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ARTICLE

Absorptive Capacity in a Public Research Company: from Maturity to Scalability

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ABSTRACT

Absorptive capacity is a dynamic capability that may generate knowledge and innovations. In Brazil, the development of new products and processes have led to technological advances in farming, especially in the last decades. In this context, the Brazilian Agricultural Research Corporation (Embrapa) has played an important role in the absorption and generation of agricultural knowledge and innovations from research and project development (R&D). Therefore, absorptive capacity (AC) is a construct involving knowledge absorption with procedural propositions that need empirical verification. In this study, we investigated how the maturity of absorptive capacity can be achieved in a public research company. We studied three R&D Embrapa projects that involved intraorganizational and interorganizational alliances that resulted in important innovations. We identified and systematized routines and organizational processes of acquisition, assimilation, transformation, and exploration of knowledge. This study contributed to the development of a propositional maturity model of absorptive capacity in a public research company that promotes scalability of routines and knowledge absorption processes at intraorganizational and interorganizational levels.

KEYWORDS

Absorptive Capacity, R&D Projects, Alliances, Agricultural Innovation

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1. INTRODUCTION

Brazil has the fifth largest world's population with 205 million inhabitants. The agricultural sector accounted for 5.3% of the Brazilian Gross Domestic Product in 2017 (IBGE, 2017), impacting the Brazilian and world economy (Crespi et al., 2019). Exports of food commodities amount to US$520 billion a year (MacDonald et al., 2015).

The region of the Americas exports large agricultural products to East Asia, especially from the United States, which uses around 6.1 million ha of its crops for exports to China. Brazil and Argentina use around 10% of their crops for exports. Brazil exports soybean, sugar, meat, and coffee to China, France, Germany, Russia, Iran, and Spain (MacDonald et al., 2015).

The United States, with an agricultural GDP of 1.43% in 2013 (Actualitix, 2018), has the Agricultural Research Service (Agricultural Research Service - ARS) of the USDA (United States Department of Agriculture) (https://www.ars.usda.gov/about-ars/). Argentina, with an agricultural GDP of 8.31% in 2014 (Actualitix, 2018), has the National Agricultural Technology Institute (INTA), which allows access of its agricultural products to international markets (https://inta.gob.ar/paginas/sobre-el-inta). Brazil has the Brazilian Agricultural Research Corporation (Embrapa), a public research company with branches nationwide and Virtual Laboratories Abroad (LABEX).

Embrapa has strategic alliances with scientific and technological partners (universities, research institutes, and companies) to carry out research and develop projects (R&D), and market innovations of products and processes (Embrapa, 2016a; Crespi et al., 2019). R&D projects are developed from strategic alliances that Gulati (1998, p. 293) defines as "agreements between companies involving exchange, sharing, or co-development of products, technologies or services".

In countries like Brazil, research institutes depend on the ability to access external knowledge and combine it with capabilities of its branches (Santos, 2006), requiring improvements to organize and handle knowledge (Inkinen, 2016; Moura et al., 2019) from decentralized branches and from foreign technological partners.

Innovations require understanding the process of knowledge absorption in organizations, and R&D projects from strategic alliances are essential, since they allow absorbing valuable knowledge and generating innovations (Crespi et al., 2019).

We investigated how maturity of absorptive capacity can be achieved at Embrapa to develop a propositional model of maturity of absorptive capacity. For that, we analyzed R&D projects developed from intraorganizational or interorganizational alliances. Intraorganizational alliances involve internal relations, between Embrapa branches. Interorganizational ones involve external relations with Embrapa partners, namely universities, foundations, and private companies.

This is an in-depth and multidimensional study of three R&D projects addressing all dimensions of absorptive capacity (Zahra & George, 2002) that contributes to the theoretical advancement of the subject within the framework of intraorganizational and interorganizational alliances. It complements the studies of Guedes et al. (2017) on absorptive capacity and explains how dimensions of absorptive capacity are interrelated with life-cycle phases of R&D projects (Ali & Ali, 2018; Bjorvatn & Wald, 2018).

The study also proposes the scalable absorptive capacity is proposed, that is, the systematic scalability of absorptive capacity dimensions for the life-cycle phases of projects.

2. THEORETICAL FRAMEWORK

Knowledge acquired externally has become important for innovations (Lane & Lubatkin, 1998; Lin et al., 2016); however, it is not enough, since success depends on the company's absorptive capacity, which is , "a set of routines and organizational processes by which companies acquire, assimilate, transform, and explore knowledge" (Zahra & George, 2002 p. 186).

For Cohen and Levinthal (1990), absorptive capacity is a dynamic capability of an organization to absorb external knowledge (Lewin et al., 2011), resulting in innovative performance (Cohen & Levinthal, 1990; Lane et al., 2006; Lin et al., 2016; Moilanen et al., 2014; Tsai, 2001), strategic innovations (Gebauer et al., 2012), transfer of intraorganizational (Martinkenaite & Breunig, 2016; Szulanski, 1996) , and interorganizational knowledges (Lane and Lubatkin, 1998). The positive relationship between absorptive capacity and organizational performance is not influenced by different cultural values in different countries (Adams et al., 2016).

The conceptual basis of this study considers absorptive capacity as a multidimensional construct (Zahra & George, 2002; Lane et al., 2006; Volberda et al., 2010; Lewin et al., 2011). Absorptive capacity comprises acquisition and assimilation routines that form potential absorptive capacity (PACAP), and routines of transformation and exploration that form realized absorptive capacity (RACAP). PACAP and RACAP are sequential and complementary, resulting in innovative performance, characterized by knowledge generation, patent registration and cultivars, and product, process, and service innovation.

Generating innovation requires complex and diversified knowledge. The search for external knowledge occurs in different ways (strategic alliances, joint ventures, mergers, and acquisitions). Strategic alliances accelerate technological advances (Costa & Porto, 2014; Shin et al., 2016).

We aim to identify a scalable absorptive capacity, in addition to PACAP and RACAP, as information technology enables "greater opportunities for diversity, sharing, and assimilation of knowledge" (Grover & Kohli, 2012, p. 227) and learning experience of companies to obtain external knowledge are essential in R&D projects, characterized by motivation to achieve better results (PMI, 2013) and dispersed at different organizational levels (Coleman & MacNicol, 2016). We propose: *(Proposition 1 – P1) Accumulation of learning experience in acquiring external knowledge enhances the absorptive capacity scalability; (Proposition 2 – P2) The presence of active organizational leadership in R&D projects enhances the absorptive capacity scalability.*

The factors that influence absorptive capacity are: antecedents, facilitators, inductors, and central components. Antecedents initially motivate organizations to prospect external knowledge, including a search for existing complementary knowledge and/or new and unique knowledge. Alliances allow accessing valuable resources of partners (Sáez et al., 2002). Technical, scientific, and market knowledge can also be obtained through alliances (Cohen & Levinthal, 1990). Idiosyncratic knowledge, in turn, is a by-product of activities (Jensen & Meckling, 1992) and is peculiar and has a decentralized location (Grant, 1996). Silva (2002, p. 109) adds that scientific knowledge shows the social organization of the research environment, idiosyncrasies of producers (scientists), and constraints imposed by the environment (e.g.: operational and technological constraints and information access).

In this study, we expected Embrapa to seek idiosyncratic knowledge in intraorganizational alliances. In interorganizational alliances, we seek complementary knowledge and market information for innovations from external partners (companies). We also propose: *(Proposition 3 – P3) Search for idiosyncratic knowledge is the main antecedent factor of the absorptive capacity in intraorganizational alliances; (Proposition 4 – P4) Search for complementary and market knowledge is the main antecedent factor of the absorptive capacity in interorganizational alliances.*

Absorptive capacity facilitators involve: a) experience in establishing alliances; b) diversity of the alliance portfolio; and c) individual absorptive capacity. Routines are related to dynamic capabilities (Teece et al., 1997; Zollo & Winter, 2002) and, as experience influences the systematization of specific routines of the company's absorptive capacity (Lewin et al., 2011), these routines enter a cyclical improvement process. Furthermore, alliances allow experience accumulation, increasing the management capacity of organizations (Rothaermel & Deeds, 2006).

Focusing on absorptive capacity facilitators, we propose: *(Proposition 5 – P5) Experience with intraorganizational and interorganizational alliances favors the development and improvement of specific routines of absorptive capacity; (Proposition 6 – P6) Diversity of the alliance portfolio provides access to diversified external knowledge, enhancing absorptive capacity, especially acquisition routines; (Proposition 7 – P7) Individual absorptive capacity of team members enhances organizational absorptive capacity.*

Greater social interaction is expected in the absorptive capacity in intraorganizational alliances, since Embrapa branches share the same organizational culture. However, the appropriability regime of generated innovations and knowledge is the most commonly practiced inductor in interorganizational alliances. A strong appropriability regime allows safe exchange of knowledge and strategic versatility (Ritala & Hurmelinna-Laukkanin, 2013). Thus, we propose: *(Proposition 8 – P8) Social interaction is practiced more in the absorptive capacity in intraorganizational than in interorganizational alliances; (Proposition 9 – P9) The appropriability regime is practiced more in the absorptive capacity in interorganizational than in intraorganizational alliances.*

Therefore, innovative organizations have routines for each dimension of absorptive capacity (Zahra & George, 2002), which interrelate with life-cycle phases of R&D projects (Mikulskienė, 2014; PMI, 2013; Ali & Ali, 2018; Bjorvatn & Wald, 2018). These phases confer maturity (Guedes et al., 2017) to the absorptive capacity (potential, realized, or scalable), that is, the ability to absorb knowledge and develop innovation and enhance innovative performance. Therefore, we propose: *(Proposition 10 – P10) Systematization and development of routines of acquisition, assimilation, transformation and exploration of external knowledge confer maturity to absorptive capacity; (Proposition 11 – P11) Routines of acquisition, assimilation, transformation, and exploration of external knowledge interrelate with life-cycle phases of R&D projects, boosting innovative performance.*

3. RESEARCH METHOD AND CONTEXT

The research conducted was qualitative in nature, since it depended on the data source in the research environment and the researcher as an instrument, essential conditions for the collection, selection, analysis, and interpretation of the information obtained (Creswell, 2017). We adopted the descriptive approach to report on the environment as a whole, and the processes were valued by perceptions of individuals through their thoughts, actions, and feelings (Godoy, 1995).

We used the multiple-case method, since it is suitable for descriptive studies (Eisenhardt and Graebner, 2007). This method does not require control of behavioral events, but it focuses on contemporary events, providing an understanding of the individual, organizational, social, and political phenomena related to the research question (Eisenhardt & Graebner, 2007).

We focused on Embrapa Soybean and Embrapa Beef Cattle, as these branches had R&D projects formed through intraorganizational and interorganizational alliances, which resulted in innovations of great relevance, namely: Soybean cultivars *Cultivance*®, Coinoculation and Neutral Carbon Meat (Embrapa, 2014; 2016a).

3.1. Research Context

The Brazilian Agricultural Research Corporation (Embrapa) was founded in Brazil on April 26, 1973. It publicly owned, governed by private law, under the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA) (Crestana, 2012). Embrapa has branches throughout Brazil and Virtual Laboratories Abroad (LABEX) in several countries.

The Embrapa intelligence process has three main components: trends observatory; analysis and studies; and strategies. Trends observatory monitors and prospects trends in agriculture in Brazil and abroad, for profitable interaction and acquisition of knowledge between the Embrapa and LABEX (Embrapa, 2014).

In 2015, Embrapa had 21 new cultivars and the licensing of 165, 12 patents (headquarters) and 19 patents abroad, intellectual protection of 65 new cultivars and registration of other 91. A licensing agreement for seeds was signed with 929 producers and private companies, corresponding to 96,000 ha of seed production, with 1,500 tons of basic seeds and 110,000 units of fruit and vegetable propagules. In addition, 102 tons of maize-variety seeds and 67 tons of cowpea benefited 500,000 family farmers in Brazil. Embrapa holds the largest genetic bank in Latin America, with 124,000 seed samples of 765 species (Embrapa, 2016a).

3.2. Data collection and analysis

We interviewed the advisor of the Research and Development Board of Embrapa, in Brasília (Brazil), and members of Central Units, Strategic Business Secretariat (SBS) and Technology Transfer Department (TTD) (Table 1). The interviews provided data on the managerial aspects of strategic alliances (Section 3.1).

We included agricultural innovations generated from collaborative R&D projects with interorganizational and intraorganizational alliances in the last five years (2013-2017), selected and validated in the first phase and investigated in the second stage (Table 2).

We conducted semi-structured interviews, in the second stage, with researchers, heads of technology transfer, and R&D of the three projects selected (Table 1). Interviews enable the addressing of complex subjects (Alves–Mazzoti & Gewandsznajder, 1999).

Table 1 shows a descriptive map of the interviews in the first and second phases. All interviews were recorded, transcribed and interpreted from the categories: (a) Antecedents; (b) Facilitators; (c) Inductors (social integration and appropriation regimes); (d) Maturity; and (e) Scalability.

We also obtained data from the analysis of secondary documents of projects (project selection, partnership contracts and R&D project reports). The collection instruments are the most adequate in qualitative research (Alves–Mazzoti & Gewandsznajder, 1999) and are not mutually exclusive.

The data were analyzed in three stages: reduction, presentation, and conclusion. Reduction involved selecting, focusing, simplifying, abstracting, and transforming the data, organizing them according to research themes or objectives. Presentation started from these data and provided a systematic analysis, observing similarities, differences, and the interrelationship. Conclusion involved data review, which was validated and confirmed (Miles & Huberman, 1994).

Table 1
Interviews conducted.

Phases of research	Date	Code	Position	Qualification	Time with the Company	Duration
First phase (interviews with members of Embrapa's central units)	07 Mar. 2017	GE1	Advisor of Embrapa R&D Board Headquarters	PhD in Agronomy	41 years	0:57:24
	07 Mar. 2017	GE2	Supervisor of the Coordination of Innovation in Business	PhD in Production Engineering	20 years	0:38:57
	07 Mar. 2017	GE3	Intellectual Property Coordinator	Master's Degree in Intellectual Property	6 years	0:49:53
	07 Mar. 2017	GE4	Information and Prospecting Coordination	Master's Degree in Agronomic Engineering	15 years	0:36:20
Second phase (interviews with members of Project A – *Innovation Cultivance®*)	13 Mar. 2017	PAE1	Researcher and Research Center Supervisor	PhD in Agronomy	20 years	1:08:37
	22 Mar. 2017	PAE2	Researcher	Postdoctoral Degree in Quantitative Genetics and Plant Breeding	11 years	0:28:55
	22 Mar. 2017	PAE3	Head of TT	PhD in Agronomy	27 years	0:31:52
	22 Mar. 2017	PAE4	Head of R&D	PhD in Agronomy	23 years	0:30:38
Second phase (interviews with members of Project B – *Coinoculation*)	22 Mar. 2017	PBE1	Researcher	Post-doctorate in Plant Physiology	7 years	0:54:40
	22 Mar. 2017	PBE2	Head of TT	PhD in Agronomy	27 years	0:31:52
	22 Mar. 2017	PBE3	Head of R&D	PhD in Agronomy	23 years	0:30:38
Second phase (interviews with members of Project C – *Carbon Neutral Meat*)	20 Mar. 2017	PCE1	Researcher	Postdoctoral Degree in Animal Science	7 years	1:15:06
	20 Mar. 2017	PCE2	Head of TT	Master's Degree in Business Administration	7 years	1:06:56
	20 Mar. 2017	PCE3	Head of R&D	PhD in Genetics and Improvement	11 years	0:49:34
TOTAL						**10:51:22**

Source: Prepared by the authors.

Table 2
R & D projects developed from 2013 to 2017 and selected for the second phase of the research.

Unit	Innovation	Classification	Type of Alliance	Key Partners	Key Highlights
Embrapa Soybean	Cultivance®	Product Process	Intraorganizational and inter-organizational alliances	External: BASF, Cerrados Foundation, West Baiano Research and Development Support Foundation, Meridional Foundation, Internal: Embrapa Cerrados, Embrapa Wheat.	Soybeans are the most important Brazilian agricultural commodities. This culture moves numerous links in the productive chain (Embrapa, 2016b).
Embrapa BEEF CATTLE	Neutral Carbon Meat	Brand concept	Intraorganizational and inter-organizational alliances	External: Certifying company and refrigerators. Internal: Embrapa Corn and sorghum, Embrapa Cerrados.	A Carbon Neutral Meat (CNM) is sheltered within the ILPF, increasing income of producers and reducing GHG emissions (Embrapa, 2016b). CNM technology represents an advance in international marketing of Brazilian beef.
Embrapa Soybean	Coinoculation	Product Process	Intraorganizational and inter-organizational alliances	External: Total Biotechnology, Meridional Foundation.	Biological fixation of nitrogen increases productivity and reduces the use of industrialized inputs, reducing carbon emissions (Embrapa, 2016b). Coinoculation is an important advance of this technology, with the use of Azospirillum as innovation.

Source: Research Data.

Triangulation for Zamberlan et al. (2014, p. 124) is the logical foundation to use multiple data sources, allowing convincing and accurate results of a case study.

The analysis was conducted in three phases: pre-analysis; material exploration; and treatment of results, inference, and interpretation. The pre-analysis involved subject organization; material exploration concerned codification, classification, and establishment of analysis categories; and treatment of results, inference, and interpretation showed condensation and relevance of information for the analysis (Bardin, 2010; Zamberlan et al., 2014). Data analysis was supported by IRAMUTEQ software (*Interface de R pour les Analyses Multidimensionnellesde Textes et de Questionnaires*), involving analyses of specificity, similarity, and the Reinert method (Camargo & Justo, 2013).

4. RESULTS

We found knowledge absorption routines in all life-cycle phases of Embrapa projects (Project A (Imidazolinone tolerant soybeans), B (Coinoculation) and C (Neutral Carbon Meat), characterizing maturity of absorptive capacity and its scalability at intraorganizational and interorganizational levels (Table 3). Seven phases are proposed based on empirical evidence and the life-cycle analysis, as in Pillai, Joshi and Rao (2002), PMI (2013) and Mikulskienè (2014), namely: 1) initial scope; 2) project specification; 3) detailed planning; 4) evaluation; 5) implementation; 6) conclusion; and 7) post-project.

Table 3
Keywords of the R&D projects under study.

Keywords of R&D projects	Project A (Imidazolinone tolerant soybeans)	Project B (Coinoculation)	Project C (Neutral Carbon Meat)
Unit responsible	Embrapa Soybean	Embrapa Soybean	Embrapa Beef Cattle
Project objective	Indicate new soybean cultivars, with the potential to maintain the annual genetic gains of productivity.	Establish innovative, basic and applied research lines with nitrogen-fixing bacteria and plant growth promoters.	Validate the Carbon Neutral Meat Protocol (CNM) in different Brazilian regions, for the implementation of the CNM concept brand.
Duration of the project	Five years	Four years	Expected to last three years
Key internal partners	Embrapa Agricultural West, Amapá, Temperate Weather, Middle North, Coastal Plains, Rondônia, Roraima and others.	Embrapa Agricultural West, Coastal Plains and Cerrado.	Embrapa Corn and sorghum, Embrapa Southeast Cattle Raising, Embrapa Beef Cattle, Embrapa Eastern Amazon, Embrapa Fishing Aquaculture and others.
Key external partners	BASF, Meridional Foundation, Cerrados Foundation, West Baiano R&D Support Foundation and others.	Total Biotecnologia, Meridional Foundation, State University of Londrina and Federal University of Paraná.	Federal University of Minas Gerais, Federal University of Mato Grosso do Sul, Federal University of Goiás, Cold Stores and Certifying Company.
Innovations generated	Soybean cultivars resistant to the herbicide of imidazolinones	Product AzoTotal Max	Carbon Neutral Meat Brand
Patents and cultivar records	Cultivars BRS 397 CV, BRS 8482 CV and BRS 8082 CV	AzoTotal Max Product Registration	National Institute of Industrial Property (NIIP) under processes 907078982, 907079156 and 907079270.
Search for external information on innovation to support projects	Bibliographic consultation, partnerships with private and multinational companies, MAPA, LABEX, consulting firms, exchange of researchers, attending conferences, courses and technical meetings.	Partnerships with research institutes, universities and private companies; MAPA; consulting firm; literature and portal of the Coordination for the Improvement of Higher Education Personnel (CAPES), among others.	Associated with individual capacity.

Table 3
Cont.

Keywords of R&D projects	Project A (Imidazolinone tolerant soybeans)	Project B (Coinoculation)	Project C (Neutral Carbon Meat)
Stimulus for absorption of knowledge and later availability for the project team	Stimulus for training, the use of the Planning System, Monitoring and Evaluation of Individual Work Results (SAAD) and LABEX.	The researcher is characterized by the constant need for knowledge. In addition, LABEX is an important mechanism being used.	Graduate Programs.
Practical approach to laboratories, research centers or universities for the development of collaborative R&D projects	BASF enabled researchers to come to Brazil and for Embrapa researchers to go to Germany to exchange information.	Exchange of researchers from international research institutes.	Related to previous experiences of researchers, especially with regard to training.
Prospecting and selection of internal and external partners for collaborative R&D projects	Due to the importance of the partner in the market or by technical capacity.	Focuses on the intellectual contribution of the partner. Can directly involve the researcher, as well as leadership. Contracts, agreements and even letters of agreement are established.	Relationship networks for researchers, ILPF Network, search for complementary and market knowledge.
Definition of rules for the formalization of external strategic alliances to enable R&D projects	Through research projects, contracts, agreements and even letters of agreement.	Cooperation Agreements, Accords, Letters of Compliance and Projects.	Support of the Technology Transfer Programming Implementation Sector (TTPIS), the Technology Prospecting and Evaluation Sector (TPES), the Strategic Business Bureau (SBB), the Intellectual Property Committee (IPC) and Legal Counsel (LCO).
Operation of internal and external strategic alliances to enable R&D projects	Attention to confidentiality during development including protection.	Definition of activities, goals and results, via the project, and monitoring by the Project Portfolio Management System (PPMS) and IDEARE.	Contracts, technical cooperation agreements, terms of reference and confidentiality, work plans and projects.
Dissemination of knowledge acquired through strategic alliances to enable R&D projects	Weekly meetings with researchers, quarterly meetings with all employees, field days, lectures and meetings with the productive sector, farmers, technicians and industries.	Weekly technical meetings, quarterly meetings, field days, lectures and meetings with the productive sector.	Research meetings and informal meetings.

Table 3
Cont.

Keywords of R&D projects	Project A (Imidazolinone tolerant soybeans)	Project B (Coinoculation)	Project C (Neutral Carbon Meat)
Exchange of knowledge among the different areas of the company to enable R&D projects	Project reports and follow-up reporting of activities in the PPMS.	Semiannual and annual project reports, monitoring of PPMS activities and meetings.	Research meeting with all researchers, internal journal and informal meetings.
Application of externally acquired knowledge in R&D projects	Especially of public or private companies that operate in Brazil.	Postdoctoral knowledge application report.	The CNM technology itself is an example, in addition to the SCP.

Source: Research data.

Phases are similar between the projects and are operationalized within the strategic scope of Embrapa, including Agropensa, portfolios, arrangements, and macroprograms. In Embrapa R&D projects, the first phase involves strategic themes, with flexibility and autonomy for the performance of researchers who influence individual absorptive capacity (Wang et al., 2014).

The specification phase includes resources (Mikulskienė, 2014) and is characterized by the preparation of bidding documents, and the connection of arrangements and portfolios for project elaboration (detailed planning phase) using the Embrapa Programming Management System (IDEARE).

For Mikulskienė (2014), the detailed planning phase is characterized by knowledge acquisition and assimilation. Projects A, B, and C are influenced by inter- and intraorganizational alliances and graduate programs. The planning phase of Project B refers to knowledge acquisition from clients, and Project C by participation in the Integration Network of Cultivating Livestock Forest (ILPF Network). Assimilation of Projects A (Imidazolinone tolerant soybeans®), B (Coinoculation) and C (Neutral Carbon Meat) occurs through dissemination and exchange of knowledge, meetings, graduate programs, field days and congresses. Project C also involves scientific trips and workshops. Alliances are designed in stage A, involving confidentiality terms and secrecy clauses.

The evaluation phase was proposed based on project selection (Pillai et al., 2002) and concerns the assimilation size, information management, evaluation of edicts, and results of calls. IDEARE was used to manage this information. Project C involves interaction with the Support Center for Projects (SCP), at the branch level.

Implementation involves the execution of activities approved during the evaluation phase (Mikulskienė, 2014), characterized by data acquisition, assimilation, and transformation, involving meetings, field days, and training programs, routines induced by social integration (Dingler & Enkel, 2016).

The implementation phase of Project A used knowledge acquired through interorganizational alliances from the chemical industry and intraorganizational alliances, from different Brazilian regions, using training and interaction with the technical team and conducting tests.

In the implementation phase of Project B, acquisition and assimilation of knowledge occurred through alliances and technical meetings, congresses, field days, and internalization of external knowledge (Zahra & George, 2002).

In the implementation of Project C, there was acquisition of technical, marketing, and idiosyncratic knowledge. This project is still under way, enabling new alliances, and assimilation occurs through meetings, workshops, technical visits, field days, and actions for information and knowledge multiplication.

The conclusion phase culminates with a final report, evaluating the fulfillment of project objectives (Mikulskienė, 2014). In this phase, exploration is revealed in Project A, by exploration of cultivars generated. In Project B, the conclusion phase is characterized by coinoculant exploration, that is, its commercial application (Lane & Lubatkin, 1998).

In Project C, the completion phase involves the registration of a brand-concept and knowledge acquisition through congresses. The registration of the brand-concept occurs with implantation in areas already validated and in different biomes (Zahra & George, 2002).

The post-project phase involves the result analysis (Mikulskienė, 2014), characterized by knowledge acquisition, contact with customers and other companies, subsidizing new projects, representing the cyclical process of absorptive capacity. For example, innovations that generate new cultivars, with different agronomic characteristics, new formulations of inoculants and validation of Neutral Carbon Meat for other biomes.

Project A aimed at developing elite events, derived from the transgenic process, providing tolerance to the group of herbicides and generation of cultivars. The experiment was performed with three herbicide-tolerant cultivars of the imidazolinone group, allowed by the absorption of external knowledge from interorganizational and intraorganizational alliances, especially BASF, a multinational company partner. Maturity of the absorptive capacity of Embrapa Soybean during the project development allowed knowledge absorption from its partners.

Project B investigated viability of Azospirillum and Bradyrhizobium coinoculation, achieved with the registration of the product AzoTotal Max. The project was possible due to external knowledge absorbed from interorganizational and intraorganizational alliances.

Project C validated the Carbon Neutral Meat Protocol, including the development of applications, support for public policies and training of multipliers.

5. DISCUSSION

Adherence of propositions in the theoretical framework are discussed (Tables 4, 5, 6, 7 and 8). Most propositions adhered to the evidence collected in the field, except for Proposition “P3”, which did not adhere to Project B, and Proposition “P8”, which did not adhere to Projects A, B and C.

In intraorganizational alliances of Projects A and C, idiosyncratic knowledge was predominant due to the high specialization level of partner researchers and unique knowledge (Jensen and Meckling, 1992). Proposition 3 was adherent in projects A and C. However, in Project C, intraorganizational alliances complemented technical and scientific knowledge. In interorganizational alliances of the three projects, we sought technical, scientific and marketing knowledge (Table 4).

All propositions related to facilitators (P5, P6 and P7) were adherent. The diversity of alliance portfolios enhanced knowledge access, resulting in the maturation of organizational absorptive capacity and scalability of absorptive capacity routines for the life-cycle phases of R&D projects, as well as individual absorptive capacity (Table 5).

Table 4
Review and Validation of the Study Proposals from the Intra-Case Analysis for the Antecedents category.

Analysis Categories	Properties reviewed from intra-case analysis	Project A	Project B	Project C	Revised propositions from intra-case analysis	Theoretical basis
Antecedent	Knowledge from intraorganizational and interorganizational alliances	A	NA	A	P3: The search for idiosyncratic knowledge is the main antecedent factor of the absorptive capacity established in intraorganizational alliances.	Lane et al. (2006), Volberda et al. (2010), Moilanem et al. (2014), Sáez et al. (2002), Jensen and Meckling (1992) and Cohen and Levinthal (1990)
		A	A	A	P4: The search for complementary and market knowledge is the main antecedent factor of the absorptive capacity established in interorganizational alliances.	

Note. A = Adherent, NA = Non-Adherent.
Source: Research data.

The study revealed that social integration is practiced in intra- and interorganizational alliances, because in the projects, social integration is a potentiator of absorptive capacity in both alliances. Since social integration is practiced in intraorganizational and interorganizational alliances, Proposition 8 was not confirmed. On the other hand, appropriability regimes are practiced more in interorganizational alliances, confirming adherence of proposition (P9) (Table 6).

The projects showed maturity of the absorptive capacity through systematization and development of their potential, realized and scalable. This maturity is demonstrated by acquisition, assimilation, transformation, and exploration interrelated with life cycle phases (Table 7). This systematization of routines, processes, and systems is evidence of its maturity in the three projects, proving adherence to Proposition 10.

The Embrapa branches under study have a strategic management system with mechanisms developed over time and with experience (Zahra and George, 2002). Furthermore, active leadership in R&D projects contributes to sharing goals and targets, as well as the execution of tests, favoring knowledge flow. Propositions 1 and 2 are adherent. Embrapa absorptive capacity, particularly its acquisition, assimilation, transformation, and exploration routines, characterized by its maturity, is scaled from the organizational to project level and is practiced in life-cycle phases of intraorganizational and interorganizational R&D projects. Therefore, scalability occurs through the improvement of the operational level routines of R&D projects. Scalability also occurs from Embrapa to the partner (Table 8), adherent to Proposition 11.

Table 5
Review and Validation of the Study Proposals from the Intra-Case Analysis for the Facilitators category.

Analysis Categories	Properties reviewed from intra-case analysis	Project A	Project B	Project C	Revised propositions from intra-case analysis	Theoretical basis
Facilitators	Experience in intraorganizational and interorganizational alliances	A	A	A	P5: Experience with intraorganizational and interorganizational alliances favors the development and improvement of specific routines of absorptive capacity.	Zahra and George (2002) Lewin et al. (2011), Wang e Rajagopalan (2015) and Rothaermel and Deeds (2006)
	Diversity of alliance portfolio	A	A	A	P6: The diversity of the alliance portfolio provides access to diversified external knowledge, potentiating absorptive capacity, especially acquisition routines.	Moreira et al. (2016), Zahra and George (2002)
	Individual absorptive capacity	A	A	A	P7: The individual absorptive capacity of the team members enhances organizational absorptive capacity.	Cohen and Levinthal (1990), Wang et al. (2014), Martinkenaite and Breunig (2016), Zahra and George (2002)

Note. A = Adherent, NA = Non-Adherent.
Source: Research data.

6. PROPOSITIONAL MODEL

The intra-case investigation and analysis of proposition adherence allowed developing a propositional model of absorptive capacity maturity at Embrapa (Figure 1).

In the propositional model (Figure 1), the central analysis is (a) the potential and realized dimensions, which confer maturity to absorptive capacity of organizations (Guedes et al., 2017). Accumulation of organizational and interorganizational learning in the management of inter and interorganizational alliances (Zahra & George, 2002) enables scalability of organizational absorptive capacity dimensions to life-cycle phases of R&D projects (Mikulskienė, 2014; Pillai et al., 2002; PMI, 2013).

Project A presents scalability of the organizational absorptive capacity for the life-cycle phases of the projects. We have as a secondary category of analysis, in the propositional model, (b) the life-cycle phases of R&D projects. In the early stages, involving (1) initial scope, (2) specification of the project and (3) detailed planning, routines, and processes of acquisition of external knowledge are predominant. In the evaluation phase (4), routines and processes of assimilation of external knowledge predominate.

Table 6
Review and Validation of the Study Proposals from the Intra-Case Analysis for Inductors category.

Analysis Categories	Properties reviewed from intra-case analysis	Project A	Project B	Project C	Revised propositions from intra-case analysis	Theoretical basis
Inductors	Social integration	NA	NA	NA	P8: Social interaction is practiced more in absorptive capacity established in intraorganizational alliances compared with interorganizational alliances.	Zahra and George (2002), Roberts (2015), Dingler and Enkel (2016),
	Appropriability regimes	A	A	A	P9: The appropriability regime is practiced more in absorptive capacity established in interorganizational alliances compared with intraorganizational alliances.	Zahra and George (2002), Teece and Pisano (1994), Ritala and Hurmelinna-Laukkanen (2013) and Henttonen et al. (2016)

Note. A = Adherent, NA = Non-Adherent.
Source: Research data.

Table 7
Review and Validation of the Study Proposals from the Intra-Case Analysis for the Maturity category.

Analysis Categories	Properties reviewed from intra-case analysis	Project A	Project B	Project C	Revised propositions from intra-case analysis	Theoretical basis
Maturity	Systematization and development of routines of the absorptive capacity.	A	A	A	P10: The systematization and development of the routines of acquisition, assimilation, transformation and exploration of external knowledge confer a degree of maturity on absorptive capacity.	Guedes et al. (2017), Lane et al. (2006), Zahra and George (2002), Dingle and Enkel (2016), Roberts (2015), Zollo and Winter (2002)

Note. A = Adherent, NA = Non-Adherent.
Source: Research data.

In the implementation phase (5), routines and transformation processes are recombined with acquisition and assimilation of external knowledge. Project life cycle, recursive cycles of absorptive capacity occur to complement knowledge and enable adequate transformation of the knowledge.

In the phases (6) conclusion and (7) post-project, routines and processes of exploration of external knowledge prevail.

Table 8
Review and Validation of the Study Proposals from the Intra-Case Analysis for the Scalability category.

Analysis Categories	Properties reviewed through intra-case analysis	Project A	Project B	Project C	Revised propositions from intra-case analysis	Theoretical basis
Scalability	Accumulation of learning experience in the acquisition of external knowledge as a potentiator of the scalability of absorptive capacity.	A	A	A	P1: The accumulation of learning experience in the acquisition of external knowledge enhances the scalability of absorptive capacity for alliances partners.	Lewin et al. (2011), Zahra and George (2002), Roberts (2015), Cohen and Levinthal
	Active leadership of R&D projects as a potentiator of the scalability of absorptive capacity.	A	A	A	P2: The presence of active leadership in R & D projects enhances the scalability of absorptive capacity for alliance partners.	Coleman and MacNicol (2016), Packendorff, Crevani and Lindgren (2014)
	Absorption capacity routines in the life cycle phases of R&D projects.	A	A	A	P11: The routines of acquisition, assimilation, transformation and exploration of external knowledge interrelate with the phases of the life cycle of R&D projects, enhancing innovative performance.	Zahra and George (2002), Lane et al. (2006), Lane and Lubatkin (1998), PMI (2013), Pillai et al. (2002), Wang et al. (2014), Dingler and Enkel (2016) and Mikulskienė (2014)

Note. A = Adherent, NA = Non-Adherent.
Source: Research data.

Experience warrants distinction of facilitators of absorptive capacity (Cohen & Levinthal, 1990; Moreira et al., 2016; Wang et al., 2014; Zahra & George, 2002) because it confers organizational maturity and enhances the scalability of routines and knowledge-absorbing practices for life-cycle phases of the projects, as this category involves experience in alliances, portfolio diversity of alliances, and individual absorptive capacity.

Action of inductors of the absorptive capacity (Teece & Pisano, 1994; Zahra & George, 2002) regard antecedents (Lane et al., 2006; Martinkenaite & Breunig, 2016; Volberda et al., 2010). The inductor of social integration enhances interorganizational and intraorganizational alliances. The inductive appropriability regime predominantly maximized interorganizational alliances, these alliances have routines and/or formalization processes to ensure innovation exploration.

A representation of the central and secondary categories of the propositional model is shown in Figure 1.

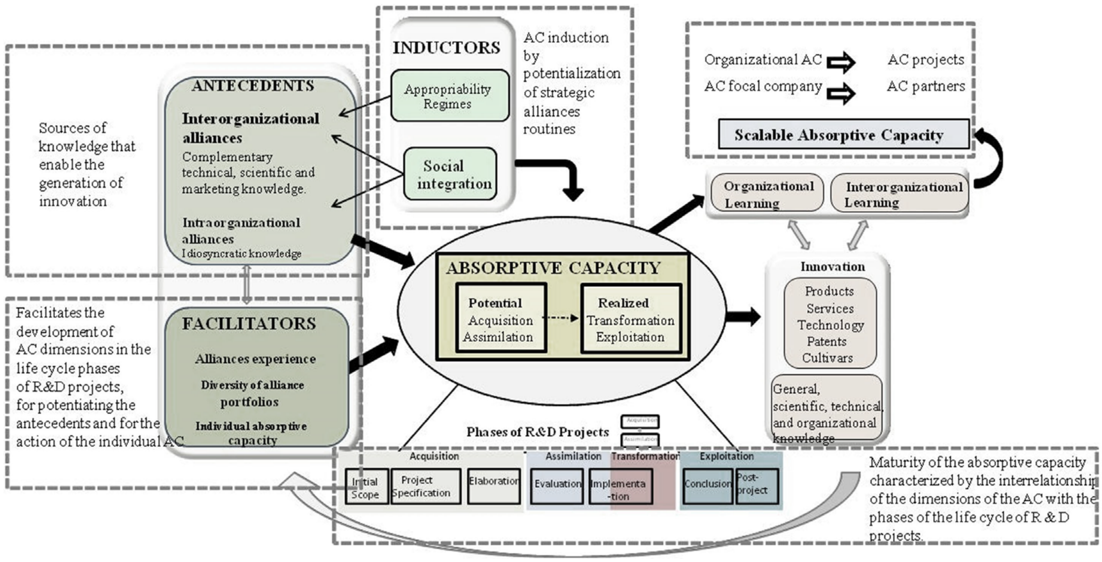

Figure 1. Proposed model of maturity of absorptive capacity in a public research company.
Note. AC: Absorptive Capacity. Representation of the central and secondary categories of the Propositional Model: central category of analysis (a) potential, realized and scalable AC dimensions; secondary analysis categories: (b) life cycle of R&D projects; (c) facilitators; (d) inductors; and (e) antecedents.
Source: Research data.

7. CONCLUSION

Productivity and technology use have increased in agriculture, focused on sustainability. Here, we investigated Embrapa main innovations of R&D projects from interorganizational and intraorganizational alliances: Imidazolinone tolerant soybeans (Project A), first transgenic soybean with 100% Brazilian technology; Coinoculation (Project B), adding *Azospirillum* to the traditional inoculation process, and the brand Neutral Carbon Meat (*Carne Carbono Neutro*) (Project C), meat sustainable production and new markets.

We identified and systematized routines and organizational processes of acquisition, assimilation, transformation, and exploration of knowledge, namely a) routines and procurement processes; b) routines and processes of assimilation; c) routines and transformation processes; and d) routines and processes of exploration.

Routines and processes of absorptive capacity are interrelated with life-cycle phases of intraorganizational and interorganizational R&D projects of Embrapa (Figure 1). Knowledge is constantly acquired, assimilated,and transformed during implementation of R&D projects. Embrapa achieved maturity in the systematization and adaptation of its absorptive capacity with these phases.

At Embrapa, scalable absorptive capacity was evidenced at two levels: intraorganizational and interorganizational. Intraorganizational occurred when routines and processes of knowledge absorption became scalable and, therefore, adapted to the particularization of routines and processes. Interorganizational refers to incorporation of Embrapa routines and processes by partners in interorganizational alliances.

The scalable absorptive capacity proposed here contributes to its emergence: learning experience in absorbing external knowledge and active leadership in R&D projects. The analysis of antecedents, facilitators, and inductors revealed details with a differentiation between intraorganizational and interorganizational alliances.

This study can guide managers of agricultural R&D institutions and other areas because it presents important considerations on the development of absorptive capacity in research institutions, such as fostering the formation of strategic alliances to search for knowledge and increase absorptive capacity, stimulating the training of technical staff, stimulating contact with clients as a source of knowledge acquisition, promoting an environment conducive to the sharing of information, autonomy for R&D execution, use of reward systems, and seeking the scalability of absorptive capacity by forming alliances with leading companies in R&D with experience in acquiring knowledge.

Limitations refer to scalability of absorptive capacity, as it was obtained only from the projects under study and conducted at Embrapa Units, from interviews, non-participant observation and analysis of secondary documents. Future studies should focus on partner's perception of scalable absorptive capacity, scalable absorptive capacity contribution to the maturity of organizational absorptive capacity, alliances in this scalability, and scalable absorptive capacity contribution to partner's innovative performance.

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ADDITIONAL INFO

The authors declare that there are no conflicts of interests regarding the publication of this article. Each author have participated sufficiently int this work. 1st author: collected the data, performed the analysis and wrote the paper; 2nd author: conceived of the presented idea and designed the analysis; 3rd author: contributed data and analysis tools; 4th author: helped shape de manuscript and contributed to the final version.