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A dynamic capabilities framework for building circular ecosystems by focal firms

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ABSTRACT

In the context of Circular Economy (CE) and sustainable transitions, firms are exploring innovative ways to create value. Circular ecosystems have emerged as a strategic response, enabling firms to navigate CE transitions by fostering collaboration and alignment with diverse actors despite market uncertainties. Dynamic capabilities (DCs) play a pivotal role in addressing these challenges, yet there is limited understanding of how focal firms develop and leverage DCs to establish and sustain circular ecosystems. To bridge this gap, we identified the DCs of focal firms in the process of circular ecosystem creation. Using a grounded theory approach, we conducted a multi-case study across seven firms leading circular ecosystems. We collected empirical data through 24 semi-structured interviews and analyzed iteratively through a triangulation process, cross-case analysis, and a conceptual framework structuration. Our analysis identified four key DCs categories: sensing circular opportunities, seizing circular solutions, reconfiguring internal practices, and integrating ecosystems. These findings reported the development of a theoretical framework that highlights the micro-foundations facilitating circular ecosystem creation. Our study demonstrates how focal firms harness circular innovations and learning processes to foster knowledge exchange, optimize resources, and co-create value with external stakeholders. The insights presented offer practical guidance for managers and policymakers to accelerate the transition to sustainable circular ecosystems, emphasizing the importance of actor alignment and collaborative strategies to advance CE practices.

1. Introduction

Recent advances emphasize the negative impact of natural resource extraction on global capacity and ecological sustainability (Millar et al., 2019; Sun et al., 2024). In response, innovative production systems must promote greater efficiency and strategic alignment with Sustainable Development Goal (SDG) 12, which highlights the construction of sustainable consumption and production patterns. Circular Economy (CE) is a leading tool for driving sustainability transitions (Evans, 2023; Millar et al., 2019). CE strategies focus on maximizing the value of products, components, and materials for as long as possible (Velenturf and Purnell, 2021; Webster, 2013) or reintegrating waste into production cycles or natural systems (Domenech and Bahn-Walkowiak, 2019). Moreover, CE requires rethinking innovation processes and business models based on sustainability principles (Geissdoerfer et al., 2020; Ranta et al., 2018). Firms are adopting diverse CE approaches, transforming traditional ecosystems into circular ones (Kolagar, 2024). Circular ecosystems are networks of independent actors that collaborate to create value propositions aligned with CE principles (Aarikka-Stenroos et al., 2021). In this context, CE innovation extends beyond traditional organizational boundaries, driven by collaborative networks (Sandberg, 2023), strategic alliances (De Angelis et al., 2023), digital infrastructures (Sun et al., 2022), and ecosystem interactions (Parida et al., 2019).

Circular ecosystems are an emerging stream that explores how organizations collaborate to create circular value. Research highlights that circular ecosystems help firms address market challenges and foster collaboration (Konietzko et al., 2020a) by orchestrating diverse assets

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and resources (Heaton et al., 2019). Scholars have explored how focal organizations innovate through product and business model development (Kanda et al., 2021) and how orchestrators manage innovation projects to build circular ecosystems (Gomes et al., 2023b), as well as design pathways for ecosystem transitions (Parida et al., 2019). While these studies outline the characteristics and conditions necessary for circular ecosystems to emerge (Gomes et al., 2023a; Trevisan et al., 2022), there is still a lack of clarity on how firms develop specific capabilities that enable the creation of win-win relationships and the successful establishment of circular ecosystems.

Dynamic Capabilities (DCs) are crucial to understanding how firms build and reconfigure competencies, processes, and routines to create circular innovations (Khan et al., 2020; Kohler et al., 2022). They also play a key role in enabling organizations to develop new business models aligned with CE and sustainability goals (Prieto-Sandoval et al., 2018; Santa-Maria et al., 2022). In both strategic and institutional contexts, DCs are critical for understanding innovation and achieving competitive advantage (Helfat and Martin, 2015; David J. Teece, 2007). These capabilities allow firms to design products that meet market and consumer demands while adhering to sustainability principles (Banka and Uchihira, 2024; Linde et al., 2021; Sandberg, 2023).

Despite capabilities relevance, DCs for innovations in circular ecosystems remain underexplored (Kim et al., 2022; Kindermann et al., 2022). Although theoretical advances emphasize circular ecosystem characteristics (Trevisan et al., 2022) and some scholars underline the significance of factors and conditions to promote circular ecosystem emergence (Gomes et al., 2024; Gomes et al., 2023b), they remain imprecise in identifying the specific internal capabilities configurations for circular ecosystem creation.

Scholars in ecosystem management streams emphasize the need for studies that provide detailed guidance on capabilities development (Kindermann et al., 2022), explore the dynamics of inter-organizational capabilities settings (Sjödin et al., 2024) and clarify capabilities co-evolution and interactions between actors (Farago et al., 2023; Gupta and Dash, 2023). In this sense, our research addresses these critical gaps, unlocking what capabilities enhance ecosystem innovation in the CE context. This study explores the following research question: *Do dynamic capabilities of focal firms enable circular ecosystem creation?* To answer this research question, we identified what DCs contribute to circular ecosystem creation and analyzed the key initiatives and micro-foundations that focal firms leverage in circular ecosystem creation stage.

Our findings represent novel DCs categories for focal firms of circular ecosystems: sensing opportunities, seizing solutions, reconfiguring resources, and ecosystem integrating. These categories are specific to the context of the emergence of circular ecosystems. These capabilities guide firms in mapping CE opportunities, experimenting with circular innovations, and restructuring resources to foster circular ecosystem development. Our study argues that answering this question is essential for theoretical and practical advancements. As circular ecosystems are still emerging concepts, they require foundational efforts to align external partners (Brasil et al., 2021) and internal resources for establishing a circular value proposition (Gomes et al., 2023a). In this context, evidence of the fundamental capabilities for circular transformation with win-win relationships and how organizations innovate and sustain transformative initiatives, creating new circular products, circular business models, and competitive advantage.

Towards answering the research question, we conducted a qualitative study on how focal firms build circular ecosystems. We also conducted content analysis on existing circular ecosystems and DCs literature to support empirical findings. Our primary contribution is a comprehensive framework that categorizes DCs into sensing, seizing, reconfiguring, and ecosystem integrating, along with their micro-foundations. Additionally, we demonstrate how focal firms orchestrate resources through specific micro-foundations to enable circular ecosystem creation. Finally, our study provides empirical insights into the role of DCs across various sectors, displaying how they drive innovation and profitability within circular frameworks. This advance contributes to SDG 12, promoting practices aligned with sustainable policies and encouraging transnational companies to adopt more collaborative approaches for CE transitions. These findings introduce a new theoretical framework referred to as circular ecosystem innovation.

2. Literature review

The literature review provides an overview of theories, which are listed in two sections. First, we discuss the theoretical basis for understanding CE and circular ecosystem creation. Second, we underline relevant studies on DCs and ecosystems and identify research gaps about circular ecosystem phenomena and DCs.

2.1. Understanding circular economy and circular ecosystem creation

The resource extraction system endangers global capacity and ecological sustainability (Sun et al., 2024). In this sense, CE is a leading tool for sustainability transitions (Evans, 2023), specifically towards SDG12's achievement. As a novel economic paradigm, CE aims to replace the “take-make-waste” model with a regenerative perspective based on R's strategies, including rethinking processes and products (Ferrer et al., 2023), remanufacturing products (Bocken et al., 2016), reusing, and recycling materials (Oliveira et al., 2020; Pansare et al., 2022). Some scholars claim CE is proposed as a sustainable development strategy addressing environmental degradation and resource scarcity (Korhonen et al., 2018b; Suzanne et al., 2020). However, CE advances have suggested that not all forms of CE practices and initiatives are sustainable, requiring diverse scales of transformations, more efficient tools, and measurements to ensure environmental and social positive impacts (Desing et al., 2020; Korhonen et al., 2018a).

A CE as a transition path implies different shifts and changes, even reshaping organizational ecosystems to circular ecosystems (Kolagar, 2024). At a minor level, CE endeavors to optimize strategic plans and operational processes, aiming to sustain the value of products, components, and materials over prolonged periods (Webster, 2013). Changes involve reintegrating waste into product cycles or natural systems (Domenech and Bahn-Walkowiak, 2019; Soo et al., 2018). Furthermore, CE encompasses interplay between a diversity of actors, scales, and products (Lieder et al., 2017; Mies and Gold, 2021). Diverse actors' synergies are crucial in CE transitions, working as enablers to acquire technologies, create business, achieve regulations requirements (Aarikka-Stenroos et al., 2021; Li et al., 2023; Wiedenhofer et al., 2020) and facilitate sustainable transitions.

In this context, an approach for CE transformation is circular ecosystems. Circular ecosystems are defined as a set of independent actors who integrate their roles to create a value proposition aligned with CE principles (Aarikka-Stenroos et al., 2021). In the process of circular ecosystem creation, incremental and radical innovations play a crucial role (Aarikka-Stenroos et al., 2023), articulating the proper set of partners (Kaipainen et al., 2023) and managing the portfolio of circular innovation projects (Gomes et al., 2023b). Focal firms create circular ecosystems aligned by sustainable and circular strategies, embarking on radical innovations. These changes facilitate the focal firms to confront uncertain markets (Medeiros et al., 2022), and co-experimentation, partners' engagement, and circular innovative practices become enablers for circular value creation (Gomes et al., 2024). In such dynamic settings, ecosystem creation evolves from resource leveraging to co-experimentation and new strategies and resources within CE contexts (Furr and Eisenhardt, 2021).

Extant literature claims that effective competencies and DCs are crucial for achieving sustainability requirements and improving organizational performance in CE implementation (Kanda et al., 2021; Marrucci et al., 2022). In an ecosystem context, firms must learn to manage ecosystems with interdependent actors and offers (e.g.,

Konietzko et al., 2020b) and distinct structures and value propositions based on CE (Gomes et al., 2023b). Firms develop specific capabilities to create circular ecosystems and design a circular value proposition (e.g., Asgari and Asgari, 2021; Gomes et al., 2024). They might innovate and create circular ecosystems from their business models by enabling other complementary actors to provide products and services that promote resource reduction, reuse, recycling, and regeneration (Snihur and Bocken, 2022; Trevisan et al., 2022). However, they might create a circular ecosystem from an existing ecosystem towards fostering CE by changing crucial components of ecosystem structures such as activities, roles, and links (Adner, 2017).

Resource management and capabilities development are fundamental to more strategic circular multi-actor systems (Sun and Min, 2024). Some practices and guidance are established in the novel ISO 59020:2024, in which organizations strive to adopt circular economy principles and practices (Patil et al., 2023), as well as in UNI/TS 11820:2022 provide a harmonized set of measurement tools for the effectiveness of circularity strategies (Adner and Kapoor, 2010; Thomas et al., 2022). Despite such guidance and tools, organizations have struggled to adopt and implement CE practices in uncertain contexts (Wierikx et al., 2023) with a diverse actor's interdependence. In a more strategic sense, some advances highlight the importance of assessing readiness in ecosystems (Konietzko et al., 2020a) and the need for focal firms to create standards, nurturing skills, and developing frameworks for circular business at the ecosystem level (Parida et al., 2019).

2.2. Dynamic capabilities for innovation ecosystems

In ecosystems, focal firms influence the system through multiple exchanges and resource integration to produce a collective value proposition (Adner and Kapoor, 2010; Thomas et al., 2022). The ability to navigate and derive value from such collaborations enhances responsiveness to emerging sustainability market niches. (Gomes et al., 2023a). Scholars in DCs theory have shown that the interdependence of actors and actors' DCs can influence and induce ecosystem-level change (e.g., Eisenhardt and Martin, 2000). DCs refer to a firm's ability to efficiently map, construct, and reconfigure internal and external competencies, addressing environment changes (Teece et al., 1997). DCs are structured by micro-foundations or foundational elements, which refer to skills, routines, and processes that enable a firm to develop and deploy innovations (Khan et al., 2020; Teece, 2007). In ecosystems, DCs promote effective construction and leverage of partnerships (Randhawa et al., 2022), innovation, and learning between organizations (Konietzko et al., 2020b) and support reinforcement of resilience and manage their risks (Linde et al., 2021).

DCs in ecosystem creation are fundamental for exploring opportunities in the market and extracting internal resources in collaborative structures (Arranz et al., 2020). Advances in those fields have been based on Teece (2007) as a reference. This research stream considers DCs to refer to the abilities of a firm to manage internal and external resources for confronting changes in the environment, considering sensing opportunities, seizing experiments, and reconfiguring processes and activities (Abbate et al., 2022; Arekrans et al., 2023). Regarding the capabilities-level view, Eisenhardt and Martin (2000) considered capabilities as organizational and managerial routines to create new resource configurations and respond to market challenges. DCs remain a driver of change and innovation, focused on the exchange and flow of resources between actors and aspects of resilience and ecosystem health (Kim et al., 2022; Nenonen et al., 2018).

Prior studies on capabilities and resource-based views argue that the heterogeneity of firms' resources explains differences in competitive advantage and performance (e.g., Barney, 2021). Indeed, some authors suggested a link between DCs on improving benefits and firm performance (Roundy and Fayard, 2019), and ecosystem leader DCs benefit all actors' resilience and health (Ambrosini et al., 2009; Pavlou and El Sawy, 2011).

Scholars use DCs categories of sensing, seizing, and reconfiguring to classify firm capabilities in ecosystems (Abbate et al., 2022; Arekrans et al., 2023). In ecosystem research streams, collaboration and networking have more relevance. Collaboration abilities guarantee co-creation and exchange of resources from internal to external environments (Siaw and Sarpong, 2021), reinforce trust, clarify roles and functions (Tabas et al., 2023), and allow co-evolution between players. In an ecosystem context, reconfiguring capabilities activate internal resources (Cui and Han, 2022), establish new businesses, and adjust ecosystem configuration (Randhawa et al., 2022). These aspects may respond to the implementation of orchestrator functions in the ecosystem.

Unlike these advances, Siaw and Sarpong (2021) and Nenonen et al. (2018) create new categories of capabilities, such as dynamic exchange capabilities. Dynamic exchange capabilities facilitate the exchange process between actors and support exploitation and exploration relationships. However, there has yet to be a consensus on capabilities in this emerging research field. Consistently with prior literature (e.g., Sjödin et al., 2024, 2023), this study proposes that DCs contribute to ecosystem creation and facilitate transition. However, in uncertain settings, advances in orchestration capabilities towards managing circular partners (Sandberg, 2023) are not evident.

Circular ecosystems show potential for systematic coordination among stakeholders for implementing circularity (Pietrulla, 2022), and scholars have described the main success factors for the creation of circular ecosystems (Barquete et al., 2022; Gomes et al., 2024). Although insightful, knowledge about specific capabilities is also needed for effectively managing circular ecosystems. Building on DCs capabilities in circular transitions (Leitão et al., 2024), this study argues that DCs might offer unique features to confront the challenges of CE implementation in circular ecosystem creation.

3. Methodology

This study addresses the gap in understanding the specific capabilities required for creating a circular ecosystem. This section provides four steps to follow the grounded theory approach. First, we expose data selection processes for multiple case studies and present how we implement data collection and analysis of primary and secondary data. Finally, we describe data analysis using framework structuring.

This inductive research follows a qualitative approach (Eisenhardt et al., 2016) by examining the circular ecosystem creation process through the lens of DCs. A grounded theory was adopted to understand how DCs of focal firms enable circular ecosystem creation. According to Mills et al. (2006), grounded theory involves different iterative processes to restructure concepts and minimize biases in qualitative data (Corbin and Strauss, 2015). Moreover, this research approach addresses gaps in understanding phenomena, processes, or interactions of concepts with an emerging research focus (Van Burg et al., 2022). It is particularly well-suited for exploring complex phenomena within real-world contexts.

Multiple case studies enable effective comparisons of emergent insights across different cases (Salerno et al., 2015). This approach provided a diverse understanding of DCs within circular ecosystems. Data collection was longitudinal, including interviews, sustainability and management reports, conference proceedings, innovation launches, websites, videos, blogs, and social media posts. This comprehensive triangulation process ensured the reliability and depth of the findings. An iterative analysis allows continuous comparison and refinement of emerging categories, leading to robust theoretical insights grounded in empirical evidence (Eisenhardt and Graebner, 2007). Fig. 1 illustrates the research design, which examines actions and processes related to innovation and circular ecosystem creation.

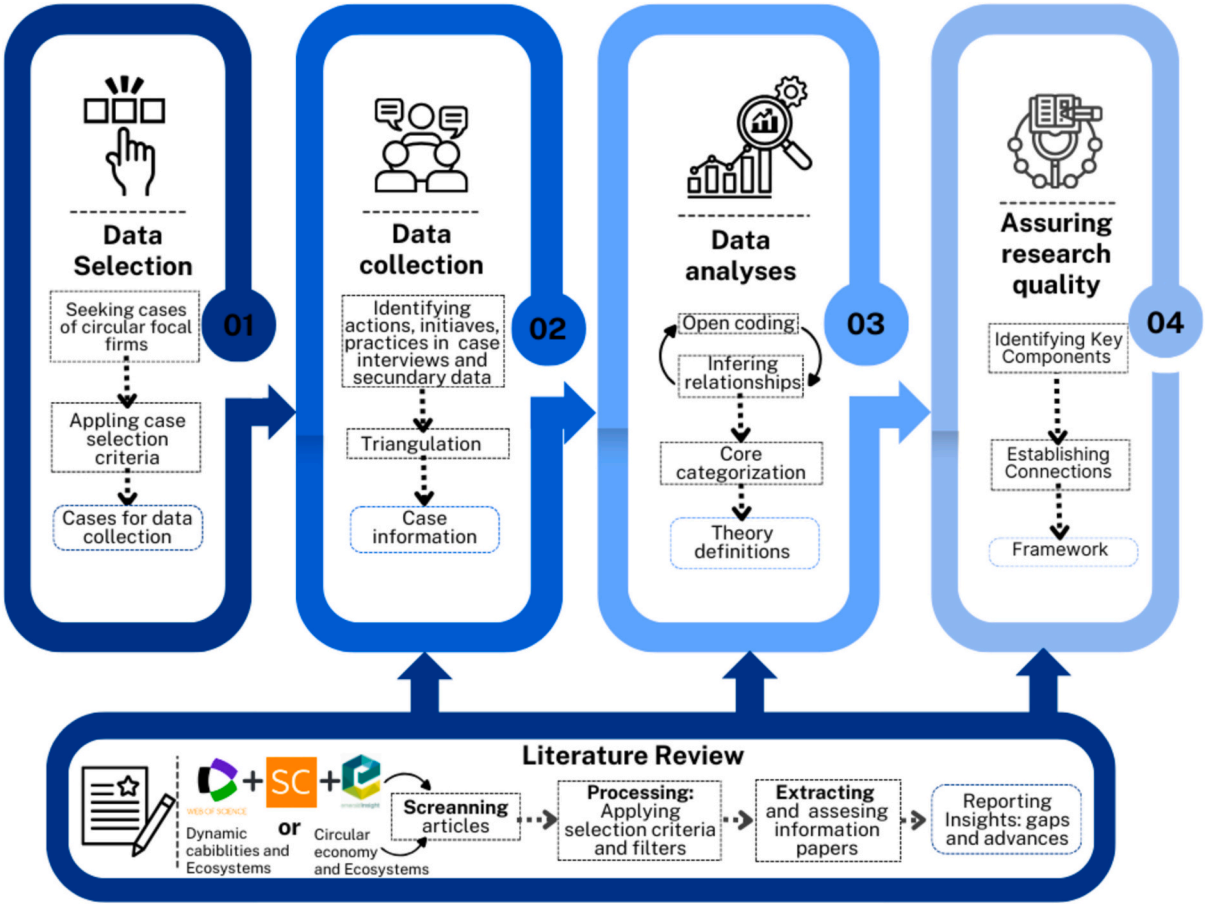

Fig. 1. Research design with the use of grounded theory.

3.1. Data selection

The selection of cases considered the study phenomenon of DCs that contribute to circular ecosystem creation. To address this, we established the following criteria for selecting focal firms or orchestrators that lead circular ecosystems and implement sustainable strategies:

- Orchestrators or focal firms create and manage ecosystems (Adner, 2017; Gomes et al., 2023a).
- Firms that have designed circular ecosystems to deliver value propositions through recycling, remanufacturing, dematerialization, and upgrading to create value (Trevisan et al., 2022).
- Firms that have developed and implemented new technologies, circular products, and business models (Gomes et al., 2022b).
- Firms that restructured and built strategic partnerships to integrate new technologies, create circular business models, and deliver circular value propositions (Sjödin et al., 2023, 2024).

An initial list of twelve firm candidates was compiled from multiple sources, including ESG workspaces, sustainability reports of 2023, open innovation platforms, our professional networks, media, and academic studies. After applying the selection criteria, seven firms that had created circular ecosystems with distinct value propositions were identified—their names have been changed for confidentiality purposes (see Table 1).

3.2. Data collection

3.2.1. Interviews and triangulation process

To ensure a robust data collection, we collected primary data from 24 semi-structured interviews with secondary sources such as reports, social media posts, videos, news articles, and websites. These data sources allowed us to identify key practices, initiatives, and actions related to sensing circular opportunities, seizing innovations, and reconfiguring processes and activities. Our interview protocol (see Supplementary Information) included questions related to circular practices, innovation experiments, and the process of circular ecosystem creation. We focused on business models, new processes, and circular products linked to regenerative systems, remanufacturing, recycling, product-as-a-service models, and dematerialization. Moreover, 38-to-60-min interviews were conducted with different sectors of focal firms, and data were collected retrospectively until data saturation. Each interview was cross-referenced with secondary data before and after the interview to enhance reliability, ensuring consistency and depth in the findings.

3.2.2. Systematic literature review

A search for literature advances in the circular ecosystem and ecosystem management and DCs was conducted to construct a phenomenon theory, identify emerging trends and unexplored research about the theory, and complement empirical data. Papers were collected from Web of Science, Emerald, and Scopus databases, with the use of the following strings: [("Dynamic capabilities AND circular ecosystem") OR ("Dynamic capabilities" AND innovation ecosystem) OR ("Dynamic capabilities" AND business ecosystem) OR ("Dynamic capabilities" AND "knowledge ecosystem")] merge ["Circular ecosystem" or "Sustainable ecosystem"]. In the first step, screening, 248 articles with no duplicates were identified by applying two selection criteria: English as the publication language and articles as the document type. In the second step, only papers on DCs in ecosystems or that showed some capabilities for ecosystems in a circular economy context were considered – article

Table 1
Case details and data collected.

Cases/description	Employees	Interviews	Circular innovations	Key partners
CASE 1. A multinational firm that offers consumer goods and has created a circular ecosystem concerning waste recycling and reuse of plastic, deforestation plans, and capture of carbon emissions.	+10,000	Three interviews: two with sustainability managers and one with a purchasing sector manager	Innovation 1: new projects of regenerative agriculture	Small farmers, ONGs, food suppliers and processors, start-ups
			Innovation 2: new offerings using resins of plastic	ONGs, food suppliers and processors, and start-ups
CASE 2. A prominent pulp manufacturer firm and paper producer. This company has created a circular ecosystem for carbon market resolutions, cellulose reuse, bio-oil and lignin	+10,000	Three interviews: two with sustainability managers and one with businesses	Innovation 3: New offer using microfibrillated cellulose in textile and cosmetics	Small farmers, ONGs, paper processors, and start-ups
			Innovation 4: new offer of bio-oil based on biomass from eucalyptus	Oil companies, ONGs, and start-ups
			Innovation 5: new offers using lignin in the supply chain of tire production	Oil companies, ONGs, start-ups
CASE 3. A prominent printer firm that configured a circular ecosystem for creating value from components of post-consumption printers.	+10,000	Four interviews: two with a sustainability head and two with operation managers	Innovation 6: new printers offer using recycled plastic components of printers	ONGs, start-ups, incubators, Waste pickers cooperatives, electronic recyclers, municipalities, Authoring institutions
			Innovation 7: project of use of metal recycled 3D printers' materials in cars	Car manufacturers, start-ups, incubators, Waste pickers cooperatives, Consultancies, electronic recyclers
CASE 4. A prominent company that offers beverages. This company has created an ecosystem for plastic packages using recycled plastic.	+10,000	Three interviews: one with an innovation manager and two with sustainability managers	Innovation 8: new offer of packaging based on corn waste	Community consumers, start-ups, innovation labs, and farmers
			Innovation 9: new offer of beverages with recycled glass packaging	Community consumers, start-ups, innovations labs, waste cooperatives, and glass processors
CASE 5. A multinational firm that offers food carton packages using recycled cartons and plastic materials for shoes, 3D printing, and roof tiles.	+10,000	Six interviews: four with sustainability managers and two With consultancy service provider	Innovation 10: new offers of paper based on carton-recycled	ONGs, start-ups, incubators, Waste pickers cooperatives, paper recyclers, paper processors, municipalities, consultancies
			Innovation 11: roof tile offer from recycled carton material	ONGs, start-ups, incubators, Waste pickers cooperatives, plastic recyclers, municipalities, consultancies
			Innovation 12: new furniture offer made from recycled carton packages	ONGs, start-ups, incubators, Waste pickers cooperatives, plastic recyclers, furniture, Universities, manufacturers, municipalities, and consultancies
			Innovation 13: new carton packaging plant-based plastics from certified sugarcane	ONGs, start-ups, incubators, Waste pickers cooperatives, plastic recyclers, municipalities, and consultancies
CASE 6. A multinational firm that creates circular ecosystems related to recovery and recycling scrap steel and modular business models for building structures	+10,000	Three interviews: one with sustainability managers, one with innovation heads, and one with operation manager	Innovation 14: new offerings using recycled scrap steel	Steel start-ups, incubators, Waste pickers cooperatives, electronic suppliers, and car manufactories
			Innovation 15: new circular platform focused on smart building	Steel start-ups, incubators, Waste pickers cooperatives, electronic suppliers, car manufactories, and architecture companies
CASE 7. A digital company for circular recycling certification and offers consultancy and digitalization of post-consumption traceability.	+500	Two interviews with sustainability managers	Innovation 16: new digital platform within a circular ecosystem focused on carton	Start-ups, investors, Waste pickers cooperatives, recycling companies, plastic producers, and auditory institutions
			Innovation 17: new consultancy for recycling glass	Start-ups, investors, Waste pickers cooperatives, recycling companies, glass producers, and auditory institutions
			Innovation 18: offers consultancy service for improving waste picker cooperative standards	Start-ups, investors, Waste pickers cooperatives, recycling companies, and auditory institutions

sections were used as selection filters. Filter 1, abstract reading, identified 113 articles, whereas filter 2, introduction and conclusion reading, selected 62 articles. The last filter, whole article reading (3), obtained 23 documents (see Fig. 2 for data collection and analysis).

3.3. Data analyses

This research involved two analyses with source data. Regarding the literature review, a qualitative data analysis (Lee and Cassell, 2013) explored the advances in circular ecosystems and DCs within ecosystems. Ecosystem streams and DCs were examined through content analyses of 23 articles selected, and the attributes of DCs were extracted, generating several ecosystem-specific categories such as sensing, seizing, orchestrating, dynamic exchanges, and reconfiguring.

We adopted an iterative coding process that combined data collection and data analysis. Each case story was developed, focusing on related events, decisions, and actions for circular ecosystem creation. Subsequently, first-order codes were created considering the main patterns of activities, initiatives, and practices that force circular ecosystem creation. The codes were then assembled into categories, of which four major ones related to DCs categories were identified. An initial categorization for sensing DCs was built, and, as expected, situations in which firms developed activities to map opportunities, their environment, and new actors for the creation of circular value were found in all cases. The second category encompassed the coding of situations where firms collaborate and experiment to create circular value propositions. In contrast, the third category included codes related to initiatives that reconfigured company sectors and processes and even created new ones

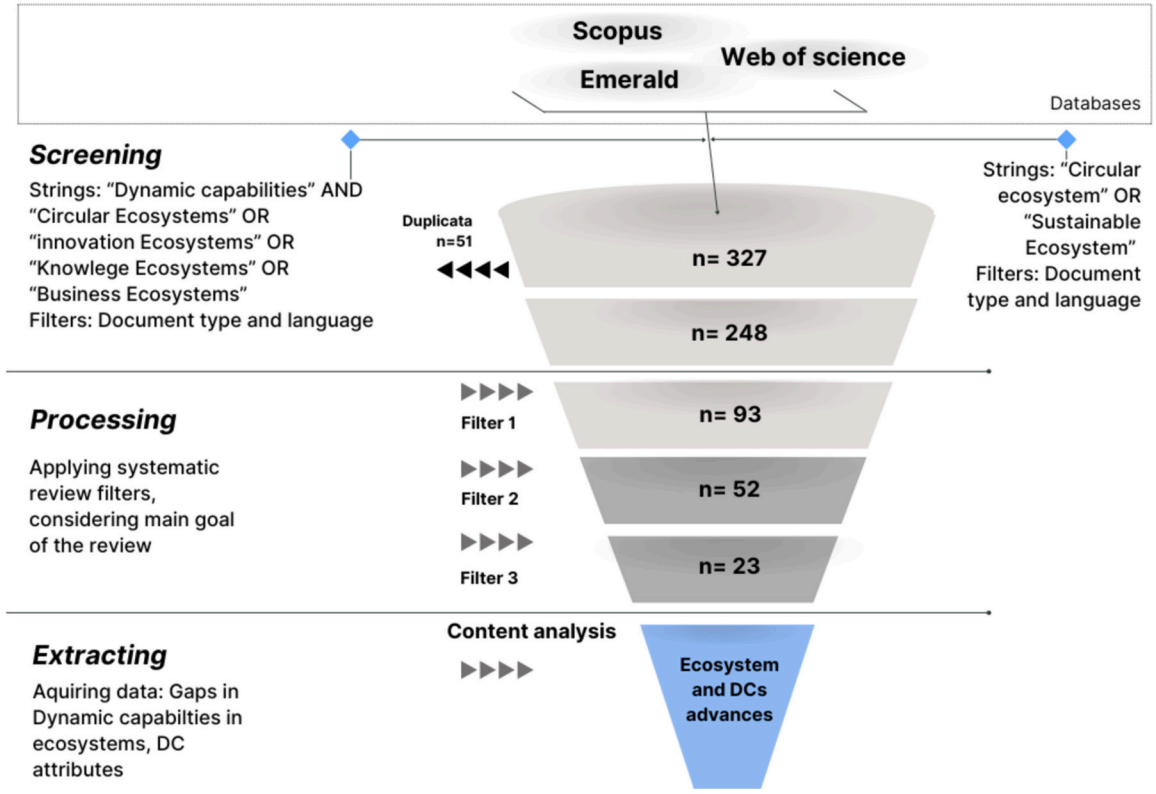

Fig. 2. Literature review processing.

towards circular value.

Although the categories were coherent with the literature (Sandberg, 2023; Sjödin et al., 2024), a distinctive category of DCs related to ecosystem integration was detected. In the circular ecosystem creation phase, firms developed activities and initiatives related to sense and experimented and aligned resources across the firm boundaries. We

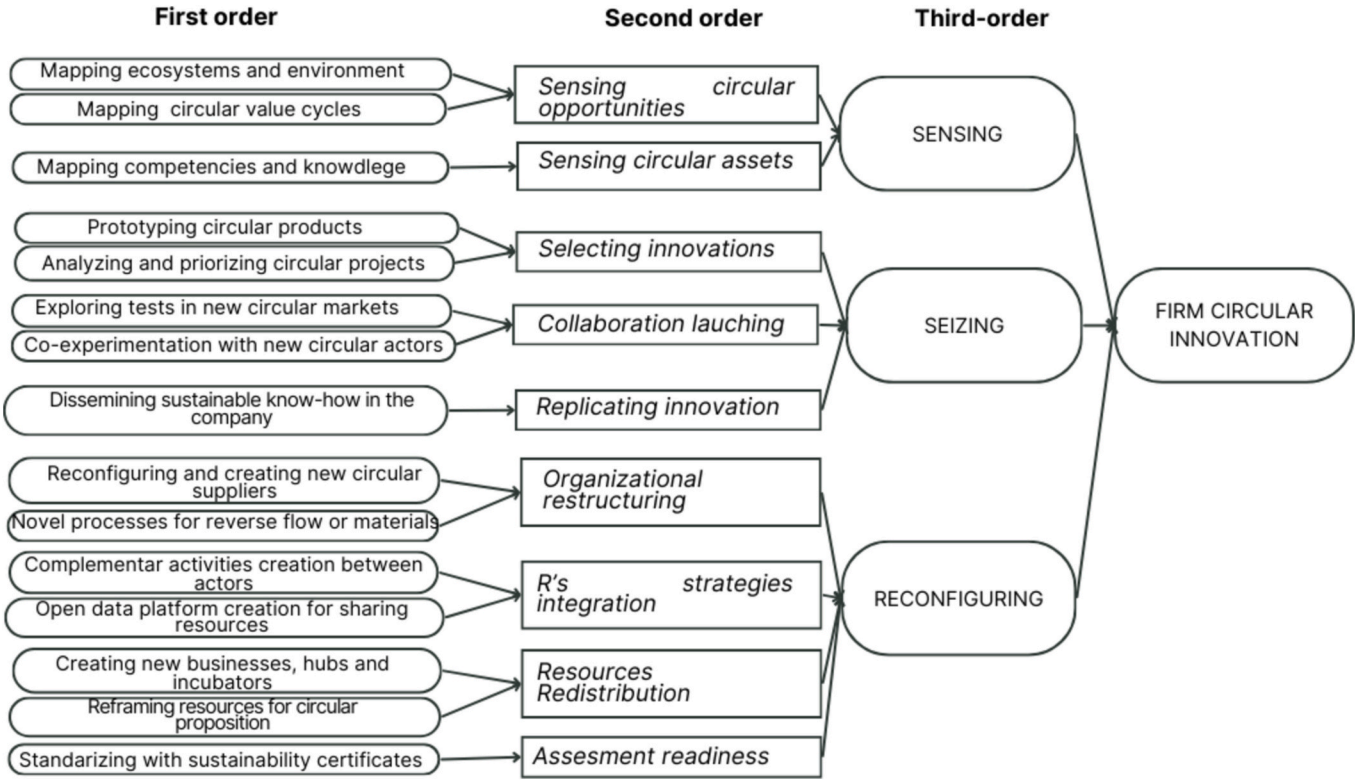

Fig. 3. Code tree in a firms' perspective.

examined how these emerging themes connected and used them to build an initial, rudimentary theory on how firms engage in sensing, experimenting, and reconfiguring processes during circular ecosystem creation. All these iterative coding processes were conducted using Nvivo software. Nvivo processed the iterative coding. Figs. 3 and 4 show the coding tree from the firms' and ecosystems' perspectives.

3.4. Assuring research quality

Several precautionary steps enhanced the quality of this research. A conceptual framework was designed to support data selection, data collection, and data analysis processes, thus strengthening reliability. According to Roller and Lavrakas (2015), a conceptual framework offers uniformity and reduces variability in how data are treated, enhancing both the reproducibility and reliability of the findings.

The framework construction involved identifying and extracting foundational components using framework theoretical bases. Articles from the literature review and seminal studies were used for framework construction. After each round of core categorization, new components were included, and their interrelationships were established. Finally, with a comprehensive understanding of the phenomenon and the results, a research group checked the accuracy and representativeness of the framework against the research insights. With this mixed and iterative process of empirical data and secondary data collection and data analysis guided by the framework, the findings reduced the subjective judgment or inconsistencies during data analysis and coding.

4. Results and discussion

This section provides insights into key capabilities developed in circular ecosystem creation. First, we explain how DCs are defined in circular ecosystems. We describe the DCs framework for focal firms in circular creation, considering micro-foundations and activities. We highlight a detailed cross-case analysis and its theoretical and practical implications. Finally, we describe our research limitations.

4.1. How do dynamic capabilities contribute to circular ecosystem creation?

Embedded in the main theories applied to DCs in ecosystems, DCs for circular ecosystems were defined according to the authors in Table 2. This table shows definitions of categories proposed in this study for DCs in circular ecosystems, considering Teece (2007) and advances in ecosystem streams.

According to the theories and advances acquired in the review of DCs in ecosystems and towards assuring research quality, Fig. 5 displays an

Table 2
Dynamic capabilities in ecosystems.

Categories of dynamic capabilities	Definition	Authors
Sensing	This category represents capabilities that sense, identify, and evaluate market opportunities and bottlenecks for performance ecosystems.	(Kim et al., 2022; Nenonen et al., 2018; Tabas et al., 2023)
Seizing	This category comprises abilities that scan, identify, and integrate different external knowledge to experiment and develop innovations.	(Abbate et al., 2022; Giudici et al., 2018; Linde et al., 2021)
Reconfiguring	This category is related to resource activation and transforming processes and business activities towards adaptations to changing market conditions.	(Heaton et al., 2019; Khurana et al., 2022; Randhawa et al., 2018)
Ecosystem Integrating	This category refers to a firm's ability to create networks, strengthen relationships, and align values, actors, and flows in ecosystems. It also aligns with the actors' ability to understand their roles and the required changes.	(Kim et al., 2022; Siaw and Sarpong, 2021; Sjödin et al., 2024)

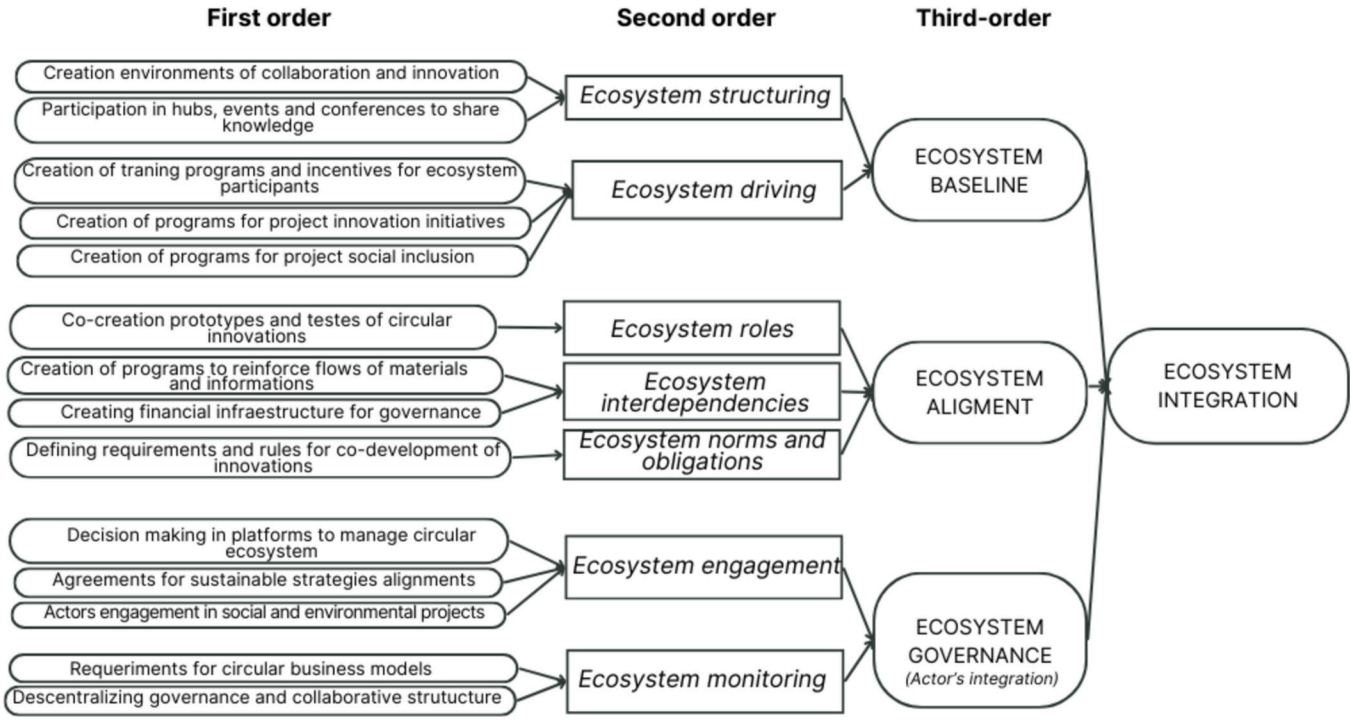

Fig. 4. Code tree in an ecosystems' perspective.

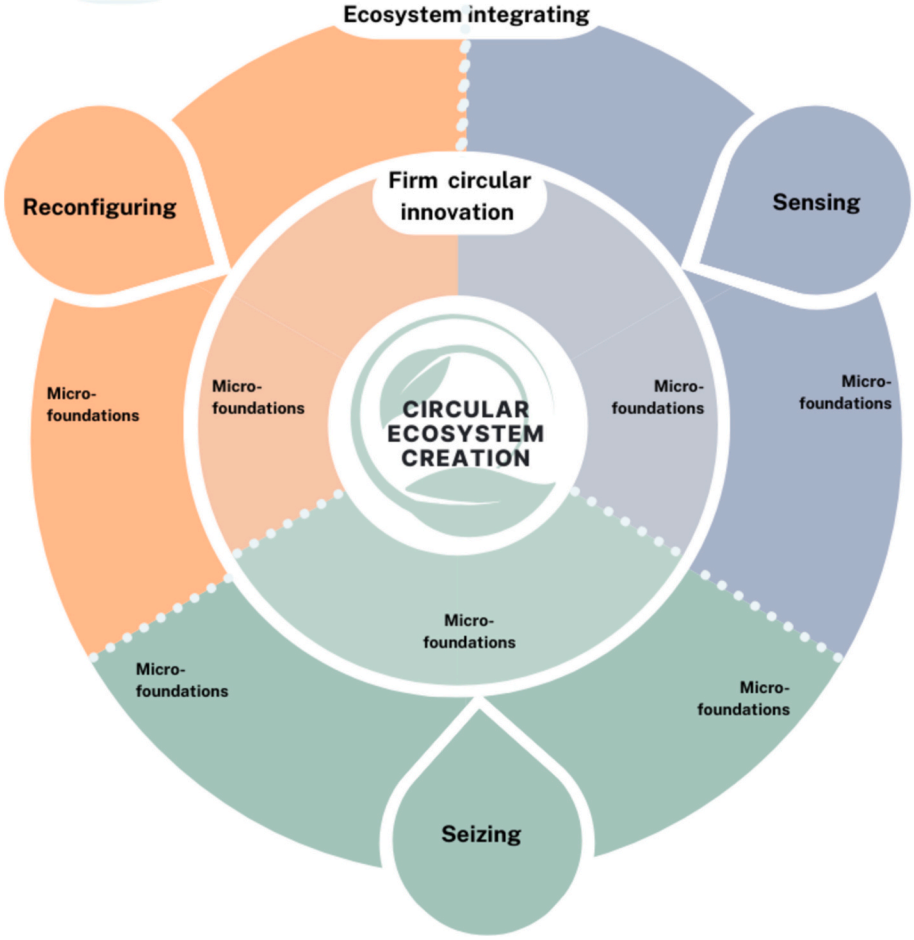

Fig. 5. General framework of dynamic capabilities in firm and ecosystem perspectives for circular ecosystem creation.

initial conceptual framework of circular ecosystem creation. The process occurred first with the innovation of a focal firm and the development of sensing capabilities, reflected in micro-foundations for identifying opportunities and challenges within and outside the firm's boundaries. Second, the focal firm develops seizing capabilities composed of micro-foundations to implement and develop strategies aligned with circular ecosystem goals. Finally, the focal firm restructures itself and creates reconfiguring capabilities with micro-foundations to adapt and reshape internal processes and activities to create a new ecosystem. In this sense, with an ecosystem integration capability, the focal firm attempts to align and connect diverse actors, processes, and resources.

4.2. Dynamic capabilities framework in focal firms for circular ecosystem creation

4.2.1. Sensing: capability to observe circular economy opportunities

Towards adapting to sustainable trends, focal firms must attend to sustainable consumers'.

preferences for developing circular business models or circular innovations (Kim et al., 2022). In this stage, firms map opportunities and resources (Khurana et al., 2022), new technologies (Zabel et al., 2023), and potential competencies for implementing circular practices and identify collaborative actors for innovations. Sensing circular opportunities involves more than observing potential reusing materials; it includes analyses of competitors, successes, and failures, identification of successful circular practices, pitfalls, barriers, and challenges, and mapping regulations to innovate beyond compliance. In this context, the empirical cases addressed in this study highlight key topics or micro-foundations for sensing that generate circular ecosystem creation:

i) Mapping ecosystem environment

Advances in circular ecosystems highlight a need for mapping environmental opportunities (Sandberg, 2023). Ecosystem environment refers to all elements outside of the landscape ecosystem, including markets, other ecosystems, political regulations, networks, and knowledge exchange events.

Circular ecosystem creation starts when focal firms are looking for opportunities for new businesses related to the CE or improving value propositions to achieve sustainability goals (Gomes et al., 2023b). We observed that firms screen market and competitors' problems and interests. Our informant affirmed that there are activities and processes focused on identifying opportunities and interests inside the sustainability market as well as problems and interests of competitors. Case 6 maps the environmental and technical demands and requirements of consumers in order to deliver products that are tailored to their needs. Case 4 conducted market research to observe consumer acceptability in packaging launches with reduced plastic use. In addition, Case 5 studies consumer satisfaction when wearing shoes that use recycled material from food packaging.

All cases mapped legislative advances and norms related to CE, sustainability, or regulation might invest in circular innovations. Some cases (Case 2, Case 5, and Case 1) participate in discussions about new green markets, such as Case 2 in the transition ecological plan. Case 1 participated in the international discussion of ISO in Brazil on circular economy implementation. Unlike some scholars in sustainable ecosystems (Konietzko et al., 2020b), all cases participated in conferences, events, networking innovations workshops, and normative panels. These activities represent evidence of openness in circular innovations.

ii) Mapping competencies and knowledge

Regarding ecosystems in sensing capabilities, competencies and knowledge can be translated into technological advancements, which play a crucial role in exploration trends, resources, and collaboration tools (Muldoon et al., 2023). Towards developing ideas of new value propositions and improved versions of the circular value proposition, focal firms must identify possible skills and knowledge required. Therefore, orchestrators map actors and stakeholders who complement the development of those circular initiatives (Linde et al., 2021). In all our cases, processes related to scanning new competencies to support circular innovation developments and opportunities for knowledge sharing are fundamental for circular ecosystems.

Among the activities highlighted by some scholars are the development of programs to attract actors with capabilities for closing cycles and post-consumption treatment as actors in charge of carrying out recycling (Parida et al., 2019) or developing technologies for closing material cycles (Asgari and Asgari, 2023). Our informant in Case 2, an innovation manager, affirmed that mapping actors and competencies is fundamental. Case 2 aims to combat water stress and identify forest areas for the carbon business. They mapped potential areas (potential suppliers) throughout Brazil, using their internal research and development skills to identify possible reforestation areas.

In Cases 1, 4, and 5, we observed other situations. They participated in business networks to brainstorm and develop new technology ideas. However, all cases created hubs or incubators that hold calls for startups and small enterprises to extract and map skills and knowledge about the other uses of recycled materials (Case 2, Case 5, and Case 3), and others participate in creating new technologies for the treatment of materials post-consumer (Case 6 and Case 4).

We share a quote from the sustainability head of *Case 5*, *"Together with this project and a startup accelerator, we sought out these small companies."* They develop activities in which the new players fit in with the demands for skills and profiles related to packaging recycling and social impact.

iii) Mapping circular value cycles

Orchestrators search for new cycles and circular value propositions by identifying opportunities for reusing and recycling products, materials, and waste inside and outside the company. An example is Case 3, in which the focal firm developed alliances and partnerships to understand the possibility of using recycled material for printers. Intending to achieve 70 % recycled material, the focal firm identified new suppliers, conducted tests, and observed the possibility of creating new cycles for recycling and using the printers.

In all cases, orchestrators sensed feasible cycles for waste reusing. We verified Case 5, which mapped various possibilities for value propositions from packaging shredding. A similar situation was observed with the sustainability manager quote of Case 2, who informed us that every waste from the production cycle could be an opportunity for circular improvement, and each potential change could be a new project or a prominent business. See Table 3 for more details of initiatives of focal firms in sensing capabilities.

Table 3
Micro-foundations evidenced in circular ecosystems in sensing dynamic capability.

Dynamic capability	Micro-foundations	Quotations	Activities, actions, or initiatives
Sensing	Mapping environment	*Case 3: "We capture market trends, understand how our competitors are doing regarding sustainability, and help bring sustainability to the market as a selling point"*	-Consumer needs research about circular products, -Consumer satisfaction researches -Decision-making processes of exploring market approaches -Developing a network of benchmarking of circular value -Participation in international forums, legislation panel of the carbon market, bio-oil international discussions, and commissions on the Circular Economy
	Mapping competencies and knowledge	*Case 6: "We look at various areas, [...] startups, research centers, universities, to see which technologies are viable for large-scale production".*	-Partnerships and alliances with external entities to explore the feasibility of circular practices, such as using recycled materials. -Benchmarking of circular technologies and innovations Identifying circular innovation technologies -Calls for startups, small enterprises -Calls for acceleration programs -Internal meeting with
	Mapping circular value opportunities	*Case 2 Sustainability manager: "One of the staff's main activities was to map all the existing nurseries in Brazil".*	-Outsource search of circular innovations -Participation in benchmarking networks of circular innovations -Mapping internal opportunities with waste

4.2.2. Seizing: experimenting and prototyping circular opportunities

Once a circular solution has been identified, focal firms experiment with product pilots and prototypes in the markets. They tried to convert external competencies into potential internal resources and competencies. Such new internalization of resources and knowledge implies new practices based on CE principles. Those seizing micro-foundations enable orchestrators to test new ideas and processes, learn from the outcomes, and iterate their strategies to meet the principles of CE (Giudici et al., 2018). Empirical data shows some particularities of circular innovation in circular ecosystems related to prototyping new products or business models, co-experimenting with circular innovations, and internal dissemination of circular know-how.

i) Prototyping new products or new business models

Circular ecosystems emerge with circular projects or new businesses; however, designing prototypes is crucial for defining circular value propositions, roles, activities, and materials flows in circular ecosystems (Abbas and Liu, 2022). Prototype circular innovations are essential for testing and refining the feasibility, viability, and acceptability of CE solutions before they are launched on a larger scale.

We observed in all cases that focal firms formulate prototypes to ensure feasibility and future scales. Case *5* tested different forms of value propositions for recycling food carton packages (roof tiles, shoe soles, pens, cardboard rolls, and paper packages), and new solutions were evaluated and standardized until they become new sustainable products that take scale as tiles and raw material for making shoes or 3D printing. To test these innovations, the focal firm created tests in innovation labs or organized alliances with startups to deploy technologies for production tiles and others with small recycling enterprises to produce the tiles.

All cases created tests of projects of social inclusion to insert new suppliers of recycling materials; for example, Case 3 created projects to develop with universities, startups, and internal research and

development sector new resins for printer solutions using materials of waste pickers. We confirmed when an environmental manager informed us: *"So this was a process that we did, we saw opportunities, we developed a project, we partnered with the engineering teams, they analyzed the types of materials*."

Case 2 acted in line with project prototypes of forest restoration to offer carbon credits. Organizations select strategic pilots to create new sustainability-oriented offers according to the requirements of sustainable market trends, such as the carbon market. *Case 2* can be described with the following quote: "*What needs to happen first is you identify the projects [...] So we're looking at... where the first pilot project is going to be*". In this case, projects are a milestone to configure the business of carbon credit, and they include small farmers when a field follows the carbon market requirements.

ii) Co-experimentation of innovations

All projects and tests were developed in co-experimentation (Gomes et al., 2023a, 2023b), in which focal firms co-develop projects with complementarians, facilitating the identification of new solutions or technologies for recovering and recycling materials traditionally considered non-recyclable.

In Case 4, we verified when they created projects and implemented market research to observe consumer behavior and consumer experiences in developing beverage packages using plant-based plastic. Co-experimentation is a natural step for circular innovations, as we observed in Case 7 when they implemented co-experimented solutions with plastic supplier partners to solve problems about returning material and focal firm demand for materials. In addition, we noted in Case 5 that we create journeys of innovation with paper processors and cellulose companies to develop packaging recycling technologies and envision solutions for using 100 % paper for food packaging, free of plastic and aluminum.

These experimenting capabilities in focal firms help to understand the potential, practical application, and benefits of experimenting with circular solutions and practices (Kim et al., 2022). A similar situation was observed in Case 1, where they developed tests for more sustainable foods and tested with small farmers to acquire organic corn. Similarly, Case 3 developed prototypes with startups and recycling innovators to create recycled plastic printers that meet quality standards.

iii) Dissemination of circular know-how

Activities related to circular know-how dissemination were widespread inside the focal firms. Orchestrators spread and share knowledge and practices of CE to create the cultural conditions to carry out prototypes of circular innovations and even create a more open innovation culture that would facilitate experimentation between ecosystem partners. Some quotes demonstrated dissemination of circular know-how when a sustainability manager of *Case 5* exclaimed *that Case 5* tested several circular innovations with recycled plastic and tried to transfer this knowledge to other markets. In addition, *Case 4* disseminated circular know-how when they participated in circular networks for knowledge-sharing with market competitors to exchange information about bioplastic from corn waste for packaging. We can confirm the importance of knowledge dissemination to structure ecosystems when the sustainability manager expresses*: "There is not much competition; it's more of a learning exchange."*

Also, Case 7 transferred the vision and principles of the CE when the firm induced client companies to be concerned about the inclusion of various actors, such as waste pickers for recycling and audited companies for the development of circular practices and traceability. Table 4 exposes details of seizing actions in circular ecosystem creation.

Table 4
Micro-foundations evidenced in circular ecosystems in seizing dynamic capability.

Dynamic capability	Micro-foundations	Quotations	Activities, actions, or initiatives
Seizing	Prototyping new products or new business models	*Case 5: "We have several small test milestones of what we're going to test to get there... ".*	-Conducting tests in innovation labs to validate circular value propositions and solutions - Evaluating and standardizing new solutions (e.g., roof tiles, shoe soles, pens) to scale sustainable products -Developing projects to integrate new suppliers of recycled materials, such as waste pickers -Collaborating with universities and internal research teams to create a test of innovative materials (e.g., resins for printer solutions) -Identifying and implementing strategic pilot projects to create sustainability-oriented offers (e.g., carbon credits)
	Co-experimentation of innovation	*Case 4: "We did a pilot to test the technology, and we made a launcher last year to test the reception of the consumer experience."*	-Collaborating with complementarians to identify new solutions or technologies for recovering and recycling materials (e.g., organic corn, recycled plastic printers, paper processors, and cellulose companies) -Implementing market research to observe consumer behavior and experiences, as seen in the development of plant-based plastic beverage packaging.
	Dissemination of know-how	Case 5: *"Because of this knowledge exchange between these sustainability actors within the entire region and globally".*	-Sharing knowledge and practices of the circular economy (CE) within focal firms to foster cultural conditions for circular innovation -Testing circular innovations (e.g., recycling plastic) to other markets with distinct characteristics -Promoting circular economy principles to client companies -Facilitating collaboration with competitors, focusing on mutual learning rather than competition -Promoting Open Innovation Culture

4.2.3. Reconfiguring: capability to integrate and transform resources for circular ecosystem creation

After the prototyping stages, circular practices are assembled in internal routines, and complementarity is included in the circular ecosystem configuration. With reconfiguring capabilities, focal firms can dynamically rearrange and adapt their resources and processes

(Mousavi and Bossink, 2017). We verified that focal firms restructure internal resources and processes to meet CE requirements with different actors. These changes involve transforming business operations (Linde et al., 2021), redefining network supply and value propositions, or creating circular businesses to enhance sustainability, resilience, and efficiency. In this sense, empirical data display evidence of readjustments related to supplier redesign, business model transformation, creating an open-data platform, creating circular processes, and standardizing with sustainable certification.

i) Suppliers redesign

Suppliers are a crucial piece in circular ecosystem structuration. In all cases, supplier selection was a process that considered the raw material source as a selection criterion. We identify that in all cases, focal firms reconfigure their supply network. Orchestrators introduce new processes, such as partner selection for value creation (Konietzko et al., 2020a). We verified an example in Case 2, which established selection criteria for defining suppliers related to optimization processes for dismissing carbon footprints and increasing social dimensions benefits. A similar situation was observed in Case 1, i.e., supplier selection considered enterprise size and organic or agricultural sustainable practices.

Orchestrators influence and encourage actors to follow their selection criteria, as observed in Case 3, which developed training of business and optimization processes to ensure the supply of plastic material. The same initiatives were detected in the following statement in Case *5*: "The recycling issue doesn't just depend on us; forming the chain as a whole isn't something that depends only on the consumer." All orchestrators created new flows and activities to enable actors' inclusion as suppliers of materials.

ii) Business model transformation

Some projects evolve after their establishment in the market and become circular businesses, which is a crucial competence in circular ecosystems. In this context, some businesses change from linear to circular value propositions (Parida et al., 2019; Asgari and Asgari, 2023). Focal firms assess internal and external resources for creating value and involve new actors, such as waste pickers, recycling enterprises, startups, and intermediaries (Gomes et al., 2023b). Orchestrators introduce new processes and redesign products to offer eco-friendly alternatives (Konietzko et al., 2020a).

In our empirical data, we observed business model transformation with CE propositions. *For example, in Cases 1, 2*, and 4, value propositions were structured and focused on upgrading biological materials, and in Cases 7, *6*, and 3, new products were created with recycled materials. All cases created new businesses using opportunities identified with circular principles. For instance, Case 7 converted recycling traceability into a circular platform certificate offering. Similarly, Case 6 introduced a modular circular business concept, with a circular business, which redesigned buildings as modular integrated, almost "living" entities. In Case 2, a new business was developed through collaboration with investors and multinationals to offer restoration initiatives for carbon credit commercialization.

Furthermore, Case 3 established a new enterprise focusing on reverse electronics logistics to separate, de-characterize, and shred parts, producing recycled raw materials with characteristics equivalent to the originals. These cases illustrate the successful identification and capitalization of opportunities in circular ecosystems and generate the development of new business ventures.

iii) Creating circular processes

Reconfiguring processes for creating circular values was a ubiquitous element in each case. Towards responding to new business models or developing new products to be launched on the market, orchestrators designed and implemented new systems for the flow of resources, materials, and knowledge that promoted continuous reuse of material and efficient exchange mechanisms. Moreover, circular processes and improvement of traditional processes contributed to minimizing and eliminating waste and even including/creating processes related to social innovation. Those shifts represent the need to achieve sustainability goals such as net zero and positive social impact. An example was *Case 2*, which created new processes related to mechanical treatment and structures to give pulp more value and reuse function, creating new value propositions, as is expressed in the following quote: "*We do a mechanical treatment, and you rearrange it, right? You create microfibrillated cellulose*". *Case 2* built new processes and adjusted existing processes to respond to emergent markets such as the carbon market, as was evidenced in *Case 2* with the quote: "*Then we adapted the methodology and created two large carbon projects*" or in *Case 5* with the quote of the sustainability manager: "*We have been working with the concept of design for the environment for many years now*".

iv) Creating an open-data platform

Platforms for managing circular ecosystems guarantee the exchange of internal and external resources. Their use goes beyond exchanging information, involving commercialization, monitoring strategic goals, and decision-making processes between actors and strategic designs (Konietzko et al., 2020b). One of the most frequent ways of using a platform is related to communication among actors, i.e., providers, operators, users, and waste collectors, who can access the architecture of the same data. In Case 2, we verified with a digital lab creation. This case created an environment that connected startups and universities to find solutions to pulp challenges. In *Case 7*, a platform was developed to approve partner operators, validate recycling processes, and certify recycling actions. *A similar situation was observed in Case 5* when the firm used a platform to facilitate the connection between waste pickers and consumers. This app optimizes access routes and proximity with recycling materials, as we can see in the following quote *from Case 7*: *"By using the app, you contribute to the environment and strengthen the work of waste pickers"*.

v) Creating standards to achieve sustainable certifications

Circular or sustainability standards ensure that activities follow sustainability principles, such as minimizing resource consumption, reducing waste generation, and supporting fair labor practices. In this sense, focal firms establish minimal criteria for developing products. Cases 4, 3, and 7 strictly followed specifications on the percentage of recycled materials used, the production of products using renewable energies, and a low carbon footprint. Precisely, Case 3 followed the marketing requirements of Dragonfly. In addition, *Case 6* searches for solutions that comply with sustainable steel certifications, using raw materials with certified green coal. In Case 2, sustainability certifications such as certification of carbon credits enable businesses of fast-growing plantations and environmental conservation and restoration areas. We verified the sustainability manager's statement: *"I've already managed to certify and even issue carbon credits"*. For more details of initiatives of focal firms in reconfiguring capabilities, see Table 5.

4.2.4. Ecosystem integrating: the new capability related to ecosystem perspective

Ecosystem integrating capability for circular ecosystem creation is crucial for coordinating and managing diverse actors' activities, goals, and interests for sustainable and efficient CE value propositions. The capability helps businesses to harmonize their efforts with suppliers, customers, regulators, and the wider community to drive systemic change towards sustainability (Siaw and Sarpong, 2021; Sjödin et al., 2024). Our empirical data verified that one of the functions of focal

Table 5
Micro-foundations evidenced in circular ecosystems in reconfiguring dynamic capability.

Dynamic capability	Micro-foundations	Quotations	Activities, actions, or initiatives
Reconfiguring	Supplier redesign	*Case 3: "Then there was this movement to consolidate manufacturing [suppliers]. This has already made it easier to develop new projects."*	-Defining Supplier Selection Criteria (e.g., raw material sources, carbon footprint, social benefits) -Influencing and encouraging suppliers to adopt circular practices that align with the orchestrator's selection criteria -Creating new flows and activities to include suppliers as prominent actors in the circular ecosystem.
	Business model transformation	*Case 3: "Business units that we have within [focal firm name], right? There's also a services front which is advancing the services model"*	- Redesign from linear to circular value propositions (e.g., offer 100 % paper food packaging, offer 60 % recycled steel strip, offer printers with recycled plastic) - Introducing modular business models that reimagine products or systems (e.g., buildings), −Traceability apps into certificate offerings on circular platforms, − Establishing Reverse Logistics Enterprises (e.g., an enterprise for reverse logistics for electronic, an enterprise for carbon credit with forest restoration)
	Creation of new circular processes	*Case 2: "New business is developing new applications and improving the process [lignin subproduct]."*	- Integrate processes for reverse logistics (e.g., Packaging stock, fair pricing for recycling materials, consumer campaigns for collection), -Integrate processes for minimizing and eliminating waste (e.g., water recirculation, ISO management system), -Integrate processes for upgrading (e.g., Converting cellulose subproducts in black licor, biofertilizer sells, Cellulose fibers for paper production in other enterprises), -Circular product design processes (e.g., design product 100 % based plant), -Decision-making processes with CE orientations (e.g., selecting suppliers, resources according to CE principles)
	Creation of open-data platform	*Case 2- "We have a trading platform, blockchain tokenization for carbon trading"*	-Strengthening the role of waste pickers with a digital platform -Develop a platform for connecting ecosystem participants -Employing platforms to assist in decision-making processes among actors and strategic designs -Communication channels platforms for providers, operators, users, and waste collectors through shared data architecture.
	Standardization with sustainable certification	*Case 6: "But some units are already certified in responsibility steel. Which is an ESG certification that we must have since our inception".*	Establishing Circular or Sustainability design product standards -Specifying material Requirements - Implementing measures to achieve a low carbon footprint in product development and manufacturing -Seeking solutions that align with certifications like sustainable steel standards and green coal materials -Leveraging carbon credit certifications

actors is orchestration. In this role, focal firms developed ecosystem integrating capability that aids in defining archetypes, roles and flows between actors. Micro-foundations of ecosystem integration support the development of sensing, seizing, and reconfiguring capabilities and stimulate the orchestration role. This study categorized the empirical advances of ecosystem integration into three micro-foundations: structuring ecosystem baseline, aligning ecosystem elements, and actors' integration.

i) Structuring ecosystem baseline

Partnerships, activities, roles, and actors are crucial ecosystem components (Gomes et al., 2022b). Building circular ecosystems implies reconfiguring and integrating relationships with customers, competitors, suppliers, and regulatory entities to foster collaboration towards shared circular propositions (Khurana et al., 2022).

Focal firms in circular contexts design ecosystem structures and create a baseline of actors, knowledge, and competencies for a circular value proposition. Focal firms define actors' selection criteria according to ecosystem intrinsic roles, as we observed in *Case 2* when roles and profiles of palm oil suppliers were established. A similar situation was observed in *Case 3*, which established specific minimum requirements for waste picker cooperatives to guarantee the flow of resources. In *Case 1,* food suppliers must meet specific criteria for regenerative practices in

agriculture to ensure that the food meets minimum carbon footprint standards.

Unlike some academic advances (Asgari and Asgari, 2023; Barquete et al., 2022), which highlight that focal firms use recruiting programs to map actors, we verified that focal firms create spaces to select possible ecosystem actors according to circular and sustainable principles. These environments follow pre-established criteria to ensure resources and actors correspond to specific roles and circular value propositions. We verified in *Case 1 that the firm* seeks information and potential players in communication channels with consumers, spaces for interaction with other actors such as events, workshops, conferences, and calls for participation in structural projects for circular innovation interests about beverage packaging. A similar situation was presented in *Case 2* when the firm held a series of workshops in the engineering, logistics, energy, R&D, supply chain, and new business areas to evaluate innovation opportunities related to decarbonization. All focal firms developed calls to capture new actors and competencies to confront sustainability challenges.

ii) Alignment of ecosystem elements

Circular ecosystem creation implies configuring actors' complementarity in activities and roles. In this sense, focal firms must understand each actor's role, function, and influence within a circular value proposition (Parida et al., 2019). This premise was validated by informants of *Case 7* when they monitored the activities of waste picker organizations and evaluated their activities to guarantee their role as suppliers. We observed a similar situation in *Case 3* when the firm mapped waste picker organizations' pains and challenges as suppliers of recycling materials and solved them with training programs, volunteering programs, and housing projects. We identified that orchestrators recognize that all roles are relevant for value creation, and each influences the success of complementarity between actors.

Complementing literature advances (Gomes et al., 2023a; Konietzko et al., 2020a), focal firms support complementarity, offering resources and incentives for competencies development and facilitating co-development, prototyping, and testing in collaboration with potential players in the ecosystem. These specialized skills contribute to circular value creation. Hubs, startup incubators, and acceleration programs were established in all cases. Case 6 created a new low-carbon steel hub, and Case 2 launched two biosolutions startup acceleration programs. In *Case 5*, a form to guarantee complementarity was mapping and establishing connections between paper companies, recyclers, and waste picker cooperatives, offering recycling equipment to recyclers and paper companies.

Another aspect of actor alignment is rules establishment for ecosystem management (Gomes et al., 2023b), particularly in contexts where resource co-specialization occurs without hierarchical structures. In *cases 1, 2, and 6,* we verified that circular ecosystems use participatory decision-making to define the rules for ecosystem management. The focal firm does not necessarily audit these rules. An example is *Case 1*, which participates in a round panel discussion of the formulation of rules related to the production and consumption of sustainable oil. We observed a similar condition in *Case 2* that contributes to the European panel of biofuel. In this panel, requirements are established to guarantee purposeful planting.

iii) Actors' integration

Focal firms strengthen actors' links, which involves monitoring value propositions, relationships, and realignment of interests, objectives, and roles of ecosystem actors. Actor integration ensures timing (Siaw and Sarpong, 2021) about market needs and the sustainability goals set by organizations. It also implies understanding influences between actors (Parida et al., 2019).

To stimulate actors' relationships and understand interdependences, *Case 7* evidenced actors' engagement and reinforcement of win-win relationships by offering support to understand certification requirements, considering each role in their platform. Similarities were observed in Cases 5 and 3, with waste picker organizations' inclusion process in a timeline of years. Both firms internalized the idea of the importance of cooperatives in developing internal circular practices while offering fair prices for waste picker cooperatives and more attractive prices than in the market. These practices aligned values and interests and strengthened complementarities.

A similar situation was observed when *Cases* 5, 4, and 3 used platforms for sharing knowledge, experiences, and technology challenges with other ecosystem players and created channels to interact with consumer needs and facilitate integrating actions of different ecosystem players. Case 5, in particular, used platforms for community engagement and marketing implementation. This firm deploys marketing strategies and actively engages in the green movement by committing to sustainable practices related to plastic recycling. They implemented marketing strategies with voluntary and housing projects to improve the social conditions of waste pickers. Also, the firm incentivized artistic movements and prizes to encourage social recognition of waste picker cooperatives and engage consumers in recycling. In this sense, information technology is critical in actor engagement and reinforcing social relationships.

Actor's integration implies managing different links and non-traditional contracts. Konietzko et al. (2020b) affirm that contractual agreements ensure fair value capture for sustainable ecosystems. However, we discovered that no-contractual relationships play a crucial role in complementarities in a circular ecosystem. We verified in *Case 3* influenced waste picker organizations to supply even when the electronics waste market is unpredictable and they were not part of the ecosystem. In addition, *Case 7* established partnerships with municipalities for mapping actors to contribute to the formalization of waste picker cooperatives. In this sense, *Case 2* established relationships between suppliers and governmental entities to offer carbon credits, and links were made without contracts, as is explained in the following quote: *"Doesn't have a single rule for everyone [for contracts between carbon market players]. What needs to happen is that you identify the projects"*.

For actors' integration, trust is a fundamental aspect of facilitating the resolution of problems between actors and strengthening relationships (Parida et al., 2019). In *Case 5*, trust catalyzes the relationships of actors participating in collaboration projects. In *Case 5*, projects were developed for business training and incentives with small food producers. These practices facilitated small production insertion, strengthened trust with other food players, and contributed to sustainable indexes of job generation. We observed that trust is a critical value within ecosystems, serving as the cornerstone for fostering actor integration and enabling interdependence among participants.

Maintaining alliances is an important factor in actor integration. We observed in *Case 5* when the firm ensured actors' integration of paper companies, recycling companies, and waste picker cooperatives. This firm monitored ecosystem relationships and studied the market stage, stocking up on material to guarantee supplies in crisis events. A similar activity of maintaining *Case 3* was reported. The focal firm translated market information to attract the attention of potential customers and maintain consumer community, as expressed in the quote by a sustainability manager of Case 3: "*Especially with sales, but not just how we communicate externally*". Table 6 exposes details of ecosystem integrating actions in circular ecosystem creation.

Fig. 6 shows a framework representing the trend of DCs developed in focal firms for circular ecosystem emergence. Organizations observed external drivers from sustainability trends in the market and social and environmental regulations. They began establishing activities that allowed them to conduct "*Sensing*" capability to explore the environment and market opportunities. This capability encouraged looking for actors and competencies with external actors that provide specialized knowledge to innovate circular products. Focal firms accomplished initiatives

Table 6
Micro-foundations evidenced in circular ecosystem integrating dynamic capability.

Dynamic capability	Micro-foundations	Quotations	Activities, actions, or initiatives
Ecosystem integrating	Structuring ecosystem baseline	*Case 1: "We have a program called Partner to In. So suppliers bring these breakthrough innovations that we're looking for."*	-Facilitating interaction environment (e.g., events, workshops, conferences, and calls for participation to foster interaction among actors) -Conducting Cross-departmental workshops (departments like Engineering Logistics, Energy, R&D, Supply Chain, and New Business to evaluate decarbonization opportunities) -Seeking information and engaging potential players via communication channels with consumers.
	Alignment of ecosystem elements	*Case 7: "People have to know what's going on, they have to know their role in the cooperative."*	-Structuring actor complementarity - Monitoring and evaluating actor contributions (e.g., waste picker organizations' activities assessment) - Mapping challenges in the ecosystem and supporting actors -Structuring actor complementarity according to roles (e.g., hubs and accelerator programs) -Mapping opportunities for connections (e.g., connections between paper companies, recyclers, and waste picker cooperatives).
	Actors integration	*Case 3: "It's translating all this information into Go to market, right? Translating everything into the way we position ourselves in the market, right?*	-Strengthening actor links (e.g., Marketing strategies and promoting the green movement), -Supporting artistic movements and awarding prizes, −Maintaining links between actors (e.g., monitoring relationships and market stages), -Building trust for actor integration, -Providing business training and incentives

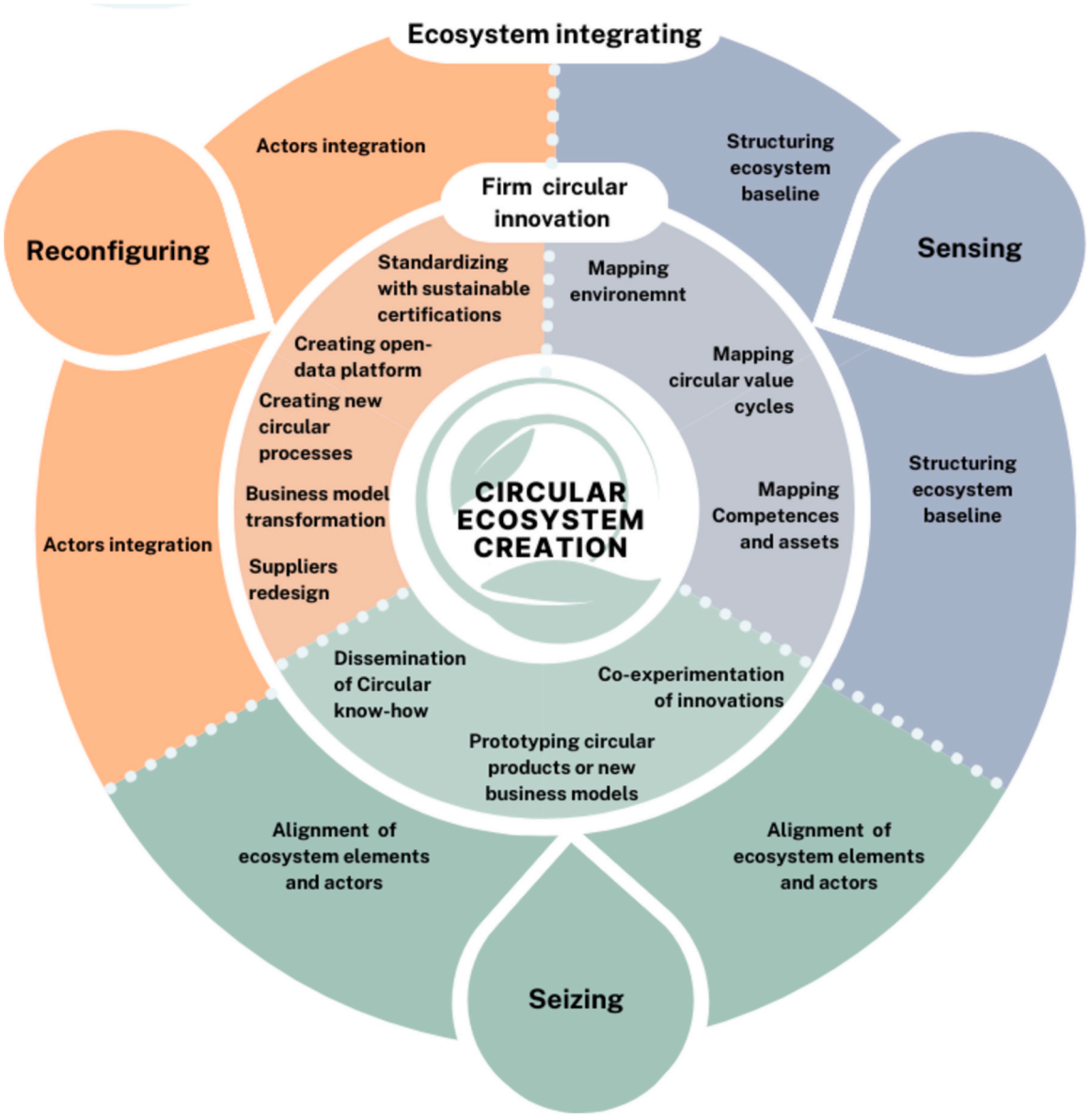

Fig. 6. Detailed framework of dynamic capabilities in firm and ecosystem perspectives for circular ecosystem creation.

(e.g., internalization of resources) for materializing products and business ideas. Such activities aim to invest in innovations (e.g., hubs and acceleration programs).

After seizing opportunities, firms enter the "Seizing" phase, focusing on co-experimentation, prototyping, and internal knowledge dissemination. They initiated pilots, leveraging startup expertise and collaborating with suppliers. The firm disseminated sustainability guidelines integral to innovation design, catalyzing alliances and financial investments like brand promotion. During "Reconfiguring," firms adjusted internal resources, redesigned suppliers, and established circular businesses. They involved sustainability standards for resource selection and actor alignment. With synchronized competencies and activities, firms develop ecosystem management capacities and decentralized governance and foster innovation in different circular ecosystem participants. Sensing, seizing, and reconfiguring categories offer support and exert pressure to create circular value. Ecosystem integrating capability structures the essential elements of the ecosystem, aligning and integrating diverse ecosystem actors.

This framework was developed under Teece (2007) lens and some theoretical bases of DCs in ecosystems (Parida et al., 2019; Sjödin et al., 2024). The emergence of circular ecosystems is not limited to capabilities. However, whether the influence of external factors (such as the market, environmental, and economic regulations) or internal factors (such as organizational culture, availability of financial resources, openness to accepting changes and innovations, and level of maturity about CE). The framework shows the possibility of capabilities within a specific market and regulatory conditions. While actors' integration is an important microfoundation for circular ecosystem integration, we do not specify how the roles and responsibilities of stakeholders are defined and balanced. In this case, there is a gap in the feedback mechanism of capabilities interdependence between actors or understanding of complementarities between actors.

4.3. Highlights of circular ecosystem creation: comparing cases

Based on empirical research, some common initiatives that facilitate circular innovations with different actors were identified. Some semi-structured interviews were conducted with the DCs lens to identify grounded micro-foundations underpinning circular ecosystem creation. Table 7 shows a cross-case comparison among the cases.

Our insights are related to the emergence of circular ecosystems in response to sustainability market demands that drive DCs development towards circular value creation inside and outside the firm. Four categories of CE-of focal firms were identified: sensing, seizing, and reconfiguring, and a novel category of DCs focused on integrating ecosystems. Sensing capability is crucial for the identification of innovation opportunities and ideas aimed at creating circular value (Linde et al., 2021). Empirical data revealed that organizations map CE ideas and opportunities and, apart from identifying and selecting potential resources and changes in the market, firms develop activities that map new technologies, innovations, partnerships, pains of potential ecosystem members, and political and regulatory environment related to sustainability.

For sensing capability development, technological advancements are crucial in data exploration, acquiring resources and innovation, and sharing knowledge for cross-sector collaboration (Tabas et al., 2023). *Case 7* and *Case 4* developed activities focused on mapping actors in platforms. However, mapping was focused only on some external elements. *Case 7* identified activities focused on fitting into the circular market, starting from zero compared to the other organizations that already had linear ecosystem resources and structures. Our empirical evidence showed that *Case 4* emphasized activities in traditional benchmarking and consumer needs and has invested in circular opportunities, innovations, or collaborative benchmarking to create circular value. The prioritization and focus of sensing development depend on internal knowledge about circular innovation, focal firm market position, and role in the ecosystem.

Seizing capability in focal firms involves recognizing internal competencies for exploiting the potential capabilities of external actors (Kim et al., 2022). In all cases, we observed that focal firms formulate prototypes using internal and external knowledge to ensure feasibility and future scales. We observed that focal firms formulate prototypes in all cases using internal and external knowledge to ensure feasibility and future scales. Cases 2 and 5 developed diverse circular innovations over time to overcome internal barriers and meet their commitments to sustainability targets. Case 2 considers waste as an opportunity to create offerings. They upgraded all their subproducts in other product cycles. Similar evidence was observed in Case 5 when the firm carried out various tests, prototypes, and projects aimed at reusing food packaging.

Different reconfigurations were made after the experimentation with other ecosystem actors. Focal firms developed *reconfiguring* capability in each organizational function, with a new network of suppliers that offer closing of the material cycle for recycling or social benefits. In addition, processes for the use of materials and evaluation of products have been restructured, communication channels have been created and strengthened, decision-making methods have been restructured in line with sustainability goals and circular principles, and governance rules and roles have been established between the players towards engaging them and responding to sustainability trends in the market. Beyond the firm level, circular innovation overlaps firm boundaries.

Well-positioned organizations have advantages in develop*ing ecosystem integrating* capabilities. The ecosystem integrating capability structures networks and the ecosystem's baselines strengthens links, aligns objectives, roles, activities, flows of information, and knowledge between actors, and drives and engages different actors in the ecosystems with new socio-environmental impact projects and high cost of

Table 7
Cross-case comparison: dynamic capabilities for circular ecosystem creation.

Category	Micro-foundation	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Y	P	%
Sensing	Mapping environment	Y	Y	Y	P	Y	Y	P	5	2	71,4
	Mapping competencies and knowledge	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Mapping circular value cycles	Y	Y	Y	Y	Y	Y	P	6	1	85,7
Seizing	Prototyping new products or new business models	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Co-experimentation of innovations	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Dissemination of circular know-how	Y	Y	Y	Y	Y	Y	Y	7	0	100
Reconfiguring	Suppliers redesign	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Business model transformation	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Creating open-data platform	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Creating circular processes	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Standardizing with sustainable certification	Y	Y	Y	Y	Y	Y	Y	7	0	100
Ecosystem integrating	Structuring ecosystem baseline	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Alignment of ecosystem elements	Y	Y	Y	Y	Y	Y	Y	7	0	100
	Actors integration	Y	Y	Y	Y	Y	Y	Y	7	0	100

Notes: keys – Y: (employed); P: (partially employed); %: total Y/cases.

production and marketing. In terms of ecosystem emergence, stakeholder engagement is fundamental to cooperation, collaboration, and value co-creation (Sjödin et al., 2024; Viglia et al., 2023). In circular ecosystem cases, stakeholder engagement plays a significant role in ecosystem governance, facilitates the alignment of actors, and promotes circular principles integration into the organizational cultures of ecosystem members.

However, the creation of circular ecosystems is limited by barriers related to CE (e.g., the influence of consumer awareness and interest (Gomes et al., 2022a) the openness of organizations to transform their business models (Kirchherr et al., 2023), market unpredictability in terms of costs of materials from other product cycles (Pietrulla, 2022), and risks of implementation of circular business models). CE transitions require an extended timeline and ensure strategies align different actors and innovations according to the principles of CE.

The contribution of this research goes beyond recognizing that the leading firm develops DCs at its level to orchestrate actors (Linde et al., 2021) or that the role of lead firms in the circular ecosystem is orchestration (Sjödin et al., 2023, 2024). Towards creating circular ecosystems, the focal firm devotes orchestration efforts, facilitates other firms to have spaces for interaction to capture resources and knowledge, uses investments and efforts to ensure the governance of the ecosystem, catalyzes the competencies of strategic actors for circular innovations, and maintains the relationships of the actors within the ecosystem. DCs with an ecosystem lens leverage the alignment of goals, data sharing, and co-creation of solutions that drive sustainability and competitive advantages.

4.4. Theoretical contributions

This study contributes to the growing stream of application of DCs (Linde et al., 2021; Teece et al., 2018), which creates new categories of DC for ecosystems in CE. DCs are fundamental to understanding the business environment, threats, and opportunities and making strategic decisions to capitalize on opportunities (Teece, 2007; Teece, 2017).

First, we respond to the calls of DCs in underdeveloped advances in knowledge integration (Thomas and Autio, 2020) and for more specific actions to allow practitioners to implement orchestration (Kindermann et al., 2022) and manage diverse capabilities in interdependencies innovation outcomes (Linde et al., 2021). We discovered that the demand for sustainability encourages the creation of circular ecosystems. A holistic view of strategy is necessary to achieve sustainability goals, where DCs go beyond integrating new knowledge and imply the orchestration of resources, actors, activities, and internal rules of ecosystem management. In this sense, we led to categories such as sensing, seizing, and reconfiguring in the focal firm view and ecosystem integrating for ecosystem creation.

The ecosystem research landscape encompasses various dimensions: co-creation (Abbate et al., 2022), coevolution (Teece, 2018), and resilience development (Khurana et al., 2022). DCs in ecosystems enhance adaptability to dynamic challenges and foster collaboration with external entities (Kim et al., 2022). However, existing DC literature in ecosystems often overlooks the need for firms to restructure resource portfolios for sustained competitive advantages (Randhawa et al., 2022; Siaw and Sarpong, 2021). Our study provides insights into microfoundations and actions of focal firms in creating circular ecosystems. Catalyzing complementarity and co-creation through circular innovations fosters circular outcomes like recycled products and new carbon markets. Ecosystem integrating capability in circular ecosystems involves more than alignment and trust. They necessitate co-experimentation and envisioning circular businesses with social impact actors as partners.

In addition, circular ecosystem creation is catalyzed by the role of the orchestrator and the openness that actors have in developing external exchange activities (Gomes et al., 2023a; Gomes et al., 2023b). Advances in circular ecosystems bring a limited view of the activities necessary for the emergence and maintenance of circular ecosystems (Arekrans et al., 2023; Asgari and Asgari, 2023; Trevisan et al., 2022). With advances, DCs can be considered a basis for addressed changes from a closed stage of organizations to a space for exchanging resources and knowledge aimed at circularity. Circular ecosystems are guided by circular innovation and the development of this innovation. Focal firms, as orchestrators, play a fundamental role. This role has different ways of addressing sustainable and circular products. The orchestrator plays a vital role in the shift from linear production to a circular ecosystem. However, each of them may have different strategies for delivering circular value.

Our contributions verify that DCs are key components to understanding organizational behavior within circular ecosystems. Furthermore, win-win relationships in the context of CE facilitate the advancement of ecosystem actors in creating competencies related to the CE and developing social and environmental benefits. Through the lens of DCs we observed that internal changes in the firm influence changes in the competencies, businesses, and structures of ecosystem participants. With the observed cases, we discovered eleven micro-foundations focused on circular value creation inside the firm and three focused on defining, structuring, and managing the roles and resources of the actors in the circular ecosystem.

Our framework is a conceptual model that reveals the generic initiatives to circular ecosystems emerging to build DCs. Our framework is a pathway that organizations follow when they play a crucial role as ecosystem creators. Focal firms developed DCs for different ways to create more sustainable products and used circular orientations to innovate and respond to sustainability trends. Therefore, focal firms must continually monitor and adjust their operations to take advantage of emerging opportunities, striving to achieve sustainability goals.

4.5. Practical implications

This study has practical implications for leader enterprises that use circular ecosystem creation as an alternative to achieve sustainability. This study has practical implications for leader enterprises that use circular ecosystem creation as an alternative to achieve sustainability. The framework provides key initiatives for creating a circular ecosystem, identifying main competencies and actions to overcome sustainability goals. It has also verified that such a creation is a journey of trial and error that demonstrates the capabilities that stand out for success in the identification of opportunities for the circular value creation, internalization and learning of new knowledge and collaboration skills, and reconfiguration of internal structures considering the interdependence of actors. Leader firms are pivotal in orchestrating relationships, engaging stakeholders, and fostering innovation and collaboration spaces. They provide essential technologies for closing material loops and support ecosystem actors to overcome bottlenecks and challenges, thereby driving sustainable progress. In a sense, circular ecosystem creation depends on including diverse actors, thus requiring the encouragement of non-traditional actors in recycling cycles. In the creation of circular ecosystems, social and environmental benefits are merely a consequence; therefore, establishing circular ecosystems serves as a strategic pathway for organizations to achieve sustainability objectives and enhance market resilience.

4.6. Research limitations

Although the information gathering was thorough and followed a qualitative method (Eisenhardt, 2021), a qualitative method is limited by the subjectivity of analysis. The focus of our study is to address the creation of circular ecosystems from the perspective of ecosystem leaders. This focus is specific to the phase of ecosystem emergence based on the orchestrator's efforts and shifts without considering other ecosystem actors. Although empirical data (i.e., interviews) and secondary information such as scientific articles and reports sustained this

research, interviews with other ecosystem actors (e.g., suppliers, regulators, complementors) could complement our findings. In addition, quantitative data might nurture DCs' understanding of organizational performance in implementing circular initiatives to create social, environmental, and economic benefits in the ecosystem. This research is synthesized in a conceptual framework that exhibits some aspects of ecosystem integration. However, how capabilities influence interdependencies and co-development among actors is not clear, which is fundamental to enabling effective ecosystem integration.

5. Conclusions

This study takes a step forward in two major research areas, DCs, and ecosystems, shedding light on the institutional and strategic aspects necessary for transforming systems towards the CE. Achieving a CE involves more than operational interdependence; it requires a strategic alignment and collaboration of actors across various levels, including strategies, business, resources, and operations.

This research provides a foundational understanding of circular ecosystem creation, contributing to academic discussions on DCs and practical insights for CE transitions. Academically, our findings show that focal firms develop sensing capabilities through micro-foundations that identify internal and external circular opportunities and challenges. They also build seizing capabilities, enabling collaborative implementation of circular strategies and reconfiguring capabilities, which adapt and reshape internal processes to foster ecosystem creation. Additionally, firms cultivate an ecosystem integrating capability, a holistic effort to align and connect diverse actors, processes, and resources within the ecosystem.

From a practical standpoint, the study highlights essential activities such as mapping strategic alliances with suppliers, customers, regulators, startups, and community groups; evaluating market trends, consumer behavior, and regulatory environments; co-experimenting with circular solutions; and ensuring complementarities while monitoring relationships. Successful circular innovation requires a synergistic approach, where firms develop internal capabilities and foster collaboration and alignment with external partners. Ecosystem leaders drive orchestration, facilitating sustainable value co-creation with strategic objectives, sharing data, and collective innovation. External factors, such as regulations and environmental challenges, are critical in encouraging circular innovation to achieve sustainability.

Circular ecosystem creation is not spontaneous. It requires organizational changes within focal firms and other ecosystem participants, implying internal and external challenges for future ecosystems. These challenges underscore the need for further research to enhance replicability in real-world contexts. Future research could explore firms in different sectors with varied circular value creation approaches, such as product-as-a-service models, dematerialization, and remanufacturing. Additionally, future research could identify new DCs based on the roles of ecosystem actors and examine more mature circular ecosystems, including feedback mechanisms between capabilities.

Finally, these findings are fundamental for understanding circular ecosystem creation and contribute to SDG 12 on *responsible consumption and production*. They offer insights into key capability configurations that enable organizations to influence stakeholders, adapt processes, and foster sustainability transitions. This research provides a roadmap for promoting practices aligned with sustainable policies, encouraging transnational companies to adopt more collaborative approaches for CE transitions.

CRediT authorship contribution statement

Dánika A. Castillo-Ospina: Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization, Writing – review & editing, Writing – original draft. **Marta Ormazabal:** Validation, Formal analysis, Writing – review & editing. **Leonardo de Vasconcelos Gomes:** Validation, Formal analysis, Data curation. **Aldo Roberto Ometto:** Validation, Investigation, Data curation, Conceptualization, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2024.12.022.

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