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Collaborative Open Innovation for Sustainable Diversification of SMEs in the Circular Economy: Mechanisms, Interactions, and Contingencies

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Abstract

This study examines how collaborative open innovation (OI) supports sustainable diversification in small and medium-sized enterprises (SMEs) operating in the circular economy (CE). While prior research has widely discussed open innovation and circular transition, less attention has been paid to how SMEs use collaboration to develop new products, services, markets, or partnership configurations under circular constraints. Using a qualitative multiple-case design, the study draws on 36 semi-structured interviews with SME managers in renewable energy, waste management, and sustainable manufacturing across Germany, France, Italy, Spain, and Sweden, complemented by documentary and policy analysis. The findings identify four recurring collaborative OI practices: cross-sectoral knowledge alliances, supplier-customer co-creation networks, academic-industry research partnerships, and digital platform-based collaboration. These practices support sustainable diversification through four linked mechanisms: improved resource efficiency, product and service innovation, expanded market reach, and stronger institutional legitimacy. These mechanisms do not operate in isolation: legitimacy often serves as a gatekeeper for market expansion, resource efficiency enables product innovation, and pursuing them in the wrong order can reverse diversification gains. The analysis further shows that absorptive capacity and policy support condition whether externally sourced knowledge can be converted into viable circular offerings. The study further identifies four failure patterns (partner misalignment, internal conversion failure, legitimacy deficit, and policy dependency trap) and shows that power asymmetry can lead to knowledge leakage or greenwashing by stronger partners. The article contributes an integrated framework that explains how collaborative OI practices, enabling mechanisms, and contextual conditions failure patterns, and power asymmetries jointly shape whether SMEs translate circular opportunities into resilient diversification or fall into collaborative traps.

Keywords

Open innovation, Sustainable diversification, Circular economy, SMEs, Collaborative open innovation, Absorptive capacity

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1. Introduction

Small and medium-sized enterprises (SMEs) account for the vast majority of businesses and remain central to employment creation, value generation, and regional resilience. Recent reporting from the Organization for Economic Co-operation and Development (OECD) shows that SMEs continue to operate under growing pressure from sustainability requirements, supply-chain disruptions, energy uncertainty, and digital transition demands [1]. At the same time, European circular economy (CE) policy has moved from broad strategic ambition to a more concrete regulatory and market agenda, placing increasing pressure on firms to reduce waste, recover materials, redesign products, and demonstrate sustainability performance [2]. For SMEs, these pressures are not only compliance issues. They also reshape the conditions under which firms pursue growth, competitiveness, and business renewal. However, when SMEs collaborate with larger firms or research institutions, power asymmetries often reshape knowledge flows, raising risks of knowledge leakage and symbolic participation (where the SME's role is merely cosmetic) rather than mutual diversification.

The CE offers an alternative to the linear take-make-dispose model by emphasizing longer product lifecycles, material recirculation, value retention, waste prevention, and regenerative resource use [3,4]. For SMEs, however, circular transition rarely involves a simple operational adjustment. It often requires changes in supplier relations, customer engagement, technological choices, and the broader architecture of value creation. In this context, sustainable diversification becomes especially important. In this study, sustainable diversification refers to the deliberate extension of an SME's portfolio into new products, services, markets, or partnership configurations that are both commercially viable and aligned with circular value creation principles such as resource recirculation, product-life extension, and waste valorization [5]. Crucially, in CE settings, sustainable diversification requires firms to manage non-standardized resource streams, navigate uncertain regulations on secondary materials, and build legitimacy for circular claims—characteristics that distinguish it from general green product diversification. This concept goes beyond general green innovation because it focuses on portfolio expansion under circular constraints rather than isolated environmental improvement.

The challenge is that sustainable diversification is both knowledge-intensive and resource-intensive. SMEs often face financial constraints, limited managerial capacity, modest research and development resources, and incomplete access to market and sustainability-related intelligence [6]. Although many firms recognize opportunities in reuse, repair, remanufacturing, recycling, or service-based circular models, they often lack the technical knowledge, partner ecosystem, and organizational capability needed to turn such opportunities into viable offerings. Open innovation (OI) offers a possible route forward. By drawing on external knowledge, technologies, and networks while recombining them with internal know-how, SMEs may reduce the uncertainty and cost associated with circular diversification [7-10]. However, OI is not uniformly beneficial: the same openness that enables learning can expose SMEs to knowledge leakage, dependency, or 'greenwashing' by stronger partners when power asymmetries are not governed.

A further challenge is that CE-oriented diversification rarely depends on a single organizational change. Firms often need to redesign products, adjust sourcing arrangements, involve customers in new usage or recovery models, comply with evolving sustainability requirements, and rethink how value is created and captured. For large firms, such complexity can be distributed across specialized functions. For SMEs, such complexity is difficult to manage internally because multiple adjustments must often be coordinated at the same time. As a result, diversification opportunities that appear strategically attractive may still remain unrealized unless firms can mobilize a broader ecosystem of collaborators to support experimentation and implementation.

Existing research suggests that collaboration is central to circular transition because redesign, reverse logistics, material recovery, and secondary-market creation cannot be achieved by isolated firms alone [11-13]. Emerging work on open circular innovation likewise suggests that stakeholder collaboration helps connect innovation activity with circular business-model change [13]. However, the literature remains less clear on how such collaboration supports sustainable diversification in SMEs. In particular, it still says too little about which collaborative OI practices are most consequential, how these practices translate into diversification outcomes, and why some SMEs are better able than others to convert collaboration into viable circular growth paths.

Against this background, several gaps in the literature still need closer attention. First, studies on OI and the CE have expanded rapidly. However, they have focused more often on innovation performance, circular business models, or sustainability transition in general than on sustainable diversification as a distinct strategic outcome for SMEs [13,14]. Second, the specific collaborative OI practices through which SMEs pursue diversification under circular constraints remain insufficiently differentiated. Third, the mechanisms linking collaboration to diversification are still under-specified, as prior studies often identify benefits without clearly explaining the organizational and market processes through which they emerge. Fourth, contextual conditions such as absorptive capacity and policy support are frequently acknowledged, but less often integrated into a coherent explanation of why similar collaborative arrangements lead to different diversification outcomes across firms [12,15,16]. Fifth, the literature has largely overlooked systematic analysis of collaboration failures and power asymmetries, instead assuming that openness naturally benefits all partners equally.

To address these gaps, this study develops an integrated analytical framework linking collaborative OI practices, enabling mechanisms, and the roles of absorptive capacity and policy support in shaping diversification outcomes in CE-oriented SMEs. Rather than treating collaboration as a generic benefit, the study examines how different forms of collaborative openness shape the translation of circular ambitions into commercially viable diversification pathways.

Accordingly, this study investigates collaborative OI as an enabling architecture for sustainable diversification in CE-oriented SMEs. It addresses three research questions:

- (1) Which collaborative OI practices are adopted by SMEs to support sustainable diversification in the CE?
- (2) Through which mechanisms do those practices contribute to diversification outcomes?
- (3) How do absorptive capacity and policy support shape the effectiveness of collaborative OI?
- (4) How do power asymmetries and collaboration failures affect the translation of OI into diversification outcomes?

These questions are addressed through a process-oriented, cross-case analysis that pays explicit attention to mechanism interactions, failure typologies, and governance of power imbalances.

By answering these questions, the study contributes both conceptually and practically. Conceptually, it clarifies how collaborative practices, enabling mechanisms, and contextual conditions interact in shaping diversification under circular constraints. Practically, it identifies which forms of collaboration appear most useful for SME managers and which supporting conditions deserve greater policy attention.

2. Literature Review

2.1 CE Transition and SME-Specific Constraints

The CE is commonly defined as a restorative and regenerative system in which economic value is retained through repair, reuse, remanufacturing, recycling, and improved product-system design [3,4,17]. Beyond waste reduction, CE scholarship emphasizes the importance of slowing, narrowing, and closing resource loops. For SMEs, the appeal of the CE lies in lower material costs, closer customer relationships, enhanced resilience to resource volatility, and access to emerging green markets [3,12]. At the same time, SME adoption remains uneven because circular initiatives demand organizational redesign, new inter-firm coordination routines, and investment in technical and managerial capabilities [11,16,18]. These demands are strategically significant because they often push SMEs beyond incremental adjustment and toward new forms of market participation and portfolio development.

Recent literature has sharpened understanding of these barriers. Case-based research shows that SMEs often confront context-specific obstacles such as weak regional ecosystems, limited infrastructure for take-back or recovery systems, low customer readiness, and fragmented policy implementation [14]. Review-based work likewise indicates that CE adoption in SMEs is shaped by a mixture of technological, stakeholder, market, organizational, and regulatory enablers, with no single path proving sufficient across contexts. This matters for the present study because entering circular markets is rarely possible through internal effort alone. SMEs must often build new combinations of partners, competences, and legitimacy before a circular offer becomes commercially viable.

There is also an important timing issue. In many sectors, CE transition creates opportunity before it creates organizational readiness. Managers may perceive demand for lower-carbon or circular solutions, while the enabling infrastructure of recycling streams, certification systems, interoperable materials, and specialized service providers remains incomplete. Such mismatched timing produces a strategic dilemma: firms that wait may lose first-mover opportunities, while firms that move early face high uncertainty and coordination cost. Collaborative OI can reduce this dilemma by distributing exploration across multiple actors and turning ecosystem uncertainty into a shared problem-solving process. This observation reinforces the need to examine collaboration not simply as a supporting condition, but as a strategic pathway through which SMEs pursue diversification under circular constraints.

Nevertheless, the institutional environment in which SMEs operate varies markedly across countries. Germany's CE Act (KrWG) imposes binding recovery quotas, while Italy's policy emphasizes extended producer responsibility with regional variation, and Sweden's waste-to-energy infrastructure creates different collaboration incentives. Such differences affect not only the feasibility of collaboration but also the relative bargaining power of SMEs versus large incumbents. Ignoring institutional heterogeneity risks producing "out-of-context" findings. To address this issue, Appendix A provides a comparative overview of the circular economy policy frameworks, SME support instruments, procurement conditions, and infrastructure maturity across the five countries included in the study (Table A1). This comparison helps contextualize the institutional environments in which collaborative OI and diversification activities take place.

2.2 Sustainable Diversification in SMEs

Diversification has long been discussed as a route to growth and risk spreading in smaller firms, especially under conditions of uncertain demand or concentrated dependence on a single product-market niche [19]. In CE settings,

however, diversification takes on a more specific strategic meaning. It may involve extending the firm's portfolio into repair services, secondary-market offerings, recovered-material applications, or new market segments built around energy efficiency, circular sourcing, or product-life extension [5,20]. In this sense, sustainable diversification is not simply about adding greener products. It concerns the creation of additional commercially viable growth paths that remain aligned with circular value creation principles.

Sustainable diversification is not simply a matter of launching greener products. Nor is it identical to broad business-model transformation. Rather, it refers to the extension of the firm's scope into new circular offerings, markets, or relational arrangements that require alignment between commercial opportunity, operational feasibility, stakeholder acceptance, and institutional fit. SMEs often need to learn how to source alternative materials, collaborate on product redesign, manage reverse flows, document environmental claims, or engage new users and partners. These requirements create a strong dependence on inter-organizational learning and external knowledge search. Diversification in CE settings should therefore be understood as a collaborative process of capability recombination rather than a purely internal strategic choice.

This perspective is important because diversification under circular conditions changes the risk profile of the firm. Traditional diversification literature often treats new product and market entry as a portfolio decision. In CE-oriented SMEs, however, diversification frequently entails experimentation with new value logics such as product-service systems, reparability or recovery-based revenue streams. These moves may increase uncertainty in the short term while enhancing resilience in the long term. The strategic challenge, therefore, is not only to identify a new market, but also to assemble a configuration of partners and capabilities that makes the new activity operationally, institutionally, and financially sustainable. This is precisely why a collaboration-centered explanation is necessary in the CE context.

However, diversification attempts often fail: collaboration may stall, knowledge may remain unused, or partners may pursue diverging goals. The literature has paid limited attention to such failure patterns, which this study systematically categorizes into four types.

2.3 OI and Collaborative Practices

OI reframes innovation as a distributed process in which valuable knowledge can enter and leave the firm across organizational boundaries [7,8]. For SMEs, the value of OI is especially clear because resource scarcity makes it difficult to rely exclusively on internal research and development. Empirical research shows that SMEs use inbound and outbound knowledge flows to improve innovation performance, accelerate problem solving, and access specialized competences that would otherwise remain unavailable [9,10,15]. In CE-oriented settings, this logic becomes especially important because diversification often depends on external technical, market, and institutional knowledge that SMEs do not possess internally.

Collaborative OI practices include partnerships with universities, customers, suppliers, peer firms, public agencies, non-governmental organizations (NGOs), and digital intermediaries. Earlier SME studies emphasized customer involvement, supplier partnerships, joint development projects, and knowledge alliances as recurring modes of openness [9]. More recent work extends that picture by demonstrating how inter-organizational collaboration and digital transformation jointly strengthen circular-economy performance, and how technology-transfer intermediaries can support OI capability development in smaller firms [21-23]. These insights suggest that the relevant question is no longer whether SMEs should collaborate, but which collaborative forms are most productive for a specific diversification objective.

In CE settings, collaboration is especially demanding because relevant knowledge is distributed across the full product lifecycle. Designers may know how to improve recoverability, suppliers may know what recycled inputs are feasible, customers may know which service features support adoption, and public actors may influence the standards or incentives that make a new offer credible. OI therefore becomes not only a knowledge-search challenge but also a governance challenge. SMEs must decide how open to be, with whom to collaborate, how formal the arrangement should be, and how to protect core know-how while still enabling meaningful exchange. These trade-offs are central to understanding why some collaborative OI practices become productive while others remain symbolic, fragile, or difficult to sustain.

Power asymmetry adds another layer of complexity. When a large firm or university controls critical resources or market access, SMEs may face pressure to share proprietary know-how without adequate protection. This can lead to knowledge leakage or make the SME's participation symbolic, benefiting the stronger partner's green claims without genuine diversification. Prior OI research has primarily assumed symmetric or mutually beneficial partnerships; this study explicitly examines how power imbalances shape outcomes.

2.4 Linking OI and the CE

The CE and OI literatures increasingly overlap because circular solutions depend on knowledge recombination across product lifecycles, industries, and stakeholder groups. Studies on open circular innovation argue that stakeholder collaboration is not peripheral but central to circular innovation, since no single organization controls all the resources needed to redesign offerings, recover materials, and build new use systems [13,24,25]. Work on circular business models in SMEs likewise shows that the move toward circularity is tied to organizational maturity, ecosystem access,

and the ability to translate sustainability intent into workable business arrangements [20]. For the present study, this overlap is important because it suggests that OI in CE-oriented SMEs should be understood not only as an innovation logic, but also as a practical route through which firms pursue new circular growth opportunities.

Recent empirical studies reinforce this linkage. Research has shown that inter-organizational collaboration and digital capabilities can positively influence CE performance [22], that CE and OI can jointly enhance SME organizational performance [26], and that open circular innovation becomes more effective when dynamic capabilities or ambidextrous learning processes are present [25]. Even so, most available studies concentrate on circularity, innovation, or organizational performance in general. The more specific question of sustainable diversification—how SMEs use collaboration to create additional products, services, markets, or growth options under circular constraint—has received far less direct attention.

Another unresolved issue is whether OI in the CE should be interpreted primarily as a technology-development mechanism or as a business-model transformation mechanism. The available evidence suggests that it is both. Firms may initially collaborate to improve a process or solve a technical problem, yet the same collaboration can later support new channels, new service formats, or entry into adjacent sectors. This duality helps explain why collaboration appears repeatedly in circular-transition research but often with different labels and outcome measures. A diversification lens is useful here because it captures both the innovation side of CE-related openness and its broader strategic implications for firms.

2.5 Absorptive Capacity and Policy Support

Two contextual variables are especially important for explaining why collaborative OI produces uneven results. The first is absorptive capacity, commonly understood as the firm's ability to acquire, assimilate, transform, and exploit external knowledge [12]. In the present context, these dimensions matter in different ways. Acquisition concerns the ability to identify and access useful external knowledge. Assimilation refers to the firm's capacity to interpret and communicate that knowledge internally. Transformation involves recombining external inputs with existing routines, resources, or capabilities. Exploitation refers to the conversion of acquired knowledge into concrete products, services, processes, or commercial outcomes. In CE-oriented SMEs, the most critical bottlenecks are often transformation and exploitation rather than acquisition alone, because circular knowledge must be translated across technical, market, and regulatory domains before it becomes a viable offering. Research on SMEs likewise confirms that absorptive capacity supports both OI practices and innovation performance [15,27].

2.5.1 CE-Specific Extensions of Absorptive Capacity

The standard absorptive capacity (ACAP) framework was developed primarily for knowledge-intensive industries with relatively stable technical standards. In CE-oriented SMEs, external knowledge differs in three important respects. First, it frequently concerns waste streams, secondary materials, or reverse logistics—domains where quality is variable and technical standards are often incomplete. Second, circular knowledge is distributed across value chain stages (design, use, collection, reprocessing) that rarely communicate directly, requiring cross-sectoral translation capabilities. Third, circular knowledge is highly regulation-sensitive, as policy changes can rapidly alter the viability of a material or process. Consequently, ACAP in CE settings requires not only acquisition-assimilation-transformation-exploitation routines but also regulatory scanning, quality-uncertainty management, and cross-sectoral integration. This study operationalizes these CE specific dimensions alongside the classic four dimensions.

The second variable is policy support. Circular transition frequently depends on public funding, pilot and demonstration projects, partner-matching platforms, procurement rules, technical standards, and regional innovation infrastructures [2,11]. Where policy support is strong, SMEs face lower search costs, greater legitimacy, and more favorable risk conditions for collaboration. Where support is weak, fragmented, or inconsistent, circular diversification can remain aspirational rather than actionable. Policy support therefore does not substitute for collaboration, but it can substantially shape the cost, timing, and scalability of collaborative OI.

2.5.2 Potential Downsides and Implementation Resistances

Policy support is not without risks. In several documented cases, pilot funding created dependency: diversification activities ceased when subsidies ended, indicating that support had not fostered sustainable business models. Moreover, public procurement rules, while well-intentioned, often impose compliance costs (e.g., insurance, lengthy documentation) that exclude smaller SMEs. Similarly, partner-matching platforms may suffer from low updating frequency or lack of human intermediation, which particularly hampers less digitally mature firms. These observations suggest that effective policy design should not only enable collaboration but also reduce procedural complexity and avoid unintended dependency. The empirical findings will elaborate on these implementation frictions.

Taken together, absorptive capacity and policy support help explain when collaboration can actually be turned into diversification. Absorptive capacity shapes what the firm can do with incoming knowledge once collaboration begins. Policy support shapes whether collaboration becomes affordable, legitimate, and scalable in the first place. Considered

jointly, these conditions help explain why similar collaborative OI practices may lead to very different outcomes across CE-oriented SMEs.

2.6 Analytical Framework

Based on the literature, this study proposes that collaborative OI practices influence sustainable diversification through four enabling mechanisms: resource efficiency, product and service innovation, market reach expansion, and institutional legitimacy. In this study, these mechanisms are understood as processes rather than as end results. Resource efficiency refers to the collaborative identification of waste reduction, recovery, or cost-saving opportunities that free capacity for experimentation. Product and service innovation refers to the co-development or refinement of new offers through external technical, user, or market knowledge. Market reach expansion refers to the opening of channels, networks, or procurement access that reduce entry barriers to new circular activities. Institutional legitimacy refers to the signaling effects through which collaboration with credible partners enhances trust, recognition, or acceptance for new offerings. The four mechanisms are not assumed to operate independently. Based on the case analysis (see Section 4), this study proposes specific interactions among them. First, legitimacy often acts as a gatekeeper for market expansion: without credible partners or recognized certifications, SMEs struggle to enter new circular markets, even when technical innovation is ready. Second, resource efficiency gains typically enable product and service innovation by freeing up operational capacity and reducing experimentation costs. Third, product innovation without market reach remains inconsequential, whereas market reach without prior legitimacy may fail to gain customer trust. Fourth, feedback from market expansion can reinforce legitimacy through demonstrated track records. These interactions imply that sequencing matters: diversification is more likely to succeed when legitimacy-building precedes market entry, and when resource efficiency creates room for innovation. The empirical findings in Section 4.2.5 elaborate on these conditional dependencies. The framework further proposes that absorptive capacity conditions the internal conversion of external knowledge, while policy support conditions the external feasibility and scalability of collaboration. The framework is process-oriented rather than strictly deterministic: diversification intentions may initiate collaboration, while collaboration shapes whether and how those intentions are translated into viable circular growth paths. Figure 1 summarizes this analytical framework and guided both coding and interpretation in the empirical stage. For discussion of interactions among the four mechanisms (e.g., legitimacy gating market expansion, resource efficiency enabling innovation), see Sections 2.6 and 4.2.5 (authors' own elaboration).

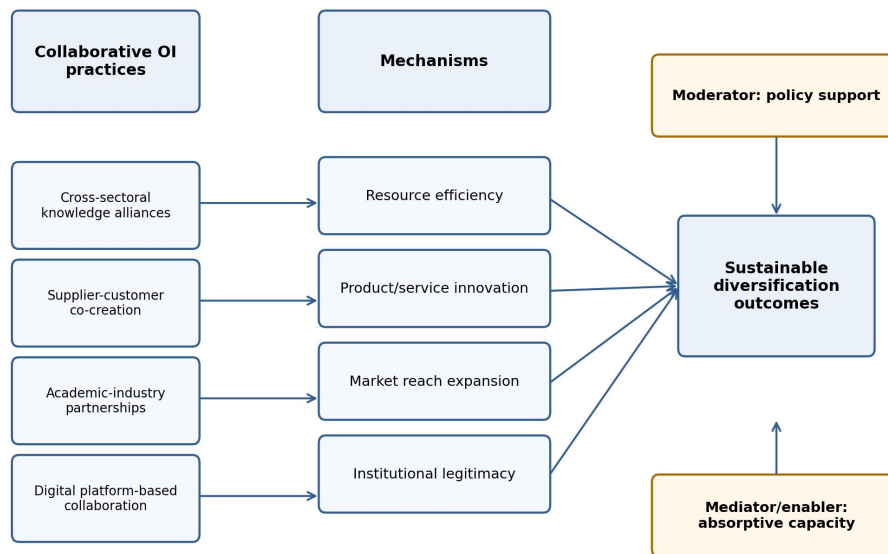


Figure 1. Conceptual framework of collaborative OI and sustainable diversification in CE-oriented SMEs.

3. Methodology

3.1 Research Design

Given the exploratory objective and the need to understand how collaboration operates in context, the study employed a qualitative multiple-case design [28]. The unit of analysis was the SME engaged in CE-related diversification activity. This design was appropriate because the study seeks to explain how collaborative OI practices operate in practice, through which mechanisms they support diversification, and under what conditions they become more or less effective. Rather than aiming for strict causal identification, the study adopts a process-oriented perspective in which collaboration and diversification may co-evolve over time.

The empirical setting comprised 36 SMEs operating in three CE-relevant sectors: renewable energy, waste management, and sustainable manufacturing. These firms were located in Germany, France, Italy, Spain, and Sweden. The selection of these five countries was intended to capture theoretically relevant variation across European CE settings, including

differences in policy support environments, industrial structures, and ecosystem maturity. The five countries differ substantially in CE legislation (e.g., Germany's KrWG vs. Spain's waste framework law), policy stringency, and infrastructure maturity. Rather than treating country as a control variable, we exploit this variation as a theoretical sampling strategy to examine whether identified mechanisms hold across diverse institutional contexts. However, the study does not claim statistical generalizability across countries; findings are presented with country labels to allow readers to assess contextual influence. A dedicated institutional comparison is provided in Appendix A (Table A1), which summarizes country-level differences in circular economy regulations, SME support mechanisms, procurement environments, and infrastructure maturity.

A qualitative design was also appropriate because the phenomenon under investigation involved sequence and interpretation. The study was not limited to asking whether collaboration existed; it examined how partnerships were formed, what kinds of knowledge were exchanged, how managers interpreted diversification opportunities, and why some collaborative arrangements generated action while others stalled. Such questions are difficult to capture through purely variable-based designs without first clarifying the processes involved. This design therefore supports a richer explanation of how collaborative OI is translated into diversification pathways in CE-oriented SMEs. The sampling strategy explicitly included SMEs that had experienced stalled or failed diversification attempts related to CE collaboration. This avoids survivorship bias and enables systematic failure analysis. Additionally, the study design incorporated coding for power asymmetry between partners (see Section 3.4).

3.2 Sampling and Case Selection

Purposive sampling was used to identify information-rich cases. Four criteria guided inclusion: the firm had to qualify as an SME under the EU definition; operate in a sector closely tied to CE activities; engage in some form of sustainable diversification, such as the introduction of a circular product, service, or market expansion; and participate in at least one collaborative OI practice. These shared criteria helped ensure case comparability by focusing the analysis on firms that faced broadly similar strategic challenges, even though they operated in different national and sectoral contexts. Table 1 presents the sample structure of the 36 SME cases included in the study.

Table 1. Sample structure of the 36 SME cases used in the study.

Dimension	Category	n
Sector	Renewable energy	12
Sector	Waste management	12
Sector	Sustainable manufacturing	12
Country	Germany	7
Country	France	7
Country	Italy	7
Country	Spain	7
Country	Sweden	8

To avoid survivorship bias, the sampling strategy explicitly included SMEs that had experienced stalled or failed diversification attempts. Nine of the 36 cases reported such experiences (see Findings 4.5), enabling systematic cross-case comparison of failure patterns. Moreover, cases were selected to include varying degrees of power asymmetry, from symmetric SME-SME collaborations to strongly asymmetric SME-large firm or SME-university partnerships.

The purposive strategy also carries limitations. Because the study focused on firms willing to discuss CE-related diversification and collaboration, the sample may be biased toward relatively visible, collaboration-active, or innovation-oriented SMEs. The aim, however, was not statistical representativeness, but analytical depth and variation across relevant CE-oriented contexts.

3.3 Data Collection

The primary data source consisted of 36 semi-structured interviews with owner-managers, innovation managers, sustainability leads, or senior operations managers. Interviews typically lasted between 60 and 90 minutes and were conducted either face to face or via videoconference. The interview protocol covered six areas: motives for circular transition; collaboration patterns; diversification initiatives; barriers and enablers; the perceived role of policy and internal capabilities; and power dynamics and failure experiences (e.g., dependence on partners, control over IP, perceived fairness of knowledge exchange, incidents of knowledge leakage or greenwashing, and reasons for stalled or abandoned collaborations).

To strengthen credibility, the interview material was triangulated with firm websites, public reports, product descriptions, sustainability communication, and sector or policy documents. Documentary evidence was especially useful for corroborating whether firms had in fact entered new circular markets, formalized collaborations, or participated in supported innovation programs. This triangulation strategy reduced the risk of over-reliance on retrospective managerial narration [25]. At the same time, because the primary interviews were conducted with

managerial respondents, the dataset remains more reflective of managerial interpretations than of partner-side perceptions.

The interview guide was intentionally designed to move from broad business context to specific collaboration episodes. This sequencing helped participants describe not only successful outcomes but also aborted, incomplete, or stalled attempts at diversification. Such contrastive accounts were valuable because they illuminated where collaboration broke down: sometimes at partner search, sometimes at implementation, and sometimes at the stage of internal translation from acquired knowledge to concrete organizational action. Figure 2 illustrates the methodological framework and research process used in the study.

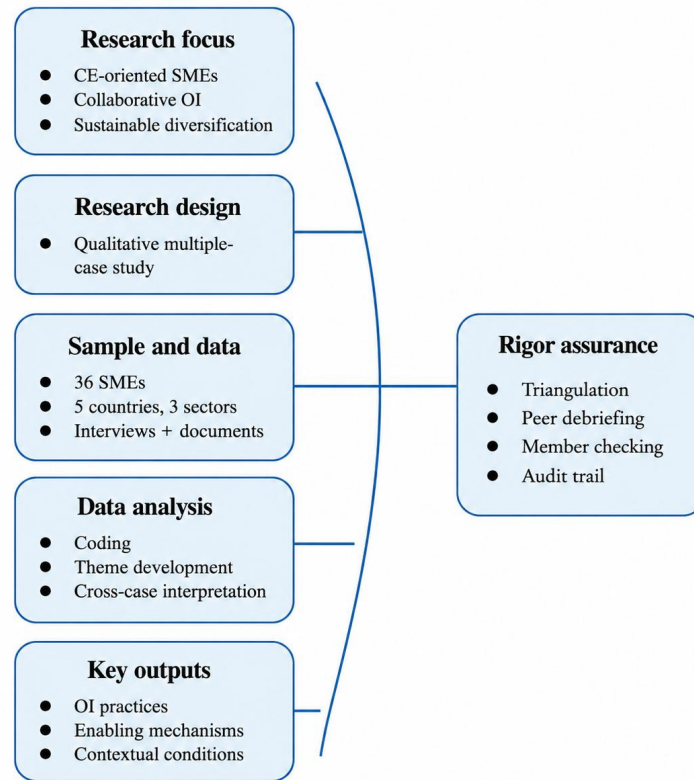


Figure 2. Methodological framework of the study.

3.4 Data Analysis and Rigor

The analysis followed thematic procedures inspired by Braun and Clarke [29]. First, the material was read repeatedly to develop familiarity with recurrent collaboration narratives. Second, initial codes were assigned to passages describing partnership types, knowledge flows, diversification initiatives, process dynamics, and contextual conditions. Third, codes were grouped into broader categories, which ultimately formed the collaborative OI practices, enabling mechanisms, and conditioning factors reported in the findings. Fourth, themes were reviewed against the full dataset to ensure that each captured a consistent pattern rather than isolated anecdotal evidence. Finally, the themes were interpreted in relation to the analytical framework in order to clarify how collaboration was translated into diversification outcomes under different internal and external conditions.

Coding for power asymmetry. Each collaboration episode was classified into one of three categories: symmetric (SME and partner have comparable bargaining power, e.g., SME-SME alliances), moderately asymmetric (one side holds moderate advantage, e.g., in market access or technology), or strongly asymmetric (large firm or university has clear dominance over the SME). Indicators included contractual terms, resource dependency, reported decision-making autonomy, and whether the SME perceived knowledge leakage or unequal value capture.

Coding for failure patterns. Collaborations that did not result in sustained diversification (9 out of 36 cases) were coded into four inductively derived types: (1) partner misalignment (divergent goals or time horizons), (2) internal conversion failure (knowledge acquired but not transformed/exploited due to internal capability gaps), (3) legitimacy deficit (collaboration did not transfer credibility to the SME's own offerings), and (4) policy dependency trap (diversification ceased after subsidy ended). This typology emerged from iterative comparison of negative cases.

Operationalizing CE-specific absorptive capacity. Beyond the classic four dimensions (acquisition, assimilation, transformation, exploitation), the coding scheme included CE-specific indicators: ability to validate secondary material

quality, routines for tracking regulatory changes, and capacity to translate knowledge across sectors (e.g., waste-to-energy). These were derived from the theoretical extension introduced in Section 2.5.

Several quality-assurance procedures were adopted. Peer debriefing was used during code consolidation to reduce single-researcher bias. Selected cases were revisited through member-oriented checking of factual descriptions. An audit trail was kept for coding decisions and category merging. The use of multiple sources further enhanced credibility by allowing interview claims to be cross-checked against documentary evidence. Negative case analysis was specifically employed to examine failed collaborations, and power asymmetry classifications were independently reviewed by two researchers to ensure reliability.

The coding process also distinguished between collaborative practice, process dynamics, and observed effects. This distinction was important because the same firm could use more than one collaborative form, and not every collaboration contributed equally to diversification. By separating practice types from enabling processes and observed consequences, the analysis avoided collapsing all forms of openness into a single undifferentiated category. Attention was also paid to incomplete or unsuccessful collaboration episodes in order to identify boundary conditions and to avoid presenting collaboration as uniformly productive.

3.5 Ethical Considerations

The study complied with university ethics procedures. Participants received information about the research purpose, the voluntary nature of participation, and the treatment of confidential information. Firm identities and personal names were anonymized in transcripts and analytical notes. Only aggregated and anonymized case evidence is presented in the manuscript.

4. Findings

4.1 Collaborative OI Practices Identified in the Cases

The analysis identified four recurring collaborative OI practices through which SMEs pursued sustainable diversification in the CE context: cross-sectoral knowledge alliances, supplier-customer co-creation networks, academic-industry research partnerships, and digital platform-based collaboration. Table 2 summarizes these practices, their typical partners, and their primary diversification effects. These practices differed in governance mode and partner composition, but all helped SMEs compensate for limited internal resources.

While most collaborations were productive, nine cases exhibited failure or significant power imbalance; these are analyzed systematically in Section 4.5.

Table 2. Collaborative OI practices and their primary diversification contributions.

Collaborative practice	Typical partners	Primary knowledge/resource contribution	Main diversification effect
Cross-sectoral knowledge alliances	Firms from adjacent sectors, technology providers, local clusters	Access to unfamiliar technical know-how and complementary assets	Entry into new circular product or service domains
Supplier-customer co-creation networks	Key suppliers, lead customers, public buyers	Demand insight, specification feedback, circular sourcing options	Customization of new offers and reduced market-entry risk
Academic-industry research partnerships	Universities, labs, research centers	Testing capability, scientific expertise, prototype development	Technology-based diversification and problem solving
Digital platform-based collaboration	Online innovation platforms, intermediary networks, EU projects	Partner search, information exchange, visibility, funding access	Geographic expansion and rapid connection to new opportunity spaces

Cross-sectoral knowledge alliances were used when SMEs needed capabilities unavailable in their own industry. A waste-management firm, for example, described collaboration with an energy technology partner as the turning point that made biogas-related service diversification technically feasible. The strategic value of these alliances was not only access to expertise but also access to application contexts, customer channels, and complementary equipment. In several cases, collaboration across sectoral boundaries converted a recycling or recovery capability into a marketable new offering. This practice was especially effective when SMEs sought unfamiliar technical competences and complementary assets that could not be developed internally within a reasonable time frame.

Supplier-customer co-creation networks played a different role. Here, SMEs used external actors to shape the design of new circular offerings and to reduce uncertainty surrounding market acceptance. Suppliers contributed information on recyclable inputs, traceability, and production constraints, while customers clarified demand conditions, procurement requirements, and expected performance standards. This practice was especially visible in firms developing repair services, tailored renewable-energy installations, or product variants using recovered materials. Co-creation did not merely improve fit with customer demand; it also reduced the probability of failed diversification by aligning technical

feasibility with user expectations. This form of collaboration was particularly useful when diversification depended on demand fit, procurement requirements, or the customization of circular offers for specific users.

Academic-industry research partnerships were central when diversification required technical experimentation or validation. SMEs turned to universities and research institutes to access laboratory infrastructure, prototype testing, and specialist knowledge related to material recovery, process redesign, or product durability. In the cases reviewed, these partnerships were most consequential when firms were moving from an operational CE initiative toward a more knowledge-intensive business line. By anchoring collaboration in joint problem-solving, academic links increased both innovation depth and the credibility of the resulting offer. Their contribution was strongest when SMEs were moving toward more knowledge-intensive circular activities that required prototyping, testing, or scientific validation.

Digital platform-based collaboration functioned as an enabling infrastructure rather than a single bilateral partnership. SMEs used online intermediary platforms, cluster portals, and EU-supported networks to search for partners, identify funding calls, share technical problems, and scan for market opportunities. For smaller firms with limited networking budgets, these platforms lowered the cost of initiating collaboration and widened the geographical scope of potential partnership. Several firms linked platform-mediated contacts to subsequent diversification into waste-to-energy services, circular sourcing arrangements, or export-oriented sustainability offerings. This practice appeared especially valuable for smaller firms facing partner-search constraints or seeking to broaden their opportunity space beyond local networks.

4.2 Mechanisms Through Which Collaboration Enabled Sustainable Diversification

Across the cases, four mechanisms explained how collaborative OI was translated into diversification outcomes. The first mechanism was resource efficiency. In process terms, collaboration helped firms identify waste-reduction opportunities, valorize by-products, redesign material flows, or improve process coordination. These efficiency gains did not constitute diversification by themselves. Instead, they released managerial attention, operational capacity, and financial room for experimentation, thereby making subsequent diversification easier to pursue.

The second mechanism was product and service innovation. External partners contributed technical ideas, user feedback, prototype input, and application-specific knowledge that SMEs could not easily generate on their own. This collaborative input shortened trial-and-error cycles, improved offer refinement, and reduced the uncertainty associated with entering new circular niches. In this way, collaboration supported diversification not simply by increasing innovation in general, but by making new products and services more viable and ready for market entry.

The third mechanism was market reach expansion. Collaboration with established actors gave SMEs access to customer groups, procurement channels, distribution networks, and reputational spillovers that would have been difficult to secure independently. This reduced entry barriers to adjacent sectors or regions and increased the practical feasibility of diversification. Market reach, therefore, was not only a consequence of collaboration, but also a pathway through which collaboration made entry into new circular activities more achievable.

The fourth mechanism was institutional legitimacy. Collaboration with universities, publicly supported initiatives, NGOs, and established firms created signaling effects that enhanced the perceived credibility of new circular offerings. These signals were important in credibility-sensitive or regulated settings, where customers, investors, or public buyers required reassurance regarding technical reliability, sustainability claims, or organizational seriousness. Institutional legitimacy therefore functioned as a relational pathway through which collaboration made new diversification moves more acceptable to external stakeholders.

A noteworthy pattern was that these mechanisms rarely operated in isolation. Efficiency-oriented collaboration often created the operational room for later experimentation; technical collaboration could later expand into market access or co-branding; and legitimacy frequently emerged from relationships that had initially been pursued for problem-solving purposes. This cumulative pattern suggests that sustainable diversification is often built through overlapping relational processes rather than through single-purpose collaborations.

The pattern of interdependence can be specified further. In 22 of 36 cases, resource efficiency gains preceded and enabled product innovation by freeing up capacity. In contrast, when market expansion was attempted without prior legitimacy (e.g., SME-F4), it failed; subsequent legitimacy-building collaboration was required. Premature product innovation without resource efficiency led to cost overruns in three cases. These observations suggest that legitimacy often gates market expansion, and resource efficiency enables innovation. Mis-sequencing can reverse diversification gains [30].

4.3 The Role of Absorptive Capacity and Policy Support

The findings show that collaboration alone was not enough. SMEs with stronger absorptive capacity were more capable of translating externally sourced knowledge into internal routines, prototypes, and commercial offers. In particular, the most recurrent bottlenecks were not simply knowledge acquisition, but the transformation and exploitation of external inputs. Firms that lacked internal processes for recombining new knowledge with existing routines often reported that useful ideas remained at the level of discussion rather than becoming practical diversification moves [11,15,30].

A CE-specific illustration: SME-G4 (waste management) acquired knowledge about recycled plastic quality from a research partner but could not transform it because quality fluctuated across batches—a challenge rare in linear supply chains. Another firm (SME-S5) succeeded only after developing an internal certification protocol for secondary materials. Thus, CE settings demand additional routines for material validation and regulatory alignment beyond standard ACAP.

Policy support also mattered substantially. Firms that had access to collaborative project funding, public innovation networks, cluster programs, or demonstration opportunities were better able to sustain experimentation and de-risk diversification. Such support reduced partner-search costs, improved matching opportunities, and increased the legitimacy of circular initiatives in the eyes of customers, investors, or public actors. The pattern suggests that policy support does not replace collaboration, but strongly influences whether collaboration becomes affordable and scalable in practice.

The interaction between absorptive capacity and policy support was especially revealing. External support created opportunities, but firms still needed internal capability to capture them. Conversely, capable firms benefited more when policy frameworks lowered coordination costs and accelerated experimentation. This indicates a reinforcing relationship rather than a simple additive one: policy support expands access to collaborative opportunity, while absorptive capacity determines whether that opportunity can be converted into diversification.

4.4 Integrative Interpretation of The Findings

Taken together, the findings indicate that collaborative OI acts as a capability multiplier in CE-oriented SMEs. It helps firms overcome resource scarcity, but its greatest value lies in how it enables recombination: external knowledge is joined with internal entrepreneurial intent to create new circular offerings. This process is mediated by operational and market mechanisms and conditioned by both internal learning capability and external institutional support. The empirical picture therefore supports a process view of sustainable diversification rather than a one-step input-output view.

The data also indicate that SMEs do not move through diversification in a uniform sequence. Some begin with customer-led co-creation and later seek technical partners; others begin with university-led experimentation and only later build a market channel. What remains consistent is that diversification becomes more robust when collaboration broadens from a single bilateral exchange to a more networked configuration involving technical, market, and legitimacy-oriented actors.

At the same time, not all collaborative arrangements generated successful diversification. Some remained exploratory, symbolic, or stalled because of partner misalignment, limited internal implementation capability, coordination cost, or uncertainty regarding commercial feasibility. These less successful cases suggest that collaboration should be understood as an enabling but contingent pathway rather than as a guaranteed route to circular diversification.

4.5 Patterns of Unsuccessful or Stalled Diversification

Of the 36 cases included in this study, 9 did not achieve sustained diversification and exhibited clear signs of collaboration failure. Cross-case comparison identified four recurrent failure patterns.

Partner misalignment (3 cases: SME-G3, SME-F2, SME-I1): Divergent goals or time horizons led to information hoarding and dissolution.

Internal conversion failure (2 cases: SME-M4, SME-R5): Knowledge was acquired but not transformed into commercial offers due to internal capability gaps.

Legitimacy deficit (2 cases: SME-S2, SME-W7): Collaboration with credible partners did not transfer legitimacy to the SME's own offerings.

Policy dependency trap (2 cases: SME-F5, SME-I3): Diversification collapsed after subsidy ended, indicating no viable business model.

Importantly, these failures occurred under similar policy support and ACAP levels. For example, two German SMEs (SME-G1 and SME-G3) used the same platform; SME-G1 succeeded via customer co-creation, while SME-G3 failed due to partner misalignment. The difference lay in governance and partner selection, not in absorptive capacity. This refines the literature by showing that collaboration alone is insufficient without attention to alignment, conversion routines, legitimacy transfer, and commercial sustainability [31].

5. Discussion

5.1 Theoretical implications

The findings suggest that sustainable diversification in CE-oriented SMEs is better understood as an ongoing collaborative process than as a straightforward result of innovation effort or sustainability intent. Instead of treating OI,

circular transition, and absorptive capacity as loosely connected themes, the study clarifies how collaborative OI practices, enabling mechanisms, and contextual conditions interact in shaping diversification under circular constraints.

First, the study contributes by differentiating among collaborative OI practices rather than treating collaboration as a single undifferentiated construct. Cross-sectoral alliances, supplier-customer co-creation, academic-industry partnerships, and digital platform-based collaboration do not perform the same function. They support diversification through different relational logics and become more effective under different strategic conditions. This distinction adds clarity to how openness is understood in research on SMEs, CE, and innovation.

Second, the study clarifies the mechanisms linking collaboration to diversification by treating them as processual pathways rather than as static outcomes. Resource efficiency, product and service innovation, market reach, and institutional legitimacy do not simply appear at the end of collaboration. They emerge through identifiable relational and organizational processes that reduce uncertainty, widen access, improve offer refinement, and strengthen acceptance for new circular activities. This helps explain more concretely how collaboration works in CE settings. Specifically, legitimacy gates market expansion, resource efficiency enables innovation, and mis-sequencing can reverse gains.

Third, the study shows that absorptive capacity and policy support should not be treated merely as background variables. They operate as conversion conditions that shape whether collaborative opportunities can actually be translated into diversification. Absorptive capacity affects the internal transformation and exploitation of external knowledge, while policy support affects the affordability, legitimacy, and scalability of collaboration. This also helps explain why similar forms of collaboration do not produce the same results across SMEs. Moreover, CE settings demand ACAP extensions for material validation and regulatory tracking, beyond standard dimensions.

Fourth, the systematic identification of four failure patterns (partner misalignment, conversion failure, legitimacy deficit, policy trap) and the presence of power asymmetry challenge the assumption that openness is always beneficial.

The findings also suggest that the relationship between collaboration and diversification is not strictly one-directional. Diversification intentions may prompt firms to seek partners, while collaboration shapes whether and how those intentions become viable circular growth paths. This co-evolving relationship supports a process-oriented interpretation and cautions against overly linear readings of collaborative OI in CE settings.

More broadly, the study suggests that sustainable diversification in CE-oriented SMEs should not be reduced to growth in a narrow revenue sense. In the cases examined, diversification also altered risk exposure, bargaining power, reputational positioning, and future innovation options. Firms that added circular service components or entered adjacent sustainability-oriented markets often described these moves as strengthening strategic resilience even before they generated large immediate returns. In this sense, diversification under circular constraints involves broader strategic repositioning rather than simple product-line expansion [32].

5.2 Managerial Implications

For SME managers, the findings suggest that collaboration should be approached as a strategic design choice rather than as a generic response to resource scarcity. Different diversification objectives require different partner configurations. SMEs pursuing technically demanding circular activities may benefit more from academic or cross-sectoral partnerships, whereas firms seeking market-facing diversification may gain more from customer co-creation or platform-based collaboration. Managers should therefore begin with the intended diversification pathway and then work backward to identify the most suitable collaborative OI practice. A concrete first step: before initiating any collaboration, managers should write down the single biggest bottleneck they need to overcome (technical validation, market access, or legitimacy), then select a partner type accordingly. The most common mistake is accepting any available partner out of urgency; being selective, even if it slows down the initial pace, prevents misalignment later.

Managers should also invest deliberately in absorptive capacity. This includes assigning responsibility for external knowledge integration, creating routines for internal interpretation and follow-up, and ensuring that collaborative learning is translated into prototypes, operational changes, or commercial offers. Without such internal conversion mechanisms, collaboration may remain informative but not transformative. A low-cost routine that worked in several cases: assign one person (even part-time) to track external knowledge and maintain a simple 'learn-change-do' checklist: what did we learn, what needs to change internally, who will do it by when. The main barrier is lack of dedicated staff, but using industry association templates or shared service models for certification support can substitute for in-house capacity.

A further implication concerns sequencing. Rather than trying to solve technical, market, and legitimacy challenges simultaneously, SMEs may benefit from a staged collaboration strategy in which one partnership removes the most immediate bottleneck and later collaborations support expansion. This staged approach may reduce coordination overload while preserving strategic direction. Define a minimal viable collaboration for each stage with clear exit criteria before moving to the next. For example: 'We will only pursue market expansion after securing a third-party certification or a university endorsement.' This prevents coordination overload and forces the firm to validate one assumption at a time.

The findings also imply that managers should treat legitimacy-building as a strategic task rather than as a by-product of technical collaboration. In CE-related markets, credibility often depends on external validation, recognized partners, or visible participation in supported initiatives. Managers should therefore pay attention not only to what collaboration makes possible internally, but also to how collaboration signals reliability and seriousness to outside stakeholders. Actively seek collaborations with recognized institutions (e.g., publicly funded projects, industry associations) specifically for their signaling value, not only for technical input. The cases show that without legitimacy, even technically sound offerings fail to gain customer trust. A practical signal is visible participation in a supported initiative, which can be communicated in marketing materials and tenders.

5.3 Policy Implications

For policymakers, the findings indicate that collaboration support is more useful than generic sustainability rhetoric when SMEs are expected to diversify under circular constraints. Public support should focus on partner-matching platforms, shared testing facilities, pilot-scale funding, cluster-based collaboration programs, and demonstration opportunities that reduce the transaction costs of experimentation. Such measures make collaboration more accessible for SMEs that lack the resources to build networks independently. However, the cases show that such facilities are underused when access requires pre-certification or insurance that exceeds SME budgets.

Policy design should also recognize heterogeneity among SMEs. Firms at an early stage of circular transition may need awareness-building and simple matchmaking support, whereas more advanced firms may benefit more from prototype funding, market access support, or internationalization mechanisms. A differentiated support architecture is therefore more likely to convert collaboration into sustained diversification than a one-size-fits-all approach. A practical risk to address is policy dependency: two cases collapsed after subsidies ended, suggesting that funding should require an exit-to-market plan.

Public procurement may also play a catalytic role by creating early demand for circular offerings and by providing credibility signals for new SME initiatives. In this sense, policy does not merely subsidize collaboration; it can help shape the market conditions under which collaborative diversification becomes viable. Yet five SMEs reported stopping bids due to complex documentation and long payment cycles; SME-friendly procurement lots and guaranteed payment terms are needed to make this work.

At the same time, the policy implications of the study should not be interpreted in purely positive terms. The findings indicate that collaboration may also generate coordination burden, dependence on stronger partners, uneven bargaining power, and concerns over knowledge leakage, especially for resource-constrained SMEs. These tensions do not invalidate the value of collaboration, but they do indicate that collaborative diversification is a negotiated and sometimes fragile process rather than a frictionless one. Policy support should therefore not only encourage collaboration, but also reduce its governance risks through clearer rules, trusted intermediaries, and accessible conflict-resolution or advisory mechanisms. In practice, this means mandating balanced IP agreements for asymmetric partnerships and funding neutral intermediaries to mediate knowledge leakage disputes.

6. Limitations

This study has several limitations. First, the empirical setting was restricted to SMEs operating in five European countries. Although this design increased analytical variation across institutionally relevant CE contexts, the findings should not be generalized mechanically to developing economies or to settings with substantially different regulatory, infrastructural, or business environments.

Second, the sample was limited to three CE-related sectors: renewable energy, waste management, and sustainable manufacturing. These sectors are highly relevant to circular transition, but they do not capture the full diversity of SME activity. Firms in services, retail, food, or other sectors may face different collaboration patterns, resource constraints, and diversification logics.

Third, the primary data were derived mainly from managerial respondents. Although documentary triangulation was used to strengthen credibility, the findings remain more reflective of managerial interpretations than of partner-side perceptions. This may have increased the risk of selective recall, retrospective rationalization, or socially desirable reporting.

Fourth, the study adopted a cross-sectional qualitative design. It therefore captures collaboration and diversification at one stage rather than tracing their development over longer periods. As a result, the analysis is better suited to process explanation and theory building than to the evaluation of long-term causal effects or the durability of diversification outcomes.

Fifth, the study does not provide quantitative validation of the relative strength of the mechanisms identified. The findings clarify how collaborative OI may support sustainable diversification, but they do not determine the comparative weight of different practices, mechanisms, or contextual conditions across a larger population of firms.

Sixth, the identification of failure patterns and power asymmetries is based on a subset of 9 cases, and the findings do not claim statistical generalizability of these types. Future research should test the prevalence of these patterns across larger samples.

Despite these limitations, the study still offers a useful account of how collaborative OI practices, enabling mechanisms, and contextual conditions interact in shaping sustainable diversification in CE-oriented SMEs.

7. Conclusion

This study examined how collaborative OI supports sustainable diversification in SMEs operating in the CE. Based on a qualitative multiple-case analysis of 36 SMEs across five European countries, the study identified four recurrent collaborative OI practices: cross-sectoral knowledge alliances, supplier-customer co-creation networks, academic-industry research partnerships, and digital platform-based collaboration.

The findings show that these practices support sustainable diversification through four enabling mechanisms: resource efficiency, product and service innovation, market reach expansion, and institutional legitimacy. The analysis further demonstrates that collaboration alone is not sufficient. Its effectiveness depends on whether firms possess the absorptive capacity needed to transform and exploit external knowledge and whether policy environments provide the support necessary to make collaboration affordable, credible, and scalable. Crucially, the four mechanisms interact: legitimacy often gates market expansion, resource efficiency enables innovation, and mis-sequencing can reverse gains.

Taken together, the results suggest that sustainable diversification in CE-oriented SMEs is best understood as a collaboration-centered and processual phenomenon. SMEs do not diversify successfully under circular constraints simply because they recognize new opportunities. They do so when collaborative relationships, internal conversion capability, and supportive external conditions align in ways that make new circular activities workable and legitimate. The study also identifies four failure patterns and shows that power asymmetry can lead to knowledge leakage or greenwashing, highlighting the need for governance-sensitive collaboration.

In theoretical terms, the study contributes an integrated explanation of how collaborative OI practices, enabling mechanisms, and contextual conditions work together. In practical terms, it suggests that collaboration can help SMEs do more than cope with resource constraints; it can also support the development of new circular growth options.

8. Future Research Directions

Future research could extend the present study in several ways. First, survey-based or mixed-method designs could be used to test the relative importance of the collaborative practices and enabling mechanisms identified here. Such work would help assess whether some pathways matter more than others across larger populations of SMEs.

Second, longitudinal research could trace how collaborative OI evolves over time as firms move from exploratory circular initiatives to more stable diversification outcomes. This would be especially valuable for understanding whether early collaboration effects are sustained, transformed, or abandoned as organizational conditions change.

Third, comparative studies across regions and institutional settings could examine how the collaboration-diversification relationship differs across developed and developing economies, across stronger and weaker policy environments, or across sectors with different levels of circular maturity.

Fourth, future research should pay closer attention to unsuccessful or fragile collaboration. Cases of breakdown, withdrawal, symbolic participation, or failed knowledge transfer may provide especially valuable insight into the boundary conditions of collaborative diversification.

Fifth, future research should examine governance mechanisms for managing power asymmetry in circular collaborations. Comparative studies of IP contract design, intermediary mediation, and trust-building routines could translate the observed failure patterns into actionable safeguards for SMEs.

Finally, growing use of AI, digital platforms, and data-driven coordination tools suggests the need for further research on how digital infrastructures reshape open circular innovation in SMEs. These developments may alter not only how partners are identified and coordinated, but also how knowledge is absorbed, governed, and translated into new circular offerings.

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Ethics Statement

This study involved voluntary interviews with adult participants. Participants were informed about the purpose of the research and provided consent prior to participation. All data were anonymized and reported in aggregate form to

protect confidentiality.

Data Availability Statement

The data supporting the findings of this study are not publicly available due to confidentiality agreements and the protection of participant anonymity. Aggregated and anonymized information is included in the manuscript. Additional information may be available from the author upon reasonable request.

Author Contributions

The author contributed to the conception, design, analysis, writing, and revision of the manuscript and approved the final version for publication.

Conflict of Interest

The author declares no conflict of interest.

Generative AI Statement

The author declares that no Gen AI was used in the creation of this manuscript.

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Appendix A. Institutional comparison of circular economy frameworks in the five countries.

The five countries included in this study differ substantially in their circular economy legislation, policy instruments, and infrastructure maturity. The table below summarizes key institutional features relevant to SME collaboration and diversification.

Table A1. Institutional comparison of circular economy frameworks in the five countries.

Country	Key CE legislation / strategy	SME-specific support	Public access	procurement	Infrastructure (waste, secondary materials)	maturity recycling,
Germany	Closed Substance Cycle Act (KrWG), binding recovery quotas	SME innovation vouchers, cluster programs (e.g., Mittelstand 4.0)	Centralized platforms, but complex documentation		High: well-developed take-back systems, industrial symbiosis networks	
France	Anti-waste and Economy Law extended responsibility (EPR) Circular (AGEC), producer	SME diagnostic tool for circularity, regional support hubs	Growing use of environmental criteria		Medium-high: strong EPR schemes, but regional disparities	
Italy	National Strategy for Circular Economy, EPR with regional variation	Tax credits for eco-innovation investment, funds	Fragmented, often local		Medium: advanced recycling in North, weaker in South	
Spain	Spanish Circular Economy Strategy (España Circular 2030), regional waste laws	SME digitalisation and circular economy grants (e.g., Kit Digital)	Procurement law includes environmental criteria, but enforcement uneven		Medium-low: improving but gaps in secondary material markets	
Sweden	National Circular Economy Strategy, waste-to-energy focus	Green innovation vouchers, testbed support	Strong environmental requirements, long payment cycles		High: advanced waste-to-energy, but variable access for SMEs	

Note: This table is a simplified synthesis based on national policy documents, European Commission reports, and case evidence. It is intended to illustrate institutional variation rather than to serve as a formal legal comparison. The differences affect the feasibility of certain collaborative practices (e.g., digital platforms are more effective in Sweden and Germany, while legitimacy-building is more challenging in Spain and Italy due to fragmented enforcement).

Sources: European Commission country reports (2022-2024); national circular economy strategies; OECD SME policy reviews.