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Assessment of absorptive capacity: a study in Brazilian manufactures of solar panels

Mensuração da capacidade absortiva: um estudo nas empresas brasileiras fabricantes de coletores solares

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Abstract: This article aims to assess the Brazilian manufacturers of solar panels based on their absorptive capacity (AC) of new technological knowledge and innovation resulting from the assimilation and transformation of this same knowledge, in order to manufacture air conditioning equipment sourcing energy from high performance solar panels. It is an article of great relevance, given the current situation of Brazilian electricity sector and the need for energy efficiency and the use of alternative sources of energy, specifically solar. The theoretical framework addresses the concepts on AC, as well as how to evaluate and measure them. A quantitative research was performed in order to evaluate the AC of these manufacturers, applying a diagnostic tool adapted to the reality of Brazilian companies. The results of this research concluded that these companies do not yet have mature AC for developing an innovative product, showing a higher tendency for the potential dimension of AC when compared to the realized dimension. This finding corroborates the prospects for future research and development projects if the surveyed companies strengthen their ability to promote interactions with other organizations devoted to that same purpose.

Keywords: Absorptive capacity; Innovation; Solar panels; Electricity sector.

Resumo: *Este artigo objetiva avaliar as empresas brasileiras fabricantes de coletores solares sob a óptica de sua capacidade absortiva (CA) de novo conhecimento tecnológico e da inovação decorrente da assimilação e da transformação desse conhecimento, com vistas à fabricação de equipamento de condicionamento de ar acionado por energia gerada por coletores solares de alta capacidade. Trata-se de artigo de importância relevante dada a atual conjuntura do setor elétrico brasileiro e diante da necessidade de se buscarem alternativas que combinem soluções de eficiência energética e utilização de energia oriunda de novas fontes, especificamente a solar. O referencial teórico aborda os conceitos de CA, bem como as formas de avaliá-la e mensurá-la. Para concretizar a avaliação da CA desses fabricantes, realizou-se uma pesquisa quantitativa, aplicando-se um instrumento de diagnóstico adaptado à realidade das empresas fabricantes de coletores solares instaladas no Brasil. Conclui-se, a partir dos resultados dessa pesquisa, que essas empresas ainda não possuem CA madura para o desenvolvimento de um produto inovador, apresentando uma maior tendência para a dimensão potencial da CA, quando comparada com a dimensão realizada. Essa constatação corrobora as perspectivas de desenvolvimento de projetos de pesquisa e desenvolvimento (P&D) futuros, se fortalecida a aptidão das empresas respondentes na promoção de interações com outras organizações voltadas a esse propósito.*

Palavras-chave: *Capacidade absortiva; Inovação; Coletores solares; Setor elétrico.*

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1 Introduction

The global energy matrix has been predominantly composed of thermoelectric sources, namely: 36% of oil derivatives, 35% of natural gas, 20% of coal, 9% of renewable energy and 8% of nuclear energy, according to the US Energy Information Administration (EIA, 2013). With regard to the portion of renewable energy, its production is distributed as follows: 35% of hydropower, 22% of wood, 21% of biofuels, 13% of wind power, 5% of biomass residues, 2% of geothermal and only 1% of solar power (EIA, 2013).

The data released by the EIA (2013) demonstrates that solar energy is still not expressive in the power generation, thus representing a field to be observed by academics and industry.

The exaggerated use of polluting thermal sources, the impacts of flooding caused by large water reservoirs from hydroelectric power plants and the increasing environmental awareness triggered a broad debate on the diversification of energy sources and the adoption of renewable energy sources. In Brazil, as in many other countries, the alternative energy sources are conquering space in the composition of the national energy matrix because of the adoption of Government's incentive policies, such as the Incentive Program for Alternative Sources of Electricity (PROINFA, 2015), the main incentive for this source of energy, whose objective was to increase the contribution of wind power, small hydroelectric plants (SHPs) and biomass residues for producing electricity, through the implementation of 144 plants, totaling 3,299.40 MW of capacity, with 1,191.24 MW coming from 63 small hydroelectric plants, 1,422.92 MW from 54 wind power plants, and 685.24 MW from 27 biomass-based plants (EPE, 2012) .

According to data from the International Energy Agency – IEA (2005) in this report World Energy Technology Outlook - WETO, world's electricity supply that comes from renewable sources reported significant growth. When comparing the results of 2010 to 2000, it is possible to see a growth of 1,200%, 509% and 136% for solar and wind power and small hydroelectric plants, respectively. There are projections for 2020 from this same agency indicating there will be sustainable growth of 183% (solar power), 292% (wind power) and 121% (SHPs), which will still be rising until 2030, when they are set to be producing 51 TWh (Terawatt hour) (solar power), 544 TWh (wind power) and 258 TWh (SHPs), values that represent a growth of 116%, 159% and 105%, respectively (IEA, 2005).

According to data disclosed by the Energy Research Company (EPE), linked to the Ministry of Mines and Energy (MME) and responsible for the analysis and energy planning in Brazil, 57.6% of the energy supply is composed by non-renewable sources and 42.4% by renewable sources. Wind and solar power and other renewable sources only represent 4.1% of the total (EPE, 2012).

According to the National Energy Plan - PNE 2030, a document prepared by the EPE, the prospects for expansion of electricity supply between 2005 and 2030 are supposed to increase 0.8% for wind power plants in the national energy matrix. To achieve this value, the PNE 2030 proposes to examine support mechanisms for renewable sources in order to increase their stake to more than 4% of domestic supply of electricity (EPE, 2012).

According to data from 2011, of the Solar Heat Worldwide 2013, released by EIA (2013), Brazil is the 5th largest country in solar power capacity, with nearly 5,000 megawatts thermal (MWth) installed. The development and expansion of this segment therefore require innovation. According to Rocha (2003) and Ziviani (2012), the last decades have been relevant for the technological innovation process.

Machado & Fracasso (2012) state that the economic context of high competitiveness leads organizations to depend on their own capacity for innovating faster than competitors. Investing in innovation in a growing unexplored sector such as the solar power is to take a step forward.

According to Marion & Sonaglia (2010), technological innovation requires a set of internal factors for absorption and enhancement of technologies. Companies need to adapt themselves not only to develop innovative products but also to absorb new technologies through the acquisition of various skills. Furthermore, recognition of the skills available for implementation as technological innovation is indispensable.

The absorptive capacity (AC) is defined by Cohen & Levinthal (1990) as the ability to evaluate the external knowledge, assimilate and apply the absorbed knowledge, transforming them into products or services. These are aspects that guide the purpose of this article, which is structured as follows: the introductory chapter presents the setting, context and purpose of this research. Following, the main concepts on AC are described and an evaluation model is proposed. The fourth chapter presents the methodology used and the last chapters present the results and the main contributions of the study.

The concept of what absorptive capacity is important for understanding knowledge transference between organizations and learning processes, which support the industry's capability of launching innovative products. This research was thus performed for discovering the technological absorptive capacity of Brazilian companies that produce solar panels, in order to industrialize innovative products.

The decisive factor that justifies and guides the development of this research is the increasing share of solar power in the national energy matrix,

strengthened by the expansion of activities performed by energy companies through government policies to encourage the use of alternative sources of energy and innovation of products.

The study seeks to remedy shortcomings in applying the concepts of absorptive capacity, to therefore implement innovative products to be manufactured by Brazilian companies of solar panels. The theoretical contribution brought by this research is the development of a specific evaluation model for assessing absorptive capacity of companies that manufacture solar panels. Regarding the practicalities, a partnership with companies of the electricity sector operating in Brazil may be offered to those companies best ranked in an assessment to be made by this study, in order to develop an air conditioning equipment prototype whose energy supply comes from solar panels of high performance. In this sense, the study shows relevant purposes, given the possibility of immediate applicability and, in the medium term, the commercialization of an innovative product in the Brazilian market.

2 Main concepts about absorptive capacity

The knowledge, as a primary asset for the development of an organization, is considered one of the most important resources for innovation and hence its consequent competitive advantage (Cruz, 2011). The concept of absorptive capacity is based on this assumption: organizational absorptive capacity is the organization's ability to evaluate the relevance of new external knowledge, assimilating and applying them for commercial purposes (Cohen & Levinthal, 1990).

Cohen & Levinthal (1990) were the first to approach consistently the concept of absorptive capacity, although the term had been used a few years earlier by other authors, such as Kedia & Bhagat (1988), who addressed the technology transfer between different organizational cultures.

According to Cohen & Levinthal (1990) the absorptive capacity is the company's ability to acknowledge the value of an external knowledge, assimilating and applying it strategically for commercial purposes. According to the authors, companies in this field are proactive or reactive. Proactive companies have the highest level of absorptive capacity. Reactive companies have little absorptive capacity.

Cohen & Levinthal (1990) propose a model composed by three dimensions: acknowledgement of the value of information, assimilation of that knowledge by the company and its application in order to generate innovation. According to the authors, the ability to absorb new information will depend on the level of prior knowledge related to basic skills and learning experiences, as well as the acknowledgement of the value of a new information, as shown in Figure 1.

Cohen & Levinthal (1990) propose two organizational background constituting the absorptive capacity: prior knowledge and internal R&D. Prior knowledge comprises individual and collective essential capabilities for absorptive capacity and is defined as the accumulation of diverse knowledge of a company throughout its existence, such as the characteristics of its workforce and activities related to innovation (Machado & Fracasso, 2012; Cruz, 2011).

Cohen & Levinthal (1990) understand that prior knowledge includes workforce characteristics and innovative practices. The workforce characteristics deal with the qualifications and expertise of the staff and experience in previous cases, where the individual learning occurs with the association between new learning and previous knowledge (Cruz, 2011).

On the other hand, as a second antecedent of absorptive capacity, internal R&D contributes to the development of technologies that allow the use of prior knowledge for launching new products or processes (Cruz, 2011). Cohen & Levinthal (1990) draw attention to internal R&D, as it contributes to technology development in the company's area of operation.

Other authors have explored the concept in addition to Cohen and Levinthal (1990), such as Lane & Lubatkin (1998), Dyer & Singh (1998), Zahra & George (2002) and Todorova & Durisin (2007), among others. These authors did not actually expand Cohen & Levinthal's concept, but sought to transform the exclusive focus on R&D of the Absorptive Capacity into a more dynamic approach (Machado & Fracasso, 2012).

The model proposed by Lane & Lubatkin (1998) was the first to extend Cohen and Levinthal's concept (1990) as it proposes three common elements in view of the technology transfer and the success of the inter-organizational relationship, as illustrated by Figure 2.

Dyer & Singh (1998) define absorptive capacity as a process of interactive exchanges that results in relational rents, as shown in Figure 3. Relational rent is the income generated by the interaction and collaboration between enterprises.

From Zahra & George's (2002) perspective, in which the absorptive capacity is defined as a multidimensional construct consisting of a set of organizational routines and processes (Machado & Fracasso, 2012). The model developed by Zahra &

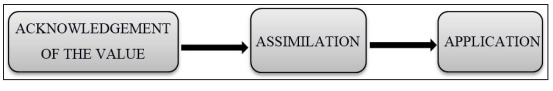

Figure 1. Model of absorptive capacity according to Cohen & Levinthal (1990).

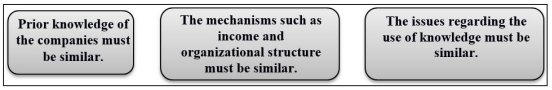

Figure 2. Model of absorptive capacity according to Lane & Lubatkin (1998).

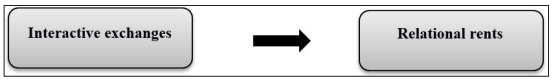

Figure 3. Model of absorptive capacity according to Dyer & Singh (1998).

George (2002) expanded the concepts of Cohen & Levinthal (1990), splitting the absorptive capacity into two conceptual dimensions: potential and realized, emphasizing that, after acknowledgement of the important information, it needs to be incorporated and transformed and may therefore be exploited.

It is noteworthy that, according to this theoretical model, the capabilities are dynamic, that is, they are interactive, changeable when necessary for contributing to the change and evolution of the organization over time. The theoretical model of Zahra & George (2002) brought the concept of "knowledge transformation", which states that knowledge is not static, changing and expanding when needed (Cruz, 2011).

Zahra & George (2002, p. 186) conceptualize the absorptive capacity as "[...] a group of organizational routines and processes by which firms acquire, assimilate, transform and exploit knowledge in order to produce a dynamic organizational capability".

The model of Todorova & Durisin (2007) proposes changes to Zahra & George's model (2002) and suggests a return to the original model of Cohen & Levinthal (1990) with a new interpretation to the scale "transformation", in which transformation is not a consequence of the assimilation, but an alternative process thereof, because during the implementation of a new knowledge the company can return to its previous knowledge structures, as illustrated by Figure 4.

According to Cruz (2011), the two dimensions of absorptive capacity (potential and realized) are actually made up of four components: acquisition, assimilation, transformation and exploitation, which are scientific and industrial capabilities beyond the innovation results. The most recent discussions regarding the components of the absorptive capacity were made by Vega-Jurado et al. (2008) and Murovec & Prodan (2009). According to the authors, absorptive capacity is divided into industrial and scientific. Industrial absorptive capacity would be the acquisition of knowledge from industrial partners such as customers, competitors and suppliers, and in the case of science absorptive capacity, knowledge would be acquired

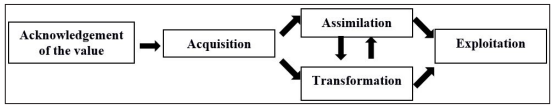

Figure 4. Model of absorptive capacity according to Todorova & Durisin (2007).

from universities, technology institutes and public and private research centers.

This study adopts the concept of Cohen & Levinthal (1990) for guidance, when it states that absorptive capacity is the "[...] collaborative ability of the firm to recognize the value of a new external knowledge, assimilating and applying it for commercial purposes". The adoption of this concept is justified by its adherence to the research objectives, which aim to assess the absorptive capacity of manufacturers of solar panels, in addition to catch sight of the manufacturing of an innovative product made by the best rated companies, in partnership with other energy companies, to implement a joint venture for commercial purposes.

In this sense, and in the light of the central concept proposed by Cohen & Levinthal (1990), a conceptual model for assessing the absorptive capacity of manufacturers of solar panels was prepared, based on the models and contributions of Cruz (2011), Murovec & Prodan (2009), Todorova & Durisin (2007), Zahra & George (2002), Lane & Lubatkin (1998), Dyer & Singh (1998) and Cohen & Levinthal (1990). The model is shown in the following subsection.

3 Proposal of a conceptual model for assessing the absorptive capacity

This study proposes the development of a conceptual model to be applied to manufacturers of solar collectors in order to assess their AC. The model was developed in the light of the studies of Cruz (2011) and adapted from Cohen & Levinthal (1990), and features a four-component construct: acquisition, assimilation, transformation and exploitation of external knowledge (Zahra & George, 2002), as well as the influence of external and internal environments.

Figure 5 shows the conceptual model proposed for assessing the absorptive capacity, which brings the interaction between the four components at the center: acquisition, assimilation, transformation and exploitation, while external and internal environments surround that core with their respective sources of knowledge.

Initially, the ambience favorable to the AC was created, based on the view of the company. As proposed by the model of Dyer & Singh (1998), this ambience is characterized by the interaction between external and internal environments. According to these same authors and in accordance with the contributions of

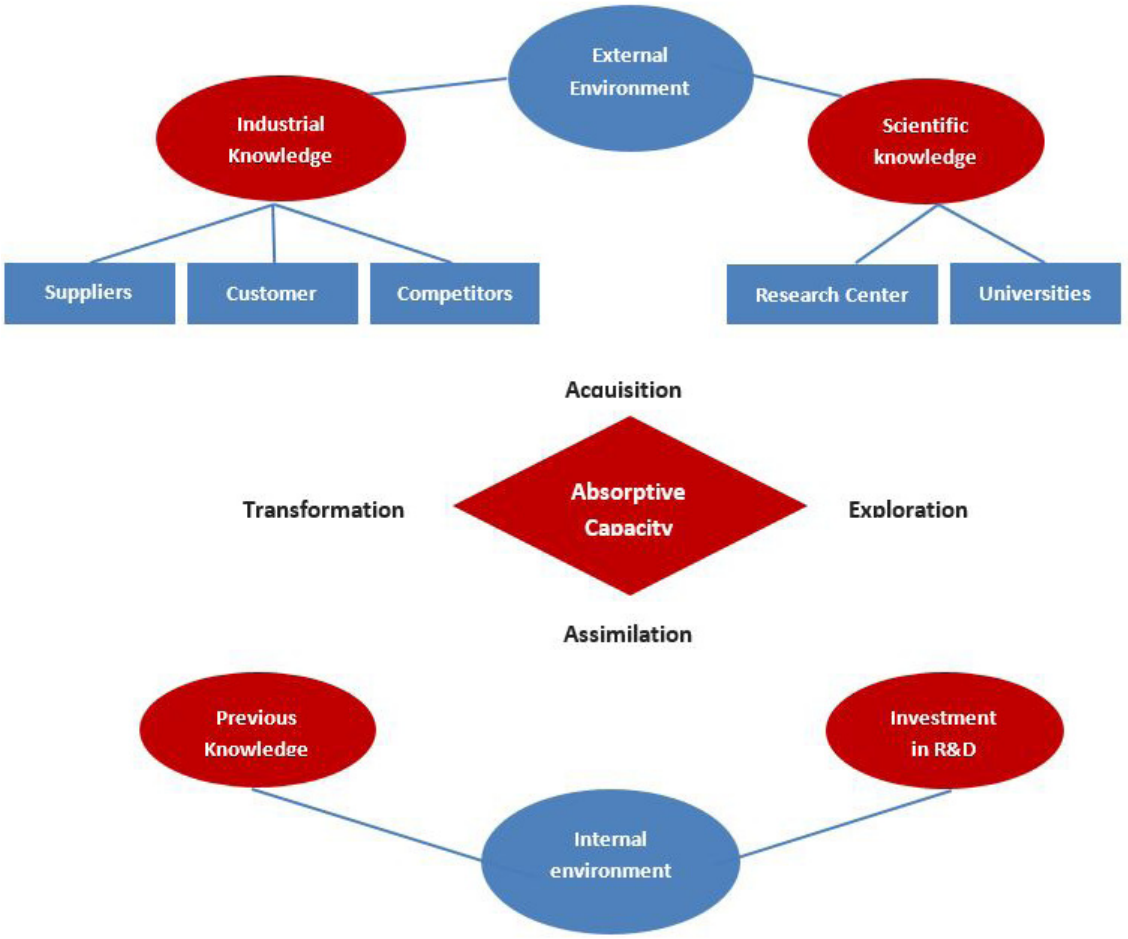

Figure 5. Conceptual Model for Assessing the Absorptive Capacity. Source: Adapted from contributions of Cruz (2011), Murovec & Prodan (2009), Todorova & Durisin (2007), Zahra & George (2002), Lane & Lubatkin (1998), Dyer & Singh (1998) and Cohen & Levinthal (1990).

Murovec & Prodan (2009), the external environment is composed of two sources, one being industry knowledge and the second being scientific knowledge. For the first source, interaction of the company with its stakeholders (suppliers, customers, competitors) is essential for building its knowledge base. In addition, the second external source of knowledge takes place within the academic contribution and participation, building partnerships and interactive exchanges with universities and research centers.

The very internal environment of the organization is the second component of the ambiance, consisting of: prior knowledge, characterized by professional experience, academic background and values accumulated by employees at all hierarchical levels of the company, as the model of Lane & Lubatkin (1998), and also investments in R&D, whose activities, as Cohen & Levinthal (1990), enhance the experiences of the staff in the development of technology geared to corporate business.

The four components of AC are at the center of the proposed model, as shown in Figure 2: acquisition, assimilation, transformation and exploitation, meeting the standards proposed by the model of Todorova & Durisin (2007), which deals with the AC from the perspective of interaction between these four components.

In view of the conceptual model of Figure 2 and using primarily the two dimensions proposed by Zahra & George (2002) (potential AC and realized AC) and the contributions of Cruz (2011), who links the main constructs for assessing the AC of the organizations, Tables 1 and 2 were constructed, presenting two components for each dimension. The main constructs proposed by Cruz (2011) and the questions used in the survey are associated with each one of these components.

4 Methodological procedures

A quantitative descriptive survey was used as a research strategy for accomplishing the assessment of AC of the manufacturers of solar panels, with the

Table 1. Constructs for assessing the potential absorptive capacity.

Dimension	Component	Constructs	Propositions
Potential.	1) Acquisition.	a) Positive attitudes toward changing.	1.a) The company highly values the attitudes that promote internal changes.
		b) Cooperation for innovating.	1.b) The company collaborates with different institutions in innovation projects.
		c) Monitoring the knowledge.	1.c) The company constantly seeks relevant external information for its business.
		d) Staff qualification.	1.d) Employees possess proper qualification to work in innovation projects.
		e) Spending on R&D.	1.e) The company heavily invests in research and development activities.
	2) Assimilation.	a) Industry knowledge.	2.a) The company often uses knowledge or technology developed by other companies.
		b) Prior knowledge of the employees.	2.b) Employees mastered the technologies used by the company.
		c) Prior knowledge of the managers.	2.c) Managers have appropriate knowledge for the development of their functions.
		d) Engagement in external environment and knowledge.	2.d) Employees are often encouraged to participate in scientific events (conferences, seminars, courses).
		e) Multidisciplinary teams.	2.e) The company groups multidisciplinary work teams from different areas and or branch offices.
		f) Social integration within the company.	2.f) The company promotes integration and sharing of knowledge between different sectors.

Source: Cruz (2011).

application of a diagnostic tool adapted to the reality of those companies.

The questionnaire was structured in two parts, the first being the identification of the surveyed companies and the second consisting of 32 questions, divided into three groups, using the Likert five-point scale (1 = lowest level and 5 = highest level). The choice of that scale allows reconciling the use of the questionnaire proposed by Cruz (2011), which was adapted to the particularities of the manufacturers of solar panels and used in this study. Furthermore, the use of another range of points would increase the complexity of choice and discrimination between each answer option, hindering the obtaining of a greater amount of valid and answered questionnaires.

This research was performed with forty (40) manufacturers of solar panels that are headquartered in Brazil. The research only addresses those companies, assessing their ability to absorb technology for the nationwide production of an innovative product, therefore justifying the choice for that target population.

According to the Brazilian Association of Refrigeration, Air Conditioning and Heating (ABRAVA, 2014) there are approximately 200 companies in the sector of solar panels distributed mainly in the South and Southeast of Brazil. Among them, only 40 are manufacturers. The others are consultants, installers, distribution centers, trade representatives, among others. Since the research is focused on manufacturers of solar panels, questionnaires were sent to all 40 domestic manufacturers, in view of the greatest possible amount of respondents. Of this total, 20 companies responded, characterizing a non-probability sample of 50% of the group studied.

This research used statistical techniques for processing and analyzing data, culminating in the creation of a ranking that places the companies according to their AC. It was elaborated based on the results of descriptive and multivariate statistical analysis, determining an overall average of each company, for all the surveyed constructs, after removal of non-significant items according to confirmatory factor analysis.

Table 2. Constructs for assessing the realized absorptive capacity.

Dimension	Component	Constructs	Propositions
Realized.	3) Transformation.	a) Internal sources of information for innovation.	3.a) The company promotes exchange of experience and knowledge between its sectors.
		b) Communication networks.	3.b) Information move with ease and agility among the hierarchical levels of the company.
		c) Turnover of functions and tasks.	3.c) The company usually practice the turnover of roles and tasks among employees.
		d) Training of staff related to innovation projects.	3.d) Employees participate in training to facilitate innovation in the company.
		e) Cooperation and integration.	3.e) There is spontaneous cooperation among the employees at all levels.
	4) Exploitation.	a) Using previous experience.	4.a) The company applies its accumulated knowledge to develop technology strategy.
		b) Development of patents.	4.b) The company is capable of incorporating technological knowledge in patents.
		c) Internal R&D.	4.c) The company has structured research and development (R&D) activities.
		d) Exploitation of new knowledge.	4.d) The company responds nimbly to business changes using new knowledge.
		e) Elaborating routines and processes.	4.e) Procedures focused on innovation are driven by clear rules disseminated in the company.
		f) Technological proactivity.	4.f) The company seeks to innovate ahead of its competitors.

Source: Cruz (2011).

The chosen technique is based on descriptive statistics with the use of position measurements (average, minimum and maximum), dispersion (standard deviation and coefficient of variation) multivariate statistical analysis through a confirmatory factor analysis (Bartlett's test of sphericity and Kaiser-Meyer-Olkin KMO measure of sampling adequacy), statistical validation of Cronbach's alpha (α), which tests the reliability of the items in terms of their correlation.

5 Presentation, discussion and analysis of results

This section presents and discusses the data collected in the survey. The text was divided into subsections for better understanding.

5.1 Profile of the surveyed companies

The concentration of companies can be seen in the Southeastern region (90% of the sample), most of them located in the state of Sao Paulo (55% of valid responses) followed by Minas Gerais (35% of respondents), confirming manufacturers of solar panels usually settle in the most developed industrial centers, where market conditions are favorable to the growth and consolidation of that sector.

The characterization of the size of the companies followed the criterion proposed by the Brazilian Institute of Geography and Statistics (IBGE, 2001) for the industrial segment, classifying them based on the number of employees. This criterion showed that none of the participating companies is large; small and medium-sized companies compose 85% of the sample; and 15% of the sample is made up by microenterprises. This result shows the sector is still consolidating itself and has growth prospects, which is justified by the increasing diffusion of the use of solar panels in the country.

Regarding the legal constitution of the manufacturers of solar panels, the research observed the prevalence of domestic capital in 95% of valid responses.

5.2 Descriptive statistical analysis

The results of the application of the five-point scaled questionnaire are presented in this subsection, corresponding to the agreement level of the respondents

towards the propositions presented, as mentioned in the questionnaire sent to the companies.

The analysis of the first group of results, related to the potential dimension and specifically to the acquisition component, points out that companies attach greater value to attitudes and actions that promote internal changes, as well as the constant search for relevant external information to their business, factors that contribute to the establishment of organizational processes, according to Zahra & George (2002), by which companies acquire, absorb, transform and exploit knowledge for the production of a dynamic organizational capacity.

These questions, with average rates of 4.30 and 4.40, respectively, highlight the concern of the companies, which seeks to keep pace with external information that support their conduction and improvement and even the promotion of internal changes. The coefficients of variation calculated for these two propositions are below standard reference proposed by Churchill & Iacobucci (2002), presenting greater homogeneity in respondents' viewpoint.

On the other hand, the construct that evaluates the contribution of companies in innovation projects conducted by different institutions and the influence of external and internal environments (Dyer & Singh, 1998) had the lowest average, 2.95, positioned at 2% below the average point of the scale (3). It is also noted that the high percentage of the coefficient of variation (48.47%) indicates there is considerable dispersion on the positioning of the participating companies.

These data are opposed to the concepts of Cohen & Levinthal (1990), which emphasize that the development of an active and diverse network of relationships may raise awareness of individuals on relevant information to be incorporated into the organization when needed.

Noteworthy is the result regarding qualification of employees to work in innovation projects whose composition includes prior knowledge, which Cohen & Levinthal (1990) understand as a contribution to the innovation practices. If the midpoint of the scale is used as a reference, the calculated rate is 16.67% above this reference, which is not a guarantee of success in executing innovation projects, but a trend signaling for the constitution of a body of employees able to act in such projects. The coefficient of variation of less than 30% indicates there is a slight homogeneity among respondents.

As discussed in the theoretical basis, highly qualified teams are better able to identify, assimilate and absorb external knowledge (Vega-Jurado et al., 2008). According to Cohen and Levinthal (1990), the absorptive capacity of a company includes the ability to recognize the value of external knowledge, assimilating and applying it to obtain more valuable results for the organization.

It is noteworthy the positioning of respondent companies towards the evaluation of results of the assimilation component concerning the qualification of their management staff, about the inherent knowledge in the execution of their duties. That positioning, according to Leonard-Barton (1998), is one of the two capacity characteristics required to maintain and develop strategic skills. The average index calculated for this proposition (4.15) demonstrates favorability higher than 80%, and the coefficient of variation of 19.52% supports lower dispersion among the responses.

Other propositions had average results above standard reference proposed (3), however, all of them did not reach score 4, representing less than 80% of favorability. With regard to the propositions below score 4, employees mastered the technologies already implemented in the company, with an average index of 3.90 and coefficient of variation of 24.87%. This result indicates that employees tend to assimilate knowledge of technologies after being trained and, in accordance with the model of Cohen and Levinthal (1990), the ability to absorb new information would depend on the level of prior knowledge related to basic skills and learning experience, as well as the acknowledgement of the value of new information.

The assimilation component has shown that participating companies are often more focused on their internal processes than on participating in scientific events, as denoted in the question concerning the encouragement of employee participation in conferences, seminars and courses, which is translated by the average index of 3.65, below proper favorability. Furthermore, the proposition about the use of external technology or knowledge had a 2.95 index, below the standard reference and a high coefficient of variation of 46.10%, indicating high dispersion of responses.

In this context, it is clear that assimilation component is strengthened by aspects related to learning the enterprise's technologies, but is weakened when external sources are needed, a counterpoint to the arguments of Dyer & Singh (1998), when they define absorptive capacity as a process of "interactive exchanges", resulting in "relational rents".

In the light of the theoretical model (Figure 6) of Zahra & George (2002) that approaches the "transformation" component, which states that knowledge is not static, constantly changing and expanding itself (Cruz, 2011), it is possible to perceive a concentration of average indexes for the five propositions belonging to that component, with

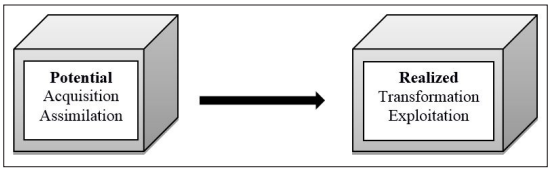

Figure 6. Model of AC according to Zahra & George (2002).

results between 3.15, when respondents were asked about employee participation in training aimed at facilitating innovation in the company, and 3.80, when the proposition is related to employees' spontaneity to collaborate with themselves at all hierarchical levels of the organization.

It was found that transformation has the lowest average indexes of the four components that make up the potential and realized dimensions of the absorptive capacity, namely acquisition, assimilation, transformation and exploitation (Cruz, 2011). This finding points to the attitude of companies in maintaining the position of their employees, raising concern about the ease and agility of dissemination of information within the company, an essential factor for any process aimed at innovation. Given the importance of being updated to introduce new products on the market faster than their competitors, there is need for strong advance in technological skills (Tidd et al., 2005; Ziviani, 2012).

Among the results found in the assessment of absorptive capacity in the light of industrial and scientific components, which is a division proposed by Vega-Jurado et al. (2008) and Murovec & Prodan (2009), it was noticed that the first component's averages stand out. Of the four propositions addressed by the industrial aspect, three obtained averages above 4.20, indicating favorability higher than 80%.

The results show greater consistency because the dispersion coefficients of these three questions are below 20%, which grants them homogeneous indexes and consistency in the positioning of the participating companies.

In evaluating the innovation component, it was clearly noticed there are elements that favors the approximation of participating companies with the electricity sector for technological development issues, either to establish a partnership with a nationally consolidated company or to avoid a competitor to do so. This statement corroborates the exception presented by respondents about the frequent use of knowledge and information developed by their competitors.

In this same regard, when asked about the frequent cooperation with the companies of the electricity sector for technology development, companies positioned themselves with high heterogeneity in responses (coefficient of variation of 54.66%), averaging 2.47, the lowest average among all questions in that section focused on innovation indicators.

However, when the companies were asked whether there was an interest in cooperating with companies of the electricity sector for developing technologies, the average index found was very satisfactory (4.37) and there was low dispersion in the responses, which can be shown by the coefficient of variation of 18.99%, a result that demonstrates the ability of these companies to assess the value of new external knowledge to apply them for commercial purposes (Cohen & Levinthal, 1990), as well as understand the importance of acquiring new technological skills through the development of relationships in which is possible to learn based on interaction (Schiler, 2008).

The descriptive statistical analysis of the average index calculated for each question is presented in Table 3.

In the light of what was shown, it is apparent that evaluation indexes of potential absorptive capacity are more significant than those reported for the realized dimension, also shown by the high averages of the components acquisition and assimilation, of 4.40 and 4.15, respectively. The dispersion of the compiled data may be considered low, with reference to the proposal of Churchill & Iacobucci (2002), for values below 30% in the evaluation of coefficients of variation.

It is also observed a better performance of industrial absorptive capacity when compared to the scientific (averages of 4.08 and 3.78), although both tend to favor the results focused on the absorptive capacity for innovation in the compiled values.

The results obtained by the compilation of the averages of each construct per component denote that they are all above the standard reference of the Likert scale, considering there is high absorptive capacity in all tested components. This finding lacks a detailed analysis such as that presented in the previous descriptive statistical analysis of each component and their propositions and constructs, and also by a multivariate statistical method, such as confirmatory factor analysis.

Table 3. Descriptive statistical analysis of the indexes.

Component	Minimum	Maximum	Average	Standard deviation	Coefficient of variation
Acquisition	2.95	4.40	3.76	0.60	15.93%
Assimilation	2.95	4.15	3.54	0.46	12.99%
Transformation	3.15	3.80	3.40	0.26	7.56%
Exploration	2.85	4.05	3.53	0.50	14.08%
Industrial absorptive capacity	3.50	4.30	4.08	0.39	9.46%
Scientific absorptive capacity	3.75	3.80	3.78	0.04	0.93%
Innovation	2.47	4.37	3.46	0.78	22.46%

Source: Research data (2014).

5.3 Confirmatory Factor Analysis (CFA)

Confirmatory factor analysis is a multivariate statistical method of wide application in management studies to confirm the consistency of the variables used for measuring the researched objects. This method contributed to the validation of the constructs developed by Cruz (2011) and adapted to this research with Brazilian manufacturing companies of solar collectors.

In assessing the potential size, it was verified that when the propositions "The company collaborates with different institutions in innovation projects" and "The company often uses knowledge or technology developed by other companies" are removed from the factor analysis they both set greater weight to issues related to the value assigned by companies to promote internal changes, seeking for external information that fits to the business itself, the appropriate qualification of its staff with emphasis on aspects related to research and development activities, increasing the value of Cronbach's alpha.

In the evaluation of industrial AC the removal of the proposition "The company often uses information and knowledge from competitors for developing its own products and processes", which seeks to measure the company's interaction with its competitors in developing its own products and processes, resulted in a higher value of Cronbach's alpha.

This analysis reflects an industry trend of sharing experiences, knowledge and information with the customers, suppliers and contacts obtained in business meetings in order to innovate the products and processes; a natural condition when there is confidence in a competitive business environment.

Facing the last-mentioned considerations, a new factor analysis was therefore performed after the removal of these propositions, seeking to review the values of KMO, Bartlett and Cronbach's alpha for confirming the validation, together with the factor loading of each proposition. All the results of the validation statistics and factor loadings were satisfactory, with significant values on the reliability and factor analysis. The results are shown in Table 4.

It is noteworthy that the value of KMO in both dimensions demonstrated suitability between the factor analysis and the sample used, and the Bartlett's test

Table 4. Confirmatory and reliability factor analysis after removing the invalid propositions.

Dimension	Propositions	Loading extracted	Variance extracted (%)	KMO	Bartlett's (p-value)	Cronbach's alpha
Acquisition	P1.a)	0.813	65.83	0.754	25.35 (0.000)	0.818
	P1.c)	0.795				
	P1.d)	0.808				
	P1.e)	0.830				
Assimilation	P2.b)	0.812	63.29	0.633	51.45 (0.000)	0.846
	P2.c)	0.805				
	P2.d)	0.813				
	P2.e)	0.766				
	P2.f)	0.780				
Transformation	P3.a)	0.637	52.99	0.680	26.70 (0.003)	0.774
	P3.b)	0.625				
	P3.c)	0.730				
	P3.d)	0.817				
	P3.e)	0.808				
Exploitation	P4.a)	0.821	66.70	0.753	66.47 (0.000)	0.893
	P4.b)	0.913				
	P4.c)	0.769				
	P4.d)	0.715				
	P4.e)	0.819				
	P4.f)	0.850				
Industrial AC	P5.a)	0.911	83.16	0.749	31.79 (0.000)	0.894
	P5.b)	0.923				
	P5.d)	0.902				
Scientific AC	P6.a)	0.900	81.02	0.500	8.51 (0.004)	0.763
	P6.b)	0.900				
Innovation	P7.a)	0.977	95.41	0.500	28.75 (0.000)	0.952

Source: Research data (2014).

of sphericity demonstrated the correlation among the variables of each factor. Reliability was also confirmed.

5.4 Ranking of companies

After validating the propositions through confirmatory factor analysis, the arithmetic average was calculated, per company, for each dimension analyzed in the research, in order to establish a ranking of which company has the highest AC in each dimension, based on the data collected in the survey and placed in descending order. Companies were numbered from 1 to 20, keeping hidden their business names because of the confidentiality assured for the respondents.

A ranking was made up by individual averages of each company, as shown in Table 5, which considers the values of all seven components (factors) using the items evaluated in the factor analysis and the reliability analysis.

Of the 20 companies participating, the numbers 7, 2 and 1 are noteworthy for presenting results that characterize them as the best ranked companies, obtaining scores above 4.50, indicating a favorability degree higher than 90%. Companies 7 and 2 highly value the attitudes that promote internal changes, the monitoring of knowledge and the constant search for relevant external information to their businesses. These factors are strengthened when assessed from the perspective of the acquisition component. However, only the Company 7 stands out when the capacity of assimilating new knowledge is evaluated, because of the appropriate training of its management staff for developing their functions, allied to employees' domain of the technologies of the company.

Table 5. Ranking of companies according to their absorptive capacity.

Placing	Identification	Overall average
1st	Company 7	4.85
2nd	Company 2	4.59
3rd	Company 1	4.52
4th	Company 18	4.48
5th	Company 11	4.33
6th	Company 6	4.15
7th	Company 4	4.11
8th	Company 16	4.00
9th	Company 13	3.81
10th	Company 12	3.63
11ht	Company 3	3.56
12ht	Company 14	3.56
13th	Company 9	3.52
14th	Company 17	3.52
15th	Company 19	3.52
16th	Company 20	3.33
17th	Company 15	3.00
18th	Company 5	2.96
19th	Company 10	2.67
20th	Company 8	1.70

Source: Research data (2014).

The best ranked companies, based on overall assessment, were the numbers 7 and 2, with averages of 4.85 and 4.59, respectively, confirming the analysis of individual components. The number 8 presented the lowest average, of 1.70, reflecting its poor performance in most individual assessments (components from potential and realized dimensions) and factors aimed at industrial and scientific AC.

5.5 Discussion of results

Based on the evaluation of results, it becomes possible to make remarks regarding the research. It was found that 80% of companies landed responses to the CA in size acquisition that characterize your average as high grade, when the adopted neutral point of the scale is the 3, according to methodological procedures.

It stands out the adoption of positive attitudes that encourage internal changes, as well as the search for external information relevant to the improvement of their businesses.

Still in the analysis of the second component of the potential dimension, specifically regarding assimilation component, it is clear that only 16.7% of respondents have average values below 3, characterizing a low degree of AC for innovation. The other 83.3% have average levels above 3, characterizing a high degree of AC for innovation.

It is noteworthy that although the percentage of companies that had favorable averages in the assimilation component is higher than the same percentage in the acquisition component, the individual averages of the last mentioned are higher, which grants as a better performance. It is also noted that the companies usually are willing to assimilate their own technologies, but are not that often willing to seek relevant external information for their businesses and qualify their managers, who are characterized as capable of performing their functions. This profile suits similar companies in the same business.

The tendency of the participating companies for the potential dimension can be seen when the results regarding the realized dimension show the averages of the transformation component were lower than the rest of the components, corroborating a business behavior focused on maintaining employees' current positions. This behavior gets worse when the difficulty of spreading information inside the companies is observed, as well as the lack of staff training related to innovation projects.

Complementing the assessment of the realized dimension, when referring to exploitation component, it is perceived by the responses of companies that there

is a gap in the internal structure of the organizations for Research and Development (R&D), in contrast to the reported positioning of a technological proactivity expressed by seeking to innovate ahead of their competitors.

The industrial vocation of the object researched justifies the results when evaluating the search for information and knowledge in the external environment. It can be inferred these companies are strongly linked to industrial behavior, given their higher favorability above 80%, which confirms the frequent use of information, knowledge and experience derived from their suppliers, customers and partners, either in everyday interaction or participating in business meetings.

On the other hand, the interaction with their competitors is not that intense, which is justified by the Brazilian traditional business approach. The interaction level with the scientific community was lower than the indexes of industrial AC; hence it needs to be developed by the manufacturers of solar panels.

This result indicates the practicability of the knowledge generated in the industry makes it more useful than the other sources. However, this practicability cannot be restricted to the adoption of knowledge developed in scientific centers and universities, given the need for innovative processes and products developed outside the industrial walls, if their applicability, profitability and adherence to corporate business are proven.

According to what was said, it appears that companies participating in this research should develop their ability to absorb and use knowledge, technology and experiences coming from universities programs and research centers, especially the R&D projects developed by companies of the electricity sector in partnership with their National Agency (ANEEL). These projects represent insertion opportunities in environments where the innovation structures have already been consolidated and most of the agents are ready to conduct innovative projects and activities.

It is noteworthy these last-mentioned agents' availability of financial resources and their interest in leveraging projects in productive sectors, especially those connected with the electricity business. In this sense, the sector of solar panels is different from many others, given its natural vocation for energy efficiency. Investment should be made in training and development of skills and competencies that guide these companies to innovation, either in their products or processes.

Besides the companies' main weaknesses, regarding their ability to absorb innovation, especially those identified by the research, the sector still has some companies that stood out in the ranking based on the seven constructs assessed in the survey.

6 Final considerations

The objective of this research was to assess Brazilian companies that produce solar panels from the perspective of their AC of technological knowledge and innovation.

The results of this research concluded that Brazilian manufacturers of solar panels do not yet have mature AC for developing an innovative product, showing a higher tendency for the potential dimension of AC when compared to the realized dimension. This finding corroborates the prospects for future R&D projects if the surveyed companies strengthen their ability to promote interactions with other organizations devoted to that same purpose.

The findings that lead to the lack of maturity conclusion are the deficiencies presented by companies in absorbing knowledge and external experience, since they are much focused on routine activities, with little focus on innovative products and processes, a present feature in most companies that responded to the survey.

The national profile of the manufactures of solar panels, which has a strong industrial behavior, also contributes to this conclusion, confirming the predominance of interactions for the exchange of information and knowledge within the industrial environment, with reduced opportunity to the scientific scope. These conditions are further exacerbated by low participation of employees in training that facilitate innovation within the organization.

Of the companies surveyed, three had results that characterize a better capacity to absorb new technological knowledge, developing innovation from that. Although they still need to strengthen some issues, it is concluded that these three companies are in the right way to mature their AC and they might be able to produce innovative equipment.

In spite of the fact that the surveyed companies still need to develop their AC maturity, the study concludes there was a clear perception of their interest in the establishment of partnerships with companies of the electricity sector, with a view to the implementation and development of innovative products and technologies, as endorsed in the responses received to the question about AC of innovation (favorability of 87.4%).

That indicates the opening of a relationship channel that strengthens the purposes of companies of the electricity sector in developing their R&D projects with the producers of solar panels, remembering that the central objective of this research is to map the production chain, seeking to evaluate the internal environment of the Brazilian manufacturers of solar panels and their tendency to develop innovative products.

Given the deficiencies presented by companies and verified in the search results, it is recommended

to carry out a detailed diagnosis in order to highlight the weaknesses that these manufacturers mentioned in absorbing external knowledge and innovating. This diagnosis may guide and encourage other agents of the electricity sector that are interested in the development of innovative products in partnership with these companies, setting up programs aimed at training and developing their absorptive capacity.

In this sense, from a practical point of view, this research guides the companies of the electricity sector to act in favor of the most qualified producers of solar panels, so they can undertake the manufacture of an innovative product, either on their own initiative or by leveraging financial resources from the electricity sector.

One limitation of this study refers to the final number of respondents, only half of the total amount of companies that would sign a satisfactory sample. It is recommended that further research involving the same sector implements strategies that encourage participation and involvement of a wider range of companies, which would provide better representation and assertiveness in the analysis and conclusions.

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