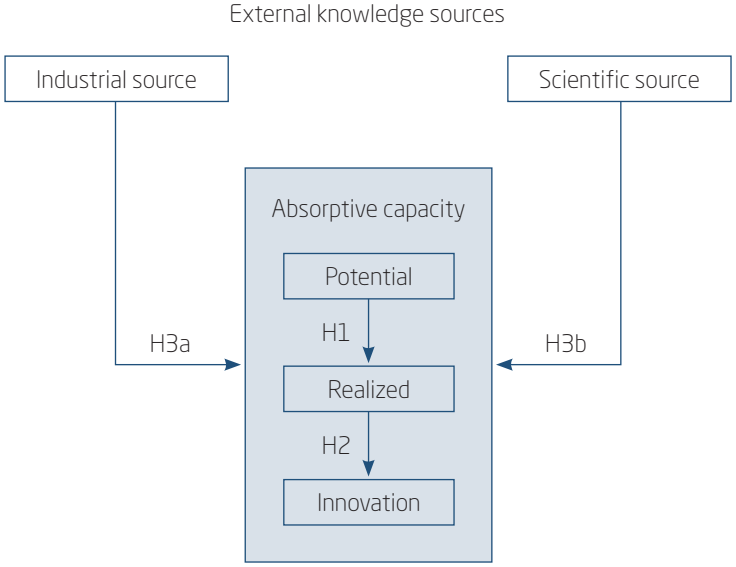
- H3a: Industrial knowledge is positively related to Racap.
- H3b: Scientific knowledge is positively related to Racap.

Figure 2.1 shows hypotheses integrated

Figure 2.1
HYPOTHESES



Source: Elaborated by the authors.

3. METHODOLOGY

The methodology details the sample, the variable definition, and the model analysis.

3.1 Sample

The population is 402 industrial suppliers of Companhia Energética de Minas Gerais (Cemig), which is a Brazilian holding company consisting of 143 companies and 17 consortia in the power sector. Data collection had the institutional support of Cemig, which sent an e-mail to each supplier requesting their cooperation to answer the online questionnaire. We had a non-probabilistic sample of 94 suppliers that represent a margin of error

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of 8.8%. Such response rate is higher than expected on similar research lines, which is surrounding 15% (Churchill & Iacobucci, 2002).

Regarding the size of the companies of the sample, 71.3% are small and medium-sized (20-499 employees), according to the classification of Instituto Brasileiro de Geografia e Estatística (IBGE, 2015). The large companies (over 500 employees) represent 18.1% of the sample, 9.6% are comprised of micro-enterprises (less than 20 employees), and 1% refers to missing data. We noticed that 22.3 % of the companies that provide for Cemig have been operating for between 11-15 years. 44 % of suppliers have more than 20 years of operation. The questionnaires were answered by executives who were responsible for the business innovation area.

3.2 Variable definition and measurement

We followed three steps in order to define the variables of the questionnaire. First, we carried out a bibliographic search in the main databases related to business management, such as Academic Search Premier (Ebsco), Business Abstracts with Full Text (Ebsco), Cambridge Journals On line, Emerald Fulltext, Oxford Journals (Oxford University Press), ScienceDirect (Elsevier), Scopus (Elsevier), and Web of Science. Such search comprised the period from 1989 to 2019 and focused on papers that validated scales to measure absorptive capacity itself. We found nine recognized papers that guide our variable definition: Camisón and Forés (2010), Daspit and D'Souza (2013), Fosfuri and Tribó (2008), Flatten et al. (2011), Jansen et al. (2005), Jiménez-Barrionuevo et al. (2011), Murovec and Prodan (2009), Tu, Vonderembse, Ragu-Nathan, and SharKey (2006), and Vega-Jurado et al. (2008).

In the second step, we listed all the tested hypotheses of those authors and made a comparison among their descriptions and operationalization. By means of content analysis, asking what this variable means in the Acap construct, we found 34 items with similar concepts. We also observed that the papers mixed and used antecedents and mechanisms to measure absorptive capacity interchangeably. The variables were unclear and conflated antecedents and mechanisms.

The third step was to make a semantic analysis of all variables to understand in which category they could be classified. We reached two contents. First, there were variables related to organizational resources, which are characterized as the organization's traits, *i.e.*, values, structure, and previous experience. Second, other variables are defined as activities that could be implemented in firms deliberately in order to leverage absorptive capacity as

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an interface between functions, training, and monitoring of knowledge. Thus, we classified the variables into organizational resources and mechanisms of absorptive capacity, both for potential absorptive capacity and realized capacity. Then, organizational resources refer to something that organizations have and mechanisms that imply what organizations do to carry out their activities (Figure 3.2.1).

We should reiterate that we choose studies that were focused on the empirical testing of absorptive capacity dimensions and our starting point is Zahra and George's model (2002) of four absorptive processes (acquisition, assimilation, transformation, and application). Regarding variables on external sources of knowledge (industrial and scientific) and innovation, they were withdrawn from those studies that discussed their consequences in Acap (*i.e.*, Murovec & Prodan, 2009; Vega-Jurado et al., 2008). Therefore, the latent construct of Acap and the sources of knowledge are composed of 35 selected variables empirically validated through previous studies. Such variables are reflective, which means they measure the reality of Acap and the external knowledge. The definition of the construct aims to capture what really exists. Those procedures are usually in the strategy research (Ringle, Sarstedt, & Straub, 2012) and imply that the causality goes from construct to variables. It means that any changes in the construct influence the indicators (Jarvis, MacKenzie, & Podsakoff, 2003).

In the fourth step, we have built the self-reported questionnaire (Figure 3.2.1), which included ten-point Likert-type response scales, ranging from number one, representing "low level", and number ten, representing "high level". We opted for the use of ten categories because such scales are better than others to carry out parametric tests (Jöreskog & Sörbom, 1999). To validate it, we conducted two pre-tests. In pre-test 1, the questionnaire was filled by three academic researchers that are familiar with innovation topics. In pre-test 2, we conducted a seminar with 20 specialists of the power sector with the aim to evaluate the adequacy of the questions in the context of the supplier firms. Their feedback provided detailed comments that led to the adequacy of the translation into Portuguese to ensure a closer relationship with the reality of the surveyed companies.

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Figure 3.2.1

VARIABLES OF THE ABSORPTIVE CAPACITY MODEL

Groups of variables	Variables names	Classification	Questionnaire Items
Pacap – Acquisition	Education level of the workforce	Resource	1. Employees hold adequate qualifications to work on innovation projects.
	Positive attitudes toward change	Resource	2. Your company highly values the attitudes that promote internal changes.
	Investment in R&D	Resource	3. Your company highly invests in research, development, and innovation activities.
	Cooperation in innovation with other firms	Resource	4. Your company usually collaborates with various institutions in innovation projects.
	Monitoring of knowledge	Mechanism	5. Your company systematically searches relevant external information for the business.
Pacap – Assimilation	Relevant prior knowledge of employees	Resource	6. Employees dominate technologies used by your company.
	Relevant prior knowledge of managers	Resource	7. Managers hold adequate knowledge to perform their duties.
	Interfaces between functions	Mechanism	8. Your company usually forms work teams involving people from different departments
	Social integration (formal and informal)	Mechanism	9. Your company usually promotes practices to integrate people from different departments.
	Involvement with external knowledge	Mechanism	10. The employees are always encouraged to participate in scientific events.
	External technology	Mechanism	11. Your company usually acquires technologies from other companies.

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Figure 3.2.1 (continuation)

VARIABLES OF THE ABSORPTIVE CAPACITY MODEL

Groups of variables	Variables names	Classification	Questionnaire Items
Racap – Transformation	Connectivity (trust, cooperation, interaction)	Resource	12. Employees of your company cooperate spontaneously.
	Training in innovation projects	Mechanism	13. Employees participate in training programs focused on facilitating innovation.
	Communication networks	Mechanism	14. In your company, information easily circulates through different hierarchical levels.
	Job/tasks rotation	Mechanism	15. Your company usually practices job and task rotation among employees.
	Internal information for innovation	Mechanism	16. Your company usually promotes the exchange of knowledge to innovate.
Racap – Exploitation	Existence of internal R&D	Resource	17. Your company has structured activities of research and development (R&D).
	Formalization	Mechanism	18. Routines and processes toward innovation are driven by clear and explicit rules.
	Exploration of new knowledge	Resource	19. Your company responds quickly to changes in the environment using new knowledge.
	Application of experience	Resource	20. In technology strategy, your company applies accumulated knowledge.
	Patent development	Resource	21. Your company has the capability to incorporate technological knowledge in patents.
	Technological proactivity	Resource	22. Your company seeks to innovate ahead of its competitors.

(continue)

Figure 3.2.1 (conclusion)

VARIABLES OF THE ABSORPTIVE CAPACITY MODEL

Groups of variables	Variables names	Classification	Questionnaire Items
External source of knowledge	Knowledge of research centers to innovate	Scientific	23. Your company often uses knowledge from research centers to innovate.
	Scientific conferences to innovate	Scientific	24. Your company often uses information from scientific conferences to innovate.
	Knowledge of suppliers to innovate	Industrial	25. Your company often uses the knowledge of its suppliers to innovate.
	Knowledge of customers to innovate	Industrial	26. Your company often uses the knowledge of its customers to innovate.
	Knowledge of competitors to innovate	Industrial	27. Your company often uses information about its competitors to innovate.
	Information of business meetings to innovate	Scientific	28. Your company often uses information acquired in business meetings to innovate.
	Information of patents database	Scientific	29. Your company often uses information acquired in patents database to innovate.
Innovation	Introduction of new product in the market	Innovation	30. Your company frequently introduces new or clearly improved products in the market.
	Introduction of new processes on the market	Innovation	31. Your company often adopts unpublished or clearly improved processes.
	Cooperation with other companies	Innovation	32. Your company often cooperates with the client to develop technologies.
	Interest in cooperating to develop technologies	Innovation	33. Your company is interested in developing technologies with clients.
	Obtaining technology licensing	Innovation	34. Your company has obtained technology licensing from another institution.

Source: Elaborated by the authors.

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3.3 Data analysis

We used the software SmartPLS 2.0 and Visual PLS 4.0 to test psychometric properties scales. The dimensionality was undertaken by exploratory factor analysis (EFA) with direct oblimin rotation (Hair, Black, Babin, & Anderson, 2010). Each subset of the variables was treated by separate factor analysis since the objective was to identify whether the predicted a priori dimensionality would be confirmed. If we had not done the factor analysis with all indicators and dimensions in a single EFA, we would not be following the best practices of EFA analysis (Tabachnick & Fidell, 2001).

To determine the number of dimensions, we applied the Kaiser Criterion, which indicates retaining factors with eigenvalues greater than one. The overall quality of the analysis was measured using the Kaiser-Meyer Olkin (KMO) and variance percentage. Both measures should be greater than 0.600 (Hair et al., 2010). The results of Bartlett's test of sphericity were significant. Therefore, the test of the null hypothesis was rejected. The correlation matrix of the set of variables is not of the identity type. As regards the quality of the indicators in each latent construct (set of variables), we used the analyses of the commonalities (h^2), which should be higher than 0.40.

The scale reliability was evaluated by the extent of random error. We tested the values of Cronbach's alpha (α) coefficient and the composite reliability (CR), whose values are higher than 0.70. Yet, the value of the average variance extracted (AVE) was higher than 0.40 (Figure 3.3.1). All of the values are considered very suitable (Hair et al., 2010).

Figure 3.3.1

AVERAGE VARIANCE EXTRACTED (AVE), COMPOSITE RELIABILITY (CR), CRONBACH'S ALPHA (α), AND DISCRIMINANT VALIDITY

Groups of variables	N.	1	2	3	4	5	6	7
Scientific knowledge	1	**0.75**	0.72	0.79	0.66	0.73	0.67	0.78
Industrial knowledge	2	0.51	**0.72**	0.74	0.71	0.77	0.73	0.71
Pacap – Acquisition	3	*0.62*	0.54	**0.62**	0.81	0.80	0.78	0.78
Pacap – Assimilation	4	0.44	0.50	*0.66*	**0.55**	0.77	0.79	0.67
Racap – Transformation	5	0.53	0.59	*0.65*	*0.59*	**0.61**	0.77	0.80

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Figure 3.3.1 (conclusion)

AVERAGE VARIANCE EXTRACTED (AVE), COMPOSITE RELIABILITY (CR), CRONBACH'S ALPHA (α), AND DISCRIMINANT VALIDITY

Groups of variables	N.	1	2	3	4	5	6	7
Racap – Exploitation	6	0.45	0.54	0.62	*0.62*	0.60	**0.66**	0.65
Innovation	7	*0.62*	0.50	0.61	0.45	*0.64*	0.42	**0.61**
AVE		0.75	0.72	0.62	0.55	0.61	0.66	0.61
CR		0.92	0.89	0.89	0.88	0.90	0.91	0.86
Cronbach's alpha (α)		0.89	0.81	0.85	0.84	0.87	0.87	0.78

The bold diagonal data show the AVE of the groups of variables. Above the diagonal are the correlations between the constructs. Below the diagonal are the squared correlations (R2).

Source: Elaborated by the authors.

Figure 3.3.1 shows the discriminant validity, which represents the scales that measure different latent constructs. For its evaluation, we used the method suggested by Fornell and Larcker (1981), wherein the values should be compared through the main diagonal of the matrix (values in bold). They represent the mean-variance extracted (R^2 obtained by means of the correlation of the estimated scores in the *Partial Least Squares* – PLS). When the value below the diagonal is greater than the AVE of its column or its line, the pair of constructs analyzed would show a discriminant validity violation. These cases are in italics and underlined in Figure 3.3.1.

We also applied the 95% confidence interval correlations (Netemeyer, Bearden, & Sharma, 2003). After performing such a procedure, no deviations of the discriminant validity were revealed for any variable since no upper value of the interval was greater than 1.00. This confirms the discriminant validity of the constructs. Therefore, the latent constructs tested represent distinct concepts, that is, they do not correlate with the other constructs (sets of indicators) measured in this research. The results of the validity of the scales undertaken with *structural equation modeling* (SEM) indicated that all variables also had convergent validity (see Figure 3.3.2).

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Figure 3.3.2

CONVERGENT VALIDITY

Relations	Load	Error	T values	Rel
Q01 ← Pacap – Acquisition	0.79	0.02	41.27	0.62
Q02 ← Pacap – Acquisition	0.68	0.03	24.34	0.47
Q03 ← Pacap – Acquisition	0.87	0.01	77.55	0.75
Q04 ← Pacap – Acquisition	0.78	0.02	32.00	0.61
Q05 ← Pacap – Acquisition	0.81	0.02	46.74	0.65
Q06 ← Pacap – Assimilation	0.69	0.03	21.22	0.48
Q07 ← Pacap – Assimilation	0.73	0.03	23.61	0.53
Q08 ← Pacap – Assimilation	0.80	0.03	31.23	0.64
Q09 ← Pacap – Assimilation	0.82	0.01	56.71	0.67
Q10 ← Pacap – Assimilation	0.79	0.02	39.99	0.63
Q11 ← Pacap – Assimilation	0.61	0.04	14.48	0.37
Q12 ← Racap – Transformation	0.76	0.03	27.54	0.57
Q13 ← Racap – Transformation	0.89	0.01	77.02	0.79
Q14 ← Racap – Transformation	0.79	0.02	39.82	0.63
Q15 ← Racap – Transformation	0.77	0.03	27.72	0.59
Q16 ← Racap – Transformation	0.84	0.01	56.82	0.71
Q17 ← Racap – Exploitation	0.78	0.02	41.64	0.60
Q18 ← Racap – Exploitation	0.82	0.03	28.54	0.67
Q19 ← Racap – Exploitation	0.84	0.01	68.50	0.71
Q20 ← Racap – Exploitation	0.80	0.02	37.75	0.63
Q21 ← Racap – Exploitation	0.66	0.04	17.10	0.44
Q22 ← Racap – Exploitation	0.78	0.02	41.75	0.61
Q23 ← Scientific knowledge	0.92	0.01	109.81	0.84
Q24 ← Scientific knowledge	0.92	0.01	113.89	0.84

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Figure 3.3.2 (conclusion)

CONVERGENT VALIDITY

Relations	Load	Error	T values	Rel
Q25 ← Industrial knowledge	0.85	0.02	48.17	0.73
Q26 ← Industrial knowledge	0.88	0.01	58.91	0.77
Q27 ← Industrial knowledge	0.82	0.02	37.00	0.67
Q28 ← Scientific knowledge	0.74	0.03	25.42	0.55
Q29 ← Scientific knowledge	0.88	0.01	74.48	0.78
Q30 ← Innovation	0.88	0.01	74.26	0.78
Q31 ← Innovation	0.90	0.01	123.36	0.81
Q32 ← Innovation	0.78	0.02	34.50	0.60
Q34 ← Innovation	0.70	0.03	23.47	0.50

a) Load is the standardized weight obtained for the complete sample; b) Error is the standard deviation of the estimate; c) T Value is the ratio of the weight not standardized by its standard error; d) Rel is the reliability of the indicators.

Source: Elaborated by the authors.

PLS tested the structural models. To evaluate the Acap measurement scale, we used the Goodness of Fit Index (GoF), which refers to the explanatory power of the model. The results of the structural model are shown in Figure 4.1. Figure 4.2 shows the standardized loads of the model and the percentage of the explained variance.

4. FINDINGS

The resulting GoF was 73. 02%. This means that the model reproduces about 73% of the total variability of the data. Such a score is considered satisfactory in relation to the 50% limit. Therefore, the relations between absorptive capacity dimensions, innovation, and sources of knowledge are confirmed for our sample.

To evaluate the scale dimensionality, we ran one EFA for each absorptive capacity dimension, one for scientific and industrial knowledge together, and another one for innovation. The predicted dimensionalities were confirmed.

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The results of the KMO test were positive for both in all the components of absorptive capacity (acquisition, assimilation, transformation, and exploitation), as well as in industrial and scientific knowledge and innovation. The measurement results were above the desired KMO 0.600 limits, and the results of Bartlett's test were significant, demonstrating that the matrix of correlations for each set of variables is not of the identity type. Therefore, the sphericity test rejected the null hypothesis that there is no correlation between the indicators of each block of variables.

The extraction method of the principal component analysis indicated one factor for each group of absorptive capacity variables. The four absorptive capacity dimensions together were composed of twenty-two variables. Regarding the distribution of variance among the extracted factors, we adopted the Kaiser criterion, which indicates retention of factors with eigenvalues greater than one (Hair et al., 2010). The results for each absorptive capacity component indicated the extraction of only one factor for each component, which confirms that the variables relate to the same latent construct and should not be grouped into separated sets (blocks of distinct variables). Further, industrial knowledge source and scientific knowledge source had two factors extracted, indicating four variables for the latter and three variables for the former. The innovation variables group had two factors extracted, resulting in four variables in one set and two variables in the other set.

The evaluation of the absorptive capacity measurement scale showed that the items proposed were satisfactory. The results for the quality of the indicators in each latent construct, verified by evaluating the commonalities (h^2), indicated that most of the indicators tested in each set of variables (the four components of absorptive capacity, industrial and scientific knowledge, and innovation) were above 0.40, except for item 11 "Your company usually acquires technologies from other companies", of the assimilation component, which obtained the result of 0.385. In this case, as the value was close to the recommended limit, and in the subsequent stages of the evaluation of convergent validity, it was made an objective assessment of the quality of each indicator, we preferred to keep this indicator. Thus, it was accepted that there was good adequacy of the indicators, and all were kept in the study. Figure 4.1 indicates high values of explained variance, structural weights, and factor loadings. The t values were above the critical point of 2.35 (assuming a one-tailed statistical significance of 1% with 148 degrees of freedom).

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Figure 4.1

HYPOTHESES RESULTS

Relations	Paw	Error	T Values
Structure weights			
Industrial knowledge → Realized Acap	0.305	0.040	7.545
Scientific knowledge → Realized Acap	0.113	0.034	3.350
Potential Acap → Realized Acap	0.553	0.039	14.253
Realized Acap → Innovation	0.396	0.054	7.340
Factor loadings			
Acquisition ← Pacap	0.945	0.006	166.007
Assimilation ← Pacap	0.952	0.004	230.361
Transformation ← Racap	0.939	0.006	162.025
Exploitation ← Racap	0.928	0.008	120.938
Q24 ← Scientific knowledge	0.920	0.007	125.951
Q25 ← Industrial knowledge	0.859	0.017	51.272
Q26 ← Industrial knowledge	0.884	0.014	65.593
Q27 ← Industrial knowledge	0.806	0.025	32.117
Q28 ← Scientific knowledge	0.744	0.033	22.912
Q29 ← Scientific knowledge	0.878	0.011	78.440
Q30 ← Innovation	0.881	0.012	72.755
Q31 ← Innovation	0.900	0.008	111.256
Q32 ← Innovation	0.777	0.022	35.547
Q34 ← Innovation	0.708	0.029	24.408

Source: Elaborated by the authors.

As shown in figures 4.1 and 4.2, the standardized loads of the model represented by PAW reveal a high impact of Pacap on Racap (PAW = 0.553). Thus, hypothesis 1 – "Pacap is positively related to Racap" – was confirmed.

The values shown also prove that Racap also has a high impact on innovation (0.396), although this result is lower than the impact of Pacap on Racap. Then, hypothesis 2 was confirmed ("Racap is positively related to innovation").

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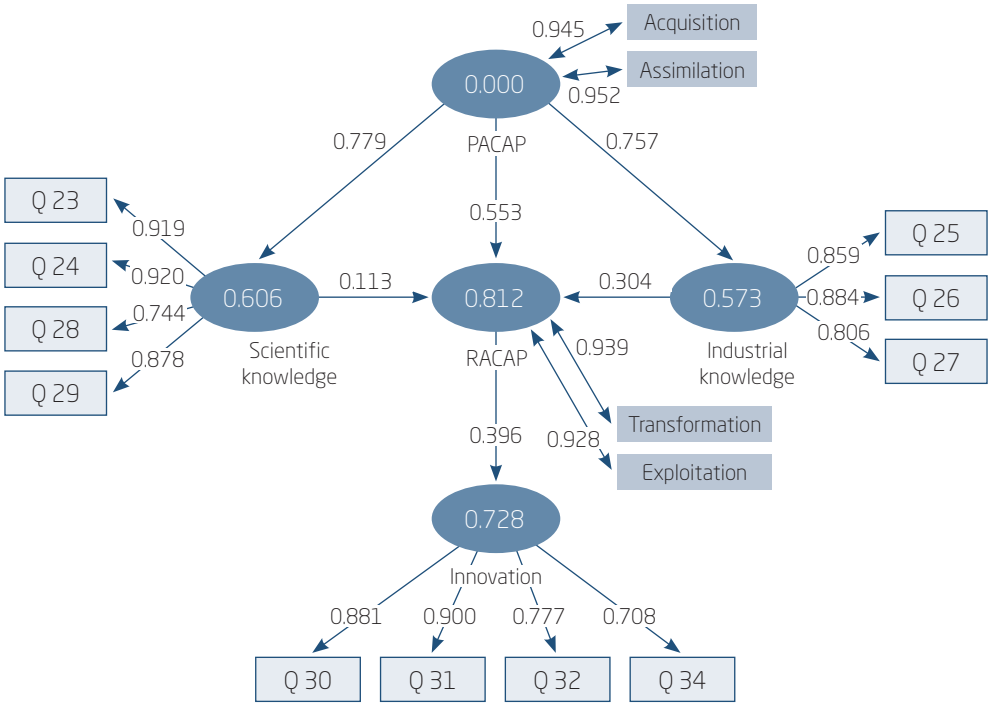
Figure 4.2

RESEARCH MODEL



The values next to the arrows represent standardized loads of the model. Values within the constructs show the percentage of explained variance (R^2). All weights are significant at 1% ($p < 0,01$).

Source: Elaborated by the authors.

Hypothesis H3a and H3b proposed that industrial knowledge and scientific knowledge are positively related to realized absorptive capacity. They were also confirmed, as the standardized loads of the model were considered high (industrial knowledge: 0.305; scientific knowledge: 0.113). The impact of the source of industrial knowledge on realized absorptive capacity is greater than the impact of the source of scientific knowledge (Figure 4.1). This result indicates that industrial sources of knowledge have a stronger influence over the ability of the organization to transform and exploit relevant knowledge than scientific knowledge sources. As we showed, the results of all hypotheses tests were positive for all relations tested, as the t values were above the critical point of 2.35 (considering a one-tailed statistical significance of 1% with 148 degrees of freedom).

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5. DISCUSSION

We empirically validated Zahra and George's (2002) construct of Acap and the relationship between Acap and the external types of knowledge. In line with past research, such findings suggest an integrated absorptive capacity construct. In doing so, we contributed to the theoretical and managerial management literature.

5.1 Theoretical contribution

Our first theoretical contribution is related to the absorptive capacity assumptions. In spite of their reification (Lane et al., 2006), we show a line of reasoning that converges the literature to focus on four processes that comprise absorptive capacity. We found support to Zahra and George's (2002) suggestion that absorptive capacity is composed of two distinct yet interrelated sets (Pacap and Racap). Our findings are consistent with conceptions that suggest that potential and realized absorptive capacity concern different realities (Camisón & Forés, 2010; Chaudhary & Batra, 2018). We posit that we need to include multi-item measurement scales in order to capture both potential and realized absorptive capacity. These findings were based on Camisón and Forés (2010) and refined by Flatten et al. (2011), who were ratified in our study. We show a cross-cultural validity of the theoretical construct of absorptive capacity to the extent it was tested in a power sector of the Brazilian context (Adams et al., 2016). We offer a literature synthesis of how to measure Acap; also, previous scales were refined since each component of Pacap and of Racap were classified as either organizational resources or mechanisms. Such classification is the second contribution of our study.

We argue that this distinction enables our understanding to go further about the nature of the absorptive capacity explanatory factors. For instance, while the resources refer to the state of the firm at a given moment in its history, the mechanisms are related to the activities and implemented practices or routines. Then, we suggest that measures of absorptive capacity should be treated, taking into account that history relates to the most enduring features of the organization. In turn, the mechanisms should be interpreted as actions seeking process changes. This distinction is useful because, in diagnoses of Acap, we can tell apart the factors or features which lead to innovation from the practices effectively applied.

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The third contribution is about the positive relationship between absorptive realized capacity and innovation. This finding supports the theoretical view that realized absorptive capacity is related to innovation (Zahra & George, 2002). However, Acap is contingent on the sources of external knowledge. This point is the fourth contribution of our study.

Our research shows that types of external knowledge (industrial or scientific) influence the development of specific companies' abilities in relation to acquisition, assimilation, transformation, and application of external knowledge (Vega-Jurado et al., 2008). It means that there are differences among absorptive capacity, according to the sources of knowledge. Therefore, we agree that it is necessary to capture the components that distinguish demand-pull and science-push absorptive capacities (Murovec & Prodan, 2009), deepening the conceptual discussion about the external sources of knowledge.

5.2 Managerial contribution

We have a dominant management discourse that values a firm's ability to innovate (Maldonado et al., 2018). Nevertheless, we do not know what indicators are validated in the literature and which can be applied right now to evaluate such capacity. There are different models of Acap as well as their measurement (Adams et al., 2016). Our research contributes to managerial sets insofar it identifies the hypotheses validated in the literature as well as it shows how that measurement is classified.

Therefore, we were able to distinguish resources versus practices that might be applied to innovation diagnostic tools. In our view, this can be used to devise strategies for promoting the innovation process (Horvat et al., 2019). We state that the assessment of the Acap of companies is the first step in proposing practices for organizational intervention. We should know how to use the literature for practical purposes. Accordingly, our paper offers a compass that can help managers to know how they can start to diagnose Acap, splitting resources from practices.

5.3 Limitations

Despite our contributions, the research has some limitations. It focuses on suppliers of a specific company, and the data does not fit a normal distribution. Thus, caution is needed to generalize the results of the research. Furthermore, the questionnaires were self-reported, and the direct measure-

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ments were non-existent. This might have been produced variance biases (Jarvis et al., 2003). An unobtrusive research should be more adequate. However, it is not trivial to get raw information from companies. In this sense, the research benefits from the unusual support of Cemig and its effort to engage the suppliers in the survey.

We also did not use typical control variables in our analysis because our sample was homogeneous. Thus, problems concerning endogeneity should not be totally discarded. To minimize concerns about this issue, it is important to say that our data is not temporal. Finally, we add the limitations of the cross-sectional studies, which lack precision in measuring subtle qualities. Consequently, studies that embrace a more longitudinal design could be able to capture each component of Acap.

6. FINAL CONSIDERATIONS AND SUGGESTION FOR FUTURE RESEARCH

Our results find the support of the relations between Acap, innovation, and external sources of knowledge. On the one hand, our research confirms previous ideas that absorptive capacity comprises both potential and realized dimensions. On the other hand, it draws attention to the roles of external knowledge on innovation. These findings open new research avenues. One is to compare the results of innovation and types of external knowledge. The other one refers to comparisons between the role of the resources and the mechanisms in the process of absorptive capacity (acquisition, assimilation, transformation, and application).

The future research questions can be some of these:

- To what extent is performance in innovation influenced by types of external knowledge to be absorbed?
- What type of external knowledge brings more returns regarding the innovation results?
- Do the resources and the mechanisms that developed absorptive capacity differ according to the types of source of knowledge companies search for?
- What are their impacts on innovation?

We also suggest that the theoretical model of Acap should be tested in different countries and diverse economic sectors to cast light on how firms embedded in different institutional contexts can improve their capabilities.

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CAPACIDADE ABSORTIVA, INOVAÇÃO E FONTES EXTERNAS DE CONHECIMENTO: O SETOR ELÉTRICO BRASILEIRO

RESUMO

Objetivo: Este artigo discute a relação entre capacidade absortiva, fontes externas de conhecimento e inovação no contexto do setor elétrico. Essa discussão guia-se pelo debate teórico sobre as dimensões da capacidade absortiva. Testou-se o construto da capacidade absortiva de Zahra e George (2002), identificando se suas dimensões encontravam suporte na realidade. Consideraram-se também as influências das fontes externas de conhecimentos científico e industrial.

Originalidade/valor: O construto de Zahra e George (2002) iniciou o debate sobre as dimensões da capacidade absortiva e se disseminou na literatura. Entretanto, tal modelo tem sido pouco testado, permanecendo o *gap* de pesquisa relativo à validação do construto. Esta pesquisa contribuiu para diminuir esse *gap*, testando o construto de Zahra e George no contexto de uma empresa brasileira.

Design/metodologia/abordagem: A metodologia da pesquisa foi quantitativa, em que se aplicou um questionário a um universo de 402 empresas industriais. Utilizaram-se técnicas estatísticas multivariadas com o modelo estrutural testado pelo *Partial Least Squares* (PLS).

Resultados: O construto de Zahra e George (2002) foi respaldado, assim como as relações dos tipos das fontes de conhecimentos relacionadas. Concluiu-se que a capacidade absortiva é contingente aos tipos de conhecimento externo.

PALAVRAS-CHAVE

Capacidade absortiva. Inovação. Fontes externas de conhecimento. Conhecimentos científico e industrial. Setor elétrico.

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