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Micro-Foundations Of Open Innovation Contributing To Dynamic Capabilities: A Case Study At Eletrobras Chesf

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Abstract:
Background: *This study aimed to understand how companies can develop dynamic capabilities (DC) through underlying processes such as open innovation (OI). Adopting a micro-foundation perspective, we examine the role of Eletrobras Chesf in shaping the UmBUH Hub over the past two years.*
Methodology: *A single case study that focused on the pioneering AI project developed by the Innovation Directorate of Eletrobrás Chesf, the UmBUH innovation hub, which resulted in the incorporation of new CD.*
Results: *The analyses reveal that the company can exploit external, market-based technological knowledge resources during OI activities, as shown by the developed process model reflecting these findings. The identification of three underlying mechanisms of OI, according to Teece (2007) - sensing, seizing, and reconfiguring - establishes a link between the OI process and a company's DC. These mechanisms sequentially and reciprocally alter the company's abilities to detect and seize opportunities.*
Conclusions: *This logic explains how the Hub assists the focal company in external search and the subsequent appropriation of knowledge. This process can rectify the misalignment between current capabilities and future market opportunities, thereby improving the company's DC.*
Keywords: *microfoundations; open innovation; dynamic capabilities; case study; Eletrobras Chesf.*

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Introduction

Within a socioeconomic landscape characterized by technological changes and globalization, organizations are actively seeking efficient strategies of open innovation (OI) to maintain competitiveness[1]. The competition among organizations and economic sectors drives innovation policies aimed at attaining sustainability in business. In such unstable environments, the necessity for dynamic capabilities (DC) to uphold competitive advantage becomes evident, with successful organizations distinguished by their responsiveness, agile innovation, and managerial aptitude [2; 3].

Companies with DC modifications exhibit the capacity to promptly renew internal resources, enabling them to capitalize on market opportunities and ensure competitive advantage[4]. This flexibility allows them to mobilize and exploit resources more quickly. Opportunities are discerned during the process of adaptation to changes or the development of new products or services. Search activities generate exploitable knowledge resources located in the external domains of the company, such as suppliers, customers, universities, technological research centers, and startups. Weber and Heidenreich [5] suggest that OI activities facilitate the exploration of external knowledge to complement internal innovation, thereby serving as an effective means to improve the company's DC[6].

To cultivate DC, companies need to develop microfoundations, which are the underlying mechanisms supporting DC development. Theoretical discussions in this domain have increasingly provided more evidence

on internal management mechanisms that can result in superior DC at the strategic level of the organization. For instance, this article examines the correlation between greater openness to external solutions and the creation of more effective organizational solutions. With this endeavor, we aim to broaden our knowledge in this area, enhancing our understanding of the underlying microfoundations of OI that contribute to a company's DC in the electric sector. This pursuit seeks to answer the question: 'How do open innovation activities contribute to the dynamic capabilities of Eletrobras CHESF, resulting in the creation of the UmBUH innovation hub?'

Eletrobras Chesf has gained prominence as a significant player in hydroelectric power generation in Brazil, overseeing the production, transportation, and commercialization of electrical energy for eight states in the northeast region[7]. In recent years, the sector has experienced market restructuring driven by technological changes, government policies, and legislative changes[8], resulting in both incremental and disruptive innovations in the provision of generation, transmission, and distribution services, as well as in the technologies, equipment, and materials employed [9, 8].

In this context, Eletrobras Chesf launched an energy innovation hub, known as the UmBUH project, in partnership with other technological centers and resources from the National Electric Energy Agency (ANEEL). Spearheaded by Eletrobras Chesf, UmBUH serves as a channel for access to startups, enabling the implementation of innovations in the sector, maximizing the outcomes of ANEEL's innovation projects, and effectively addressing the evolutions in the electric power sector [10].

Adopting the micro-foundations perspective facilitates a more comprehensive empirical understanding of the OI mechanisms that have contributed to the company's DC. This is particularly pertinent given the extensive literature available on OI and DC, which has documented numerous cases of both success and failure, thereby resulting in the refinement of three micro-foundations developed by Teece [11]: (1) sensing, (2) seizing, and (3) reconfiguring. Each of these micro-foundations interacts with one another and can be identified in the structuring of DC.

The motivation for this study stems from the understanding that OI activities induce behavioral changes, leading to the inception of the UmBUH Hub project in the company, thereby contributing to the company's DC. With this objective in mind, we aim to deepen our understanding of the underlying relationship between OI and DC from the perspective of micro-foundations.

I. Theoretical Framework

Micro-foundations and Dynamic Capabilities

The micro-foundations perspective describes lower-level managerial mechanisms that impact the operations and outcomes of the organization. Grigoriou and Rothaermel[12] posit that these mechanisms include the actions of individuals that exert the most impact on business outcomes, while others emphasize the role of organizational processes and activities[13]. In this study, we adopt the concept of micro-foundations as articulated by Felin et al.[14] and Ferraris et al. [15]. They define micro-foundations as the actions of agents in proximity to a specific event that are not solely explicable by the actions of these agents alone, thereby indicating that they are not reducible to individuals. This perspective can be used in identifying operations that facilitate the absorption of external knowledge and the interaction with new partners to integrate new knowledge into the focal organization[16].

Consequently, the micro-foundations perspective can be used to empirically explore the actions that shape organizations and enable the incorporation of innovation, thereby enhancing the understanding of organizational mechanisms that contribute to the DC of the company.

DC represents the capacity to create new resources and strategically broaden the current resource base [17] in response to external transformations. These resources include tangible, intangible, and human assets that the company possesses, controls, or accesses[18]. They can be continually adapted to align with external dynamics. Rothaermel and Hess [19] propose that DCs can be deconstructed into micro-foundations, which represent processes, skills, and structures.

The first micro-foundation, termed sensing, pertains to activities centered on recognizing and shaping market opportunities, with research investment serving as a necessary complement. This entails identifying opportunities through a thorough examination of customer needs, available technological alternatives, latent demand, sector evolution, and supplier and competitor behaviors[20]. Such efforts enable the company to effectively adapt to environmental changes[4, 2].

After the detection of opportunities through sensing, it becomes imperative to invest in them through seizing activities, typically done through the introduction of new products, processes, or services. This necessitates investment in development and commercialization, as well as the implementation of timely decision-making strategies. The challenge of this phase also involves selecting a business model that adheres to the organization's strategy and investment priorities. The execution of seizing requires the direct involvement of managers to reduce the inherent anti-innovation bias towards what is new. Seizing seeks to align business models with customer needs and provide conditions for value capture[4].

The preceding elements (sensing and seizing) can result in growth and profitability, but it is the reconfiguration activities that will ensure continuity to routines and the configuration of organizational culture in changing environments. For the sustainability of the new business model, reconfiguration should aim for decentralization, as the absence of which threatens organizational flexibility, along with the implementation of modern techniques of human resource management, knowledge, and learning mechanisms[4, 2]. Table 1 below presents the micro-foundations of dynamic capabilities.

Framework 1 – Micro-foundations of Dynamic Capabilities

	MICRO FOUNDATION	CHARACTERISTICS
Micro Foundations of Dynamic Capabilities (DCs)	Sensing	Monitoring phase where the organization seeks to detect new opportunities through the exploration of new technologies.
	Seizing	Appropriation phase where managers will make decisions regarding which opportunities to invest in and allocate resources.
	Reconfiguring	Reconfiguration phase where the organization's design is implemented, and internal culture is nurtured to embrace changes.

Source: Adapted from Teece

Therefore, the development of DCs requires a set of behaviors and skills pertinent to change and innovation, including attitudes, loyalty, and commitment to transformation[21, 22], including: (a) identification and exploration of opportunities, as well as the recognition of the value of external information and its commercial application[23]; (b) development of new, rapid, or superior strategies in relation to the competition, coupled with the ability to learn and adapt; and (c) competencies beyond operational routines, such as communication, negotiation, conflict resolution, leadership, economic analysis of ideas, problem-solving, and project and people management[21].

The approach to DCs holds particular relevance in the context of innovation, as the accumulation of new resources is more important than its current stock[4, 24]. These interactions are useful for building competencies in R&D, as well as in the development of new products and technological innovations. To effectively harness these capabilities, it is important to manage distinct stakeholders, who may be separated by geographical and cultural distances and possess varying senses of urgency, yet can collaborate to share knowledge, competencies, and technologies, thereby generating innovations that may be unattainable individually[25].

Open Innovation (OI)

OI represents a distributed process depending on the management of information and knowledge flows to transcend organizational boundaries. It uses both financial and non-financial incentives to strengthen the company's business model[26, 27, 28] . This protocol facilitates innovation activities by actively seeking, shaping, and integrating external knowledge. External factors, including suppliers, customers, industry experts, and consultants, serve as sources of knowledge that complement internal innovation activities[5].

In this context, innovation hubs are tasked with facilitating knowledge exchanges and actively seeking new ideas, concepts, and technologies that can benefit the company, often collaborating with technology-based companies (TBCs), startups, and other stakeholders[29]. Hubs serve as agents of change, bringing together various stakeholders in the ecosystems where focal companies operate and generating value through knowledge exchange[30]. During the hub's active search process, the external knowledge accessed can be classified as either market knowledge or technical knowledge[31].

Market knowledge pertains to understanding customer needs, a facet that can be explored through the internal R&D department, leading to the inception of new products and services in alignment with market requirements[22]. Conversely, technical knowledge involves an understanding of the materials or products with which the company engages, ultimately influencing their application within the company. The Hub assimilates both technical and market knowledge to innovate new solutions for customers or employees[32], thereby playing a fundamental role in the operationalization of OI processes.

Dynamic Capabilities linked to Open Innovation

The focus here lies on the inflows of knowledge that enable access to external solutions through the initiatives of the UmBUH Innovation Hub. This dynamism empowers the company to develop expertise about its business environment, resulting in the development of DCs[32, 33], thereby enabling it to perceive changes in the market, opportunities, and potential threats[34]. According to Jasimuddin and Naqshbandi[35], companies must develop an organizational structure, culture, and managerial techniques to facilitate this flow of knowledge, thereby improving the internal capacity to seek and integrate external knowledge, ultimately improving performance[36, 37].

As noted by Hutton, Demir, and Angwin[38], the microfoundations of OI occur at the individual or project level. From an individual perspective, individuals identify external knowledge flows, perceive environmental

changes, and capitalize on opportunities to explore resources and capabilities, thereby demonstrating sensing capability. From a project perspective, for instance, analyzing the correlation between the quest for external knowledge and the success of Innovation Hub activities constitutes an OI project.

After identifying the opportunity, the next step is seizing it in the market, a fundamental aptitude for the development of DCs, which manifests in mobilizing and creating capabilities for technological and management solutions[4]. A corporate innovation hub enhances the capacity to integrate external knowledge and solutions with internal processes[29] by mobilizing individual and project-level factors, thereby influencing the company's seizing capability.

According to Dahlander et al. [3], the individual level is elucidated when individuals leverage their personal relationships to build external relationships. The scope of these relationships depends on technical expertise, creativity, informal relationships, willingness to take risks, experimentation, and willingness to learn[39]. From a project perspective, both formal and informal project management approaches impact outcomes[21,40,41]. Generally, authors such as Du et al. [40] understand that lower-level devices can impact a company's seizing capability; however, the definition of which OI mechanisms contribute to the seizing capability—an important function of DCs—remains unclear, as noted by Teece [22].

Consequently, the literature indicates a relationship between OI and a company's DCs [22, 1, 6, 38], yet there remains no convergence on how DCs can be strategically planned and developed to achieve greater business competitiveness. Despite the delineation between the individual and project levels as important aspects of microfoundations, individual-level OI knowledge that can be causally linked to the development of DCs still warrants further study[38] .

This study does seek to provide definitive answers demonstrating this causality. Instead, by proposing this study, it aims to provide more evidence explaining the activities that can assist in creating resources and capabilities, thereby bestowing greater dynamism upon the organization. The Hub, functioning as an OI strategy, necessitates access to technological resources and external market knowledge for integration into the Eletrobras Chesf Corporation. The description of this experience, as conveyed through managers' reports, presents an opportunity to examine the mechanisms adopted by individuals in the relationship between CHESF and the Hub, thereby explaining certain micro-foundations of OI that contribute to the development of a company's DCs.

Materials And Methods

Research Design

This research methodology aims to assist in understanding how OI can contribute to DCs, particularly from the perspective of the managers of the Innovation Directorate. According to Randhawa et al[42] and Obradović, Vlačić, & Dabić[43], existing studies on OI have focused on the role of knowledge, technology, and R&D, often from the perspective of innovative companies. While other gaps remain, particularly regarding individual perspectives.

The single case study was deemed appropriate for analyzing the actions undertaken in the investigated company's subunit [44], as it is a representative organization within the sector and its suitability for the application and testing of the chosen theoretical framework [45].

We analyzed the pioneering OI project, the UmBUH innovation hub, by following the actions of the directors and employees of the Innovation Directorate. This involved identifying behavioral regularities in OI activities and understanding the foundations for the development of DCs. The chosen level of analysis was individual, which facilitates the identification of knowledge flows and is better positioned for understanding environmental changes and the seizing of opportunities to explore resources and capabilities [20, 38]. The chosen unit of analysis pertained to the actions undertaken within the company to facilitate the innovation hub.

Research Context

The chosen unit of analysis was Eletrobras Chesf, a subsidiary of Eletrobras that has been operating in the Brazilian electrical sector since 1948. It plays a strategic role in electricity generation and transmission in the Northeast region of Brazil[46], boasting significant installed capacity and being distinguished by its comprehensive infrastructure and crucial role in the regional energy matrix. Moreover, it plays a significant role in research and development endeavors concerning technologies for energy efficiency and sustainability, aligning with the contemporary demands of the global electrical sector.

It actively participates in activities and OI initiatives for the development of innovation projects and partnerships with companies and experts across various fields. In essence, it is an ideal corporate environment for conducting a study on OI, considering both the range of activities undertaken and the stakeholders involved[47]. Consequently, it was feasible to identify the underlying principles of OI activities that contributed to the development of DCs, meticulously analyzing the strategies and operations of managers and employees during the years 2022 and 2023. During these two years, the hub mapped more than 10 innovation challenges, with five currently in the implementation phase, while the remaining ones are still in the MVP and prototype phases. The

anticipated financial gains from the implementation of these solutions substantially exceed the project's cost. Presently, the portfolio of projects developed by the Hub is growing, supported by the successful implementation of the first challenges, indicating ongoing support in the development of Eletrobras Chesf's DCs through OI activities.

Case Selection

Eletrobras Chesf Corporation currently has 10 major R&D projects underway, indicating a commitment to investing in and prioritizing innovation to leverage the company's operations. One of these projects is the UmBUH Hub, designed to structure the innovation cycle, providing a platform for the application of agile OI methods, aiming to leverage new business opportunities and ensure compliance with the regulatory framework of the sector, specifically the ANEEL Innovation Manual (PeQuI 2023–2028)[48]. The innovation hub is poised to provide support, training, and capacity building, thereby fostering competitiveness and potentially contributing to the future development of the Brazilian Electrical System by combining established OI concepts with the search for innovative solutions.

The establishment of the Hub was a response to the company's diminished innovative capacity compared to other entities within the sector. It sought to address a knowledge gap and competitive disadvantage while endeavoring to adapt and integrate external solutions into the company's operational environment—an operation that, according to Chesbrough[49], is not fully documented and still lacks structured processes, making it challenging to monitor and measure results. Consequently, this analyzed case serves as a lens through which to explore the internal and external forces driving innovation and the capabilities developed to leverage new flows.

Data Collection

Primary data collection was conducted through interviews with managers and employees of the innovation directorate during the implementation of the Hub project. The authors, as part of the executive team of the hub, were granted access to project reports, internal communications, and interaction with the managers and employees involved. This facilitated comprehensive data collection, including aspects such as the preliminary costs of the Hub, the requisite competencies of the members, the execution schedule, partial reports, and participation in selected meetings and challenge workshops organized by the Hub. These pieces of information enabled the assembly of a *corpus* of secondary data for the research, supplemented by subsequent interviews conducted with key informants possessing insights into the venture[50]. These subjects, usually challenging to access for research purposes, are directly involved in the development of DCs instrumental to the implementation of the OI Hub, thereby offering access to relevant data.

Table 1: Data obtained from the UmBUH project.

Data	Source	Project UmBUH
Emails	Messages	87
Meetings	Google Meet sessions	47
In-person	Meetings Face-to-face	7
Reports	Documents	6
Interviews	Duration	4h:30 min

Source: The authors (2024)

The interviews recounted the internal dynamics involved in the execution of the Hub, explaining the underlying motivations and the process involved in searching for critical resources and knowledge. They were based on a meticulously structured research protocol organized in three phases, including a total of 22 questions. This process involves the identification of the present motivations behind seeking knowledge beyond the company's walls, thereby explaining the contributions of OI to the viability of the Hub and the knowledge flows that contributed to the acquisition of new capabilities. Key questions, such as: 1) "Tell us a bit about the internal and external articulations necessary for innovation projects to occur?" and 2) "Can you summarize the main gaps present in this previous process that led to the need to create an open innovation strategy with the UmbUH?" were instrumental in this regard. The interviews resulted in a total of 37 transcribed pages. However, certain strategic details were omitted from the transcriptions due to the involvement of external actors.

Data Analysis

The data analysis entailed a combination of a case study approach with a theoretical survey to substantiate the findings and achieve a better understanding of the object under examination[51]. The analyses began during the data collection stage, noting the first impressions based on previously conducted theoretical readings.

We created a timeline detailing the execution of the project under analysis, mapping pivotal decisions and important meetings. This phase was facilitated by the obtained emails and reports, which provided information for internal decisions and identified gaps that resulted in the establishment of the Hub. Subsequently, our focus shifted towards external interactions to gather evidence of OI activities. This approach facilitated the emergence of certain categorizations, deduced inductively, relating to the knowledge flows and assets mobilized.

There was a concern to elucidate how external contributions influenced the overall project execution, highlighting the most important activities that helped overcome the identified capacity gaps. In summary, the analysis was structured in three stages: data pre-analysis, material categorization, and data treatment, as depicted in Figure 1.

Chart 1: Structuring of the analyses

Monitoring and identifying capacity gaps	Prospecting external resources and knowledge	Appropriation of knowledge
• Lack of knowledge. • Absence of critical resources.	• Seeking external knowledge. • Identifying lack of experience. • Market knowledge entry. • Technical knowledge entry. • Expanding the search for knowledge.	• Inflows of knowledge leading to new ideas. • Behavior modifications.

Source: The authors (2024)

Data triangulation was consistently used, enhancing the validity and reliability of the data[52] through comparison and discussion to address data gaps and resolve inconsistencies. We followed the investigation trail to ensure construct validity, thereby ensuring the accuracy and consistency of the measures adopted. Furthermore, while this study constitutes a single case study analysis, its representation stems from theoretical generalization, bolstering external validity. Finally, external validity was bolstered by transparency in presenting the research stages, facilitating the application of the findings to broader contexts or similar situations where OI contributes to companies' DCs.

Results

Both the global electrical sector and the Brazilian Electrical System (SEB) are undergoing transformations that require DCs to adapt to innovations in the provision of generation, transmission, and distribution services, as well as advancements in the technologies, equipment, and materials employed[46, 53]. In this context, Eletrobras CHESF must resort to OI to meet the demands of a vast territory with continental dimensions and a growing electricity demand, estimated at 1.6% annually until 2050. These transformations have led CHESF to prioritize investments in OI solutions to facilitate knowledge-based innovation.

Given these specific technological and market challenges prevailing in the sector and in compliance with Law No. 9,991/2000 enacted on July 24, 2000, which mandates that concessionaires, permittees, and authorized companies in the public electricity service sector allocate 1% of their net operating revenue (NOR) to R & D projects, seeking to align with the guidance of this law, Eletrobras Chesf scheduled the allocation of R$ 420 million for technology development and innovation projects spanning the period from 2019–2023[53, 54].

These milestones represent significant achievements in reducing the innovation gaps within the company, focusing on shifting the focus of innovations from R&D projects to market-integrated innovations. The UmBUH emerged with the objective of improving the maturity level of innovative solutions tailored for Eletrobras CHESF, a feat unattainable within the confines of traditional institutions and research centers. Other motivations stem from the study by Junior et al.[55] indicating a limited internal innovation chain wherein only a small portion of R&D projects reach the industrial development stage. Out of a sample comprising 41 completed projects within companies operating in the electrical sector, merely 02 advanced to the stage of procedures leading to intellectual property treatment, and 1 made it to the market with technological licensing to a startup. Both Cabral[56] and Bezerra [53] studies recommended the need to integrate innovation management strategies for the sustainable development of the entire innovation cycle. The Hub highlighted the need for the development of mature, innovative solutions, leading to the mobilization of resources and knowledge to address this *capacity gap*.

Starts with Sensing

At Eletrobras CHESF, the inception of the UmBUH Hub project was due to a response to market changes identified internally by the managers. As soon as the project began, it became evident that there was a knowledge gap in the company, necessitating the development of new critical resources essential to enabling the Hub (Framework 2).

Framework 2: Monitoring Capacity Gaps

Mechanism	Description	Example
Absence of Capability	The company recognizes market opportunities with innovation potential.	We realized that we needed to keep up with the market and accelerate our innovation processes here, bringing changes to processes to stand out in the market more efficiently. We felt the need to increase confidence in the innovation process, simplify and make it clear, as well as empower employees to embrace the culture of innovation" (E5).
Absence of critical resources	The company acknowledges a lack of internal knowledge to develop innovative projects.	"If I have a portfolio of ten projects to be addressed in the next five years, how much will that investment I'm going to make translate into results? The market wants projects with high maturity. And how much of that result was incorporated within the company. And it doesn't stop there. Was it incorporated? Okay. How much did it translate into returns. Financially and economically. The big challenge now is this. This is already the biggest of all" (E2).

Source: The authors (2024)

Acknowledging this capacity gap is necessary for attaining higher rates of innovation and immediately underscores the need for a new capacity, facilitating access to critical resources and engagement in technical and market knowledge flows. Such imperatives are enabled by the OI strategy, as shown in the following reports:

> *With the hub, we adopted a direct approach to problem identification and resolution. We start with a survey of company demands and pain points to find practical solutions that add value. Our goal is to highlight Eletrobras CHESF in the market, creating effective solutions in the short, medium, and long term for identified demands (E5).*

It was the company's first innovation hub and was financed with R$2.09 million. The innovation department realized the need to keep up with trends observed in other companies within the sector, which were hiring startups and mature technology-based companies for Proof of Concept (PoC) or Minimum Viable Product (MVP) development. In a bid to overcome the previous slow pace of innovation projects, the hub's implementation started with a survey of internal technical challenges in the first month. Subsequently, a call for 05 challenges was issued across the thematic areas, including energy commercialization, electric system operation, asset management, processes, and information, '*with a final investment of approximately R$1.0 million to address the 5 Challenges'* (E4).

The circumstances before the establishment of the Hub were characterized by a dearth of projects close to the final stage of the innovation chain (TRL 7, 8, and 9), namely those operational in the company and meeting the demands of managers from different departments of the company. This deficiency was further underscored through interactions with external stakeholders, serving as an external source of knowledge. Therefore, during the modeling phase of the Hub in 2021, the Innovation Department called in external experts, outside the typical bureaucratic routines of large companies in the electrical sector, from various areas to form a team with multiple competencies, connected to the dynamics of innovation in the current electrical sector.

The scarcity of innovation projects with higher maturity levels raised concerns within the corporation as it *'could not develop projects with higher TRL levels that we could even choose to commercialize to other companies in the electrical sector'* (E4) and needed to keep up with other companies in the sector such as EDP Energias do Brasil, Copel, Companhia Paranaense de Energia, and CPFL, all reaping good results through the establishment of their respective innovation hubs.

This concern for Eletrobras Chesf to realign with market dynamics is evident in the research conducted by Cabral[56] and Bezerra[53], wherein they analyzed the results of mandatory investments dictated by Law No. 9,991/2000. This notion was further supported by the studies undertaken by the Center for Management and Strategic Studies[58] and the Institute of Applied Economic Researc[57.] These four works examined the alignment of the company's technological development projects with OI management trends, identifying a dearth of clarity regarding the anticipated results. This diagnostic revelation, suggesting the gap, highlights the challenges in defining the project scope and its framing within the stages of the innovation chain defined by ANEEL. Additionally, the studies underscore the importance of the project to not only focus on technological development but also facilitate market integration.

Advances to Seizing

Acknowledging the knowledge gaps at Eletrobras Chesf, efforts were made to address these through the modeling of the hub, using the mechanisms described in Framework 3, as described below.

Framework 3: External Research Prospecting

Mechanism	Description	Example
Seeking external knowledge	Seeking knowledge outside of Eletrobrás Chesf to support the development of new products.	"The idea of the hub arose due to the difficulties encountered in the development of internal solutions and also looking at the market dynamics" (E1).
Revealing lack of experience	Demonstrating a lack of knowledge within the focal company for the development of a new product.	"We want to develop some projects, right, from various areas [...] but people want agility. They want answers that are faster than what we currently have" (E4).
Market knowledge flows	New market opportunities presented during the development process.	"For many years, we lived in a bubble, doing only the minimum and mediocre, and the hub has shown that we needed to take a step forward. It brings relevant knowledge valued in the market" (E1).
Technical knowledge flows	Technical knowledge from outside the organization being communicated to the innovative company.	"We have some criteria, but we try to take the best practices from other companies, both state-owned and private" (E1).
Expansion of Knowledge	Search Technical knowledge outside the company being provided by an extension of the original recipient	"So, I saw there a presentation of a project that the startup had a link, for example, with UFCG. The other had a partnership with a research company, you know? So this brings them closer and increases this exchange of ideas, which is very good," (E4).

Source: The authors (2024)

During the external knowledge search, findings highlighted that Eletrobras Chesf lacked certain knowledge and needed to involve not only internal collaborators associated with the innovation department but also external partners and management teams from various divisions within the company. This collaborative approach is important in collectively devising solutions, particularly when embarking on unique OI projects in the market. The company seeks to achieve specific goals and strengthen its flexibility, adaptability, and continuous learning, as well as the ability to quickly mobilize internal and external resources. Therefore, project co-creation ends up not being just an isolated strategy but a continuous approach to strengthen the organization's innovation and continuous learning and overcome the lack of experience[17, 59].

The hub's decision-making process meets the proposal to accelerate the OI process by consolidating the specific challenges encountered by various internal departments. This alignment entails harmonizing corporate demands with the intrinsic challenges of each business area and, externally, with solutions available outside the company. The significance of achieving this alignment is underscored, as it involves an understanding of the unique business dynamics of Eletrobras Chesf, meticulous modeling of the challenges, and the establishment of an effective match with the sector ecosystem. The viability of the hub was due to a strategic partnership between Eletrobras Chesf, the National Institute for Semi-Arid (INSA), and the Paraíba Technological Park Foundation (PAQTCPB) in partnership with ANEEL[60]. Interviewees highlighted the complexities of this consortium, highlighting the challenges that some hubs encounter when exploring and making this *match* between internal challenges and external solutions. The challenge arises within the corporate framework, and the hub's mandate is to effectively address these challenges to fulfill its purpose of delivering business value.

The **absence of experience** in certain innovative capabilities poses the risk of the hub failing to demonstrate economic and technical viability. This risk is associated with the alignment process between startups and technology-based companies (TBCs) with Eletrobras Chesf executives, who seek to raise the quality of deliverables to surpass existing market solutions.

This risk stems from the process of **seeking external knowledge,** where Eletrobras Chesf identifies internal gaps to undertake innovation projects aimed at yielding mature, innovative products. Therefore, the search for "best practices" and the assimilation of external technical knowledge become key dynamic capabilities. These capabilities facilitate access to startups and TBCs, enabling the incorporation of unique solutions at an operational level and leveraging internal learning. In essence, the flows of **technical and commercial knowledge serve as** a response to the company's knowledge gap, manifested as a technical obstacle hindering the attainment of sustainability amidst industry changes. For instance, a technician from Eletrobras Chesf was asked about their opinion on the increased access to external knowledge flows brought by the hub, to which they responded, *'The establishment of the innovation hub shows Eletrobras Chesf's ability to connect with the external innovation ecosystem and seek solutions outside the organization, contributing to the electrical industry, for example, in sustainability*' (E3).

The knowledge gap, coupled with specific requirements, led to the **expansion of knowledge search** to address the challenges. Consequently, external actors began to be actively sought, resulting in the emergence of new knowledge flows:

> Our innovation practices were more focused on what already existed, generating a very rigid structure, and today we are managing to have flexibility, we are oxygenating ourselves and having the opportunity to act more quickly in this context of sector changes by actively seeking knowledge in our ecosystem, both from ICTs and startups (E1).

In this new context, active search facilitates knowledge flows from previously unknown or inaccessible domains.

Reaches Knowledge Appropriation (Reconfiguration)

At Eletrobras Chesf, the most successful projects have demonstrated the appropriation of technical or market-related knowledge from external sources. Knowledge appropriation represents the introduction of new ideas that lead to new knowledge outputs and can also result in changes in behavior. The processes for appropriating new knowledge resources are described in Framework 4.

Framework 4. Knowledge Appropriation - Conceptual Descriptions and Empirical Examples.

Mechanism	Description	Example
Knowledge input flows leading to new ideas	External knowledge input that stimulated a new idea within the company to support the development of the Hub.	"There was an initiative [...] of innovation training [...] four classes with twenty or thirty members were formed [...] then there was an immersion where groups with different needs would come together to propose ideas on their own. The Hub complements this training with ideas and helps in understanding what the company asks for" (E1).
Modifying Behaviors	Internal behavior modification after external knowledge input.	"We are reaping the benefits with this expanded approach to innovation. We are already launching a new challenge. We have matured so much that we save a huge amount of time on this innovation journey (...). The employee is qualifying much faster with this knowledge exchange, and, as a result, Chesf has promoted the culture of learning and innovation internally" (E1).

Source: The authors (2024)

The Hub was a new approach for the company, diverging from its previously used innovation strategy, which entailed addressing various technological challenges through partnerships, mainly with universities and ICTs, over a time horizon of several years of research. The inception of the Hub brings new **flows of knowledge input** and processing, stimulating, and accelerating the maturation of this process: '*Recently, with the issue of bringing startups on board, we have obtained very positive and faster results (...). We have products from challenges that had good proposals from partnerships with these startups'* (E1).

This resulted in a change in behavior among internal collaborators, who acknowledged cultural and operational changes towards a more innovative and agile mindset, thereby resulting in the perception of added value and strengthening of the CD. This strengthening is evident when the collaborator states that: '*The hub makes it clear that agile methodologies bring added value to our collaborator more quickly, and this is what companies are trying to seek in the market in general, and Eletrobras Chesf is attentive to this'* (E5). Here, agility emerges as a component of CD, as it underscores the importance of the company's capacity to adapt its practices and processes to align with market dynamics. Additionally, the prompt recognition of the added value for collaborators and market orientation reinforces the pursuit of effective external orientation, which is essential for OI.

Behavioral modifications occur amid the influx of internal and external knowledge, facilitating the transition from the conventional procedural paradigm inherent in conservative organizations, such as Eletrobras Chesf, to agile methodologies. This transition constitutes another manifestation of dynamic behavior intrinsic to the organization. This operation stems from the influence exerted by the Hub, which brings '*a constant concern to evolve and improve internal processes in the operations carried out by delivering value in the form of mature, inexpensive solutions that impact the market'* (E5), contributing to the establishment of new capacities aimed at designing processes, operational standards, and professional attitudes focused on generating collaborative solutions[6].

Finally, involvement in OI activities during the development process of the Hub UmBUH facilited Eletrobras Chesf in its quest for innovation capabilities, thereby bridging a competency gap between the focal company and its competitive environment. The mechanisms through which OI activities contributed to the acquisition of new capabilities *include sensing a capacity gap (sensing), engaging in external search (seizing), and knowledge appropriation (reconfiguring).* These mechanisms operate sequentially, with each mechanism interacting with the sensing and capturing abilities of the CD.

The sensing of a capacity gap occurred when CHESF became aware of an opportunity to develop innovation competencies and the lack of critical resources to seize the opportunity. This realization constitutes a sensing mechanism and, in our case, was triggered by external commitments. Once the capacity and critical

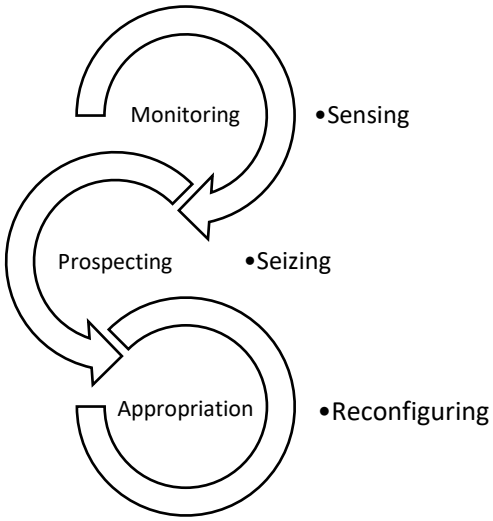
resource requirements were established, Eletrobras used OI activities to leverage external knowledge resources (*seizing)* located in the knowledge domains of external stakeholders.

Knowledge appropriation *(reconfiguration*) occurs subsequently to market and technical knowledge flows and serves as a *seizing* mechanism. This mechanism was observed through the development of innovative approaches, resulting in the generation of more mature solutions and behavioral modifications that also led to a greater perception of market opportunities.

Discussion

The aim of our study was to recount the establishment of the UmBHU innovation hub by the company Eletrobras CHESF. Our study reveals that the OI process consists of three micro-foundations, each exhibiting different levels of interaction with OI activities. The analyses lead to the suggestion that these three micro-foundations can be integrated into a process that explains how these mechanisms interact, ultimately fostering the development of firm-level capabilities (see Figure 1).

Figure 1: AI Micro-Foundations Contributing to Firm CD



Source: The authors (2024)

The depicted process illustrates how Eletrobras Chesf used OI to build new capabilities through a sequential process guided by the three micro-foundations. Initially, *monitoring* occurs as the company recognizes the need for new capacity, a need met through the establishment of the UmBUH Innovation Hub. *Monitoring, serving as* a *sensing* mechanism, can be initiated internally or externally and occurs when previously unknown market-related knowledge is brought to the attention of the company, thereby opening new opportunities for value creation. This external knowledge is acquired through the organization's external relationships and commitments. OI facilitates market monitoring and fosters open communication, enabling the company to glean insights into the demands and available solutions in the electric sector ecosystem.

Previous studies have highlighted that ideas for prospective projects may arise after knowledge-seeking activities[21, 20] and that the realization of resources and capabilities occurs when the company recognizes the value of new opportunities[17, 2]. However, we contend that monitoring expands the role of search activities. The findings demonstrate that the conditions necessary for initiating monitoring occur before the start of an OI process and during the AI development process. This implies that OI commitments increase the probability of the company identifying opportunities, thereby reducing the gap with external stakeholders possessing valuable information[61, 62]. Consequently, it is understood that the OI process enhances monitoring, and a company adept at monitoring may experience greater ability to perceive new opportunities in support of its CD.

After conducting monitoring, companies may choose to act on a newly identified opportunity through *appropriation* when they perceive a knowledge or capacity gap, which can be technical or market-related. Appropriation is an iterative process that combines externally sourced knowledge with the company's internal knowledge stock in pursuit of new knowledge and solutions. Therefore, as per Pollock et al.[43], it represents a mutual learning process that can grant the company access to an expanded network of knowledge while granting external stakeholders access to specific technical expertise for project modeling purposes. The study illustrates that, during engagement, the company can benefit from these new flows, while external stakeholders develop a greater understanding of the company's capabilities, a situation that, as noted by Remneland Wikhamn and Styhre[63], engenders greater assertiveness in Hub modeling.

Previous AI studies have mapped knowledge input and output flows as OI micro-foundations at the firm level that grant access to knowledge resources located outside their boundaries [63, 64, 20, 24]. However, our analyses extend the contribution of these studies, revealing that the OI process incorporates input and output knowledge-seeking mechanisms, and these mechanisms can occur as part of a cumulative learning process based on reciprocal knowledge and extended knowledge networks. Therefore, echoing Demir and Angwin[36] and Yassiva, Priyono, and Wibowo[37], we suggest that companies engaging in high levels of knowledge input and output may experience higher levels of innovation outcomes. Additionally, this research attempted to associate a company's knowledge recombination capability with increased innovative performance [65, 63.]

Referring to the final element, *deployment*, is the process of incorporating knowledge and developing new capabilities. Deployment occurs after appropriation and requires knowledge flows to impact the course or direction of the OI project. Deployment occurs when there is a mutual understanding of project requirements and external technical knowledge flows trigger an internal idea that leads to opportunity creation [66, 67]. It may also result in behavioral modifications that occur at the process level, affecting the project's direction and leading to new experiences and approach changes.

Existing AI research has established various factors influencing the creation of new ideas. We contribute to this stream of research by revealing that the OI process incorporates a knowledge creation process that can lead to new ideas in support of business innovations. This knowledge creation process can result in new technical knowledge, triggering behavioral modifications that impact the course or direction of the OI process, or new market-related knowledge that can trigger the realization of new opportunities.

Conclusions And Implications

This study aimed to answer the following research question: *How do OI activities contribute to firm dynamic capabilities (CDs)*? We used Teece's (2007) theoretical lens of micro-foundations of dynamic capabilities to analyze the creation process of the UmBUH innovation hub. In describing this experience, three OI artifacts were established: monitoring, prospecting, and appropriation, representing a sequence of actions that allow access to knowledge and the creation of resources that strengthen the firm's CDs. There was an effort to map the micro-foundations treated by Felin et al.[15] that enable access to and renewal of the firm's critical resources through AI strategies. This process changes the behaviors and skills of the firm to locate and seize market opportunities. The *sensing* and *seizing capabilities* end up aiding in identifying new market opportunities that were not previously on the companies' radar. Thus, supporting incremental capability and creating critical knowledge resources are fundamental activities that sustain the CD framework. The OI activities developed during the Hub implementation process represented an internal restructuring of the old innovation board, relinquishing responsibility and control of innovation resources and knowledge to a structure that favors inclusion and co-creation of solutions. In these terms, OI ends up shifting the focus of CD structure from something strictly related to the internal resources of the firm to incorporating the ability to seek external relationships. Certainly, this OI movement towards seeking external knowledge results in an improvement of internal capabilities, enhancing CDs.

The **initial theoretical contribution** to **OI micro-foundations** research lies in the empirical translation of the subcategories of AI dynamic capabilities that lead to the creation of new resources and capabilities. These are: monitoring, prospecting, and implementation. The intention is to democratize the understanding of a theory that has been gaining increasing prominence in open innovation studies [68]. The research here identified some individual-level factors[20, 63,39] that can affect innovations at the corporate level. This perspective leads to exploring research paths that may analyze the micro-foundations of OI at the project level, such as modeling and managing AI projects[21, 69,70], or factors at the process level[71], and how they may or may not affect mechanisms at the individual level.

Moreover, the conclusions consider that the implementation of AI micro-foundations occurs through a dynamic and sequential process, highlighting the firm's ongoing ability to adapt to market changes. Thus, a way to enable future research is through exploring micro-foundational mechanisms at various levels of analysis and how each one influences the analysis of capabilities.

The research also had **implications for OI and CD analyses**. Teece[13, 2] argues that CDs have been vital for firms' survival in markets with high rates of technological change by embracing digital transformation, for example. Here, AI becomes an ally by providing management tools that assist existing CDs in mobilizing new external resources and knowledge. Therefore, it is crucial for firms to strive to develop AI capabilities that assist sensing and seizing capabilities at the firm level.

The micro-foundations perspective also allowed for deeper exploration of previous research on the relationship between AI and CDs [41], offering an individual perspective instead of just staying at the company level. Consequently, it opened up the perspective of analyzing these mechanisms from different levels of analysis.

It was also possible to reveal that AI is an important strategy in mobilizing critical knowledge resources, highlighting its importance in firms' absorptive capacity[34], who also highlight individuals' perspectives in creating new and innovative ideas that are later incorporated into firm innovation activities. In this study, we showed that

access to knowledge flows can occur while innovation projects are being developed, as happened during Hub execution. This occurs as access to knowledge generates behavioral changes that impact the execution of innovation projects.

With regards to the **research limitations,** it can be highlighted that, despite being representative of its sector, empirical data were extracted from a single large corporation in the electric sector. Thus, the data may have biases from the idiosyncrasies of the organization. However, other studies can explore this relationship between OI micro-foundations and CD development or the model presented in Figure 2 in other companies and business environments, such as agribusiness, mining, construction, retail sectors, or even SME environments, where this sequential pattern of new knowledge input, which generates new internal ideas, changes ingrained behaviors, and can generate knowledge output flows, can be identified. Analyzing these relationships in other contexts may lead to a better understanding of suitable behaviors for the development of successful innovation projects and behaviors to be avoided. Other organizational processes and OI mechanisms that also lead to CD development can be investigated, including other OI micro-foundations that strengthen CDs.

Finally, we suggest that future research analyze the outcomes of the new CDs incorporated by the investigated company, developing an embedded case study that will enable a better understanding of OI activities throughout the corporation. Furthermore, access to embedded units of analysis should allow to produce more comprehensive evidence than in single cases (Yin, 2018), as well as allow access to different levels of analysis (individual, processes, company, projects), their relationships, and their co-relations, allowing for a better understanding of the achieved results.

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