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Navigating Complexity: Exploring the Dynamics of SMEs' Transition towards Circular Economy

TARLAN AHMADOV

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Contents

emissions and a significant share of industrial waste, particularly in resource-intensive sectors like manufacturing and construction (Gajanayake et al., 2024; Piispanen et al., 2022). Manufacturing, for example, accounts for 50–60% of global industrial emissions and 64% of air pollution in Europe, making the adoption of circular practices in SMEs critical for mitigating environmental degradation (Dainelli et al., 2024; Subramanian & Suresh, 2022).

Implementing CE measures such as resource efficiency, waste reduction, and energy optimization allow SMEs to reduce their environmental footprint significantly. Closed-loop systems and recycling decrease raw material dependency, enhance resource efficiency, and contribute to SDGs related to responsible consumption and climate action (Gao et al., 2024; Kara et al., 2022; Knable et al., 2022). In the manufacturing sector, these practices result in cost savings, improved supply chain sustainability, and enhanced competitiveness, while reducing reliance on imported materials (Baldassarre, 2025; Kumar et al., 2023; Sakao et al., 2024).

These characteristics enable SMEs to address local environmental needs efficiently, leveraging digital technologies like automation, Internet of Things (IoT), and data analytics to optimize operations and advance CE goals (Moktadir et al., 2018; Schöggl et al., 2023). As pivotal players in supply chains, SMEs significantly influence sustainability by adopting and promoting circular practices, which often cascade across industries (Lüdeke-Freund et al., 2019; Primadasa et al., 2024). Through collaborative partnerships with larger corporations, SMEs benefit from technology transfer and shared learning, enhancing their capabilities and accelerating the wider adoption of CE principles (Mishra et al., 2019). Integrating CE practices also supports social inclusion and economic equity, positioning SMEs as critical actors in advancing the SDGs. Their unique ability to balance innovation, community engagement, and sustainability underscores their essential role in the transition toward a more resilient and circular economic model.

SMEs demonstrate both strengths and limitations in their transition towards CE, having a complex dynamic that shapes their transition. SMEs possess distinct advantages that position them favourably for CE adoption. Their operational agility and flexibility enable them to respond quickly to market changes and implement innovative practices (Arsawan et al., 2022; Chan et al., 2019). Their close ties to local communities and markets allow them to better understand and respond to customer needs, while their smaller size facilitates faster decision-making and implementation of new practices (Christodoulou et al., 2024). The capacity for innovation stands as a key strength of SMEs in CE transition. Their ability to experiment with and adopt innovative business models faces less bureaucratic resistance compared to larger corporations (Faiz et al., 2024). This adaptability enables them to pioneer various circular approaches (Howard et al., 2022).

Despite the advantages of CE adoption, SMEs face unique barriers stemming from their limited resources, operational scale, and structural constraints, creating a complex web of challenges that impede successful implementation (Takacs et al., 2022). These barriers manifest across various dimensions, from organizational to systemic levels, highlighting the multifaceted nature of the transition to CE for smaller enterprises.

SMEs grapple with significant financial constraints, which severely limit their capacity to invest in CE initiatives. The high upfront costs associated with circular products and processes, combined with restricted access to capital, create substantial constrains (Heras-Saizarbitoria et al., 2023; Rizos et al., 2016). Unlike larger corporations, SMEs typically operate with tighter budgets, forcing them to prioritize immediate operational needs over long-term sustainability investments (Bakos et al., 2020). The situation is

The role of consumers and market demand is another critical aspect of industry interactions that influence SMEs' transition to CE. Increasing consumer awareness and demand for sustainable products can create market pull for circular offerings. SMEs that are attuned to these market trends and can effectively communicate the value of their circular products or services are better positioned to succeed in their CE transition (Triguero et al., 2022).

Interactions with larger firms in the industry can also play a significant role in SMEs' CE transition. Large companies often have more resources to invest in CE initiatives and can exert pressure on their SME suppliers to adopt circular practices. This can create both challenges and opportunities for SMEs, potentially driving innovation but also requiring significant adaptation (Agyabeng-Mensah et al., 2022).

Digital platforms and technologies are transforming industry interactions and creating new opportunities for CE implementation. These platforms can facilitate the sharing of resources, connect waste generators with potential users, and enable new CBMs. SMEs that effectively leverage these digital ecosystems can enhance their ability to implement circular practices and access new markets (Neri et al., 2023).

The development of circular value chains is an important aspect of industry interactions that influences SMEs' CE transition. This involves rethinking entire value chains to minimize waste and maximize resource efficiency. SMEs that can position themselves effectively within these circular value chains, for example by specializing in refurbishment or recycling services, can find new opportunities for growth and innovation (Le et al., 2022).

1.3.3 Policy and Institutional Frameworks for CE adoption by SMEs

The broader policy and institutional landscape play a pivotal role in shaping the environment for CE adoption and implementation among SMEs. These frameworks, encompassing regulations, incentives, and support structures, play a crucial role in shaping the environment for CE adoption and implementation.

Regulatory policies are a key driver of CE adoption among SMEs. Governments at various levels can implement laws and regulations that mandate or encourage circular practices. For instance, extended producer responsibility regulations can incentivize SMEs to design products for easier recycling and take responsibility for end-of-life management (Ostermann et al., 2021). Similarly, waste management regulations can create opportunities for SMEs in recycling and resource recovery sectors. However, the effectiveness of these regulations depends on their design and enforcement. Overly complex or burdensome regulations can pose challenges for SMEs with limited resources to navigate compliance requirements (Kayikci et al., 2021).

The development of standardized approaches for CE disclosure and reporting is an emerging area of policy focus. Massari and Giannoccaro (2023) highlight the importance of such standardization in creating a level playing field and enabling SMEs to communicate their circular performance effectively. Clear and consistent reporting frameworks can help SMEs benchmark their progress and attract investment and customers interested in circular solutions. Also, the development of sector-specific CE roadmaps and action plans can provide a framework for coordinated action within industries. These initiatives, often led by industry associations or government bodies, can help align efforts across the sector and provide clear pathways for SMEs to transition towards CE practices (Droege et al., 2023).

Financial incentives and support mechanisms are critical components of policy frameworks that can facilitate SMEs' transition to CE. These can include tax incentives

for circular practices, grants for eco-innovation, and subsidies for implementing resource-efficient technologies. For example, Austin and Rahman (2022) highlight the importance of diverse finance sources, including crowdfunding and capital market funding, in helping SMEs acquire the necessary knowledge and resources to adopt CBMs. Government-backed loan guarantee schemes can also help SMEs overcome financial barriers to CE implementation.

Public procurement policies can serve as a powerful tool to drive CE adoption among SMEs. By incorporating CE criteria into public tenders, governments can create significant market demand for circular products and services. This can provide SMEs with the incentive and opportunity to develop and scale circular offerings (Rodriguez-Espindola et al., 2022).

Education and training policies play a crucial role in building the skills and knowledge necessary for CE implementation. Policies that support the integration of CE principles into educational curricula, vocational training programs, and professional development initiatives can help create a workforce equipped to drive CE transitions in SMEs (Maher et al., 2023).

Innovation policies and support for R&D are essential for fostering the technological advancements and business model innovations needed for CE. Policies that provide funding for CE-related R&D, support collaboration between SMEs and research institutions, and facilitate knowledge transfer can accelerate the development and adoption of circular solutions (Triguero et al., 2022).

Infrastructure development policies are crucial for creating the physical and digital systems necessary to support CE practices. This includes investments in recycling facilities, reverse logistics networks, and digital platforms for resource tracking and sharing. Policies that support the development of such infrastructure can create enabling conditions for SMEs to implement circular practices (Zhu et al., 2022).

The role of intermediary organizations, often supported by public policies, is important in facilitating SMEs' transition to CE. These can include business support agencies, technology transfer offices, and CE hubs that provide guidance, networking opportunities, and technical assistance to SMEs. Policies that support the establishment and operation of such intermediaries can help bridge the gap between SMEs and larger organizations, as well as between SMEs and policymakers.

Several studies highlight the significance of these intermediary organizations in the CE transition process. Hull et al. (2021) explore the development of circular economy incubators, emphasizing their role in supporting SMEs in developing and scaling CBMs. These incubators serve as platforms for knowledge exchange, networking, and access to resources, which are crucial for SMEs with limited internal capabilities.

Holzer et al. (2021) further emphasize the importance of intermediaries in addressing key areas such as resource efficiency, cooperation with stakeholders, and sustainability. Their research provides insights for policymakers and intermediaries on how to effectively target diverse SMEs with varying needs and capacities.

Moreover, Maher et al. (2023) stress the need for training and support programs to encourage and facilitate the uptake of CE practices among SMEs. These programs, often delivered through intermediary organizations, can help SMEs overcome knowledge gaps and build the necessary skills for implementing CBMs.

The below table summarizes the key factors influencing SMEs' transition to CE at three levels: individual enterprise, industry collaboration, and policy frameworks. These multi-level factors collectively shape the landscape for SMEs as they navigate the transition towards CE.

Table 1. Summary of Factors, Actors, and Mechanisms in SMEs' Transition CE.

Focus	*Key Topics*	*Description*	*References*
Enterprise-Level Dynamics (micro)	Strategic Management	Comprehensive approach to CE implementation, including leadership, innovation, and resource management	Gallardo-Vazquez et al. (2024); Chen et al. (2022); Neri et al. (2023); Centobelli et al. (2021); Austin and Rahman (2022); Agyabeng-Mensah et al. (2022)
	Operational Practices	Adoption of circular processes in supply chain, human resources, and performance measurement	Kayikci et al. (2022); Omarova and Jo (2022); Cagno et al. (2023)
	Technological Integration	Incorporation of digital technologies to enhance circular capabilities	Neri et al. (2023)
	Organizational Adaptation	Structural changes and risk management for CE transition	Arranz et al. (2022); Werning and Spinler (2020); Ludeke-Freund et al. (2019)
Industry Ecosystems (meso)	Supply Chain Relationships	Cooperation for improved resource efficiency and circular practices	Susanty et al. (2020); Agyabeng-Mensah et al. (2022)
	Collaborative Networks	Industry associations, cross-sector partnerships, and circular ecosystems	Staicu and Pop (2018); Centobelli et al. (2021); Hull et al. (2021); Holzer et al. (2021); Agyabeng-Mensah et al. (2022)
	Market Dynamics	Consumer demand and large firm interactions influencing CE adoption	Triguero et al. (2022); Agyabeng-Mensah et al. (2022)
	Digital Ecosystems	Platforms facilitating resource sharing and circular business models	Neri et al. (2023)
	Circular Value Chains	Development of industry-wide circular approaches	Le et al. (2022)
Policy and Institutional Frameworks (macro)	Regulatory Environment	Laws and standards promoting circular practices	Ostermann et al. (2021); Kayikci et al. (2021); Massari and Giannoccaro (2023); Droege et al., 2023
	Economic Instruments	Financial incentives and public procurement for CE	Austin and Rahman (2022); Rodriguez-Espindola et al. (2022)

Capacity Building	Education, training, and support programs for CE skills development	Maher et al. (2023)
Innovation Support	Innovation policies and support for R&D	Triguero et al. (2022)
Infrastructure Development	Investments in physical and digital systems for CE	Zhu et al. (2022)
Intermediary Support	Establishment of organizations facilitating CE transition	Hull et al. (2021); Holzer et al. (2021); Maher et al. (2023)

Source: Composed by the author.

1.4 Theoretical Perspectives used in the Thesis

1.4.1 Multi-Level Perspectives

The MLP has emerged as a prominent theoretical framework for understanding and analysing socio-technical transitions, particularly in the context of sustainability and circular economy. Originally developed by Rip and Kemp and further refined by Geels, MLP conceptualizes transitions as the result of interactions across three analytical levels: niches (micro), regimes (meso), and landscapes (macro) (Geels, 2011). This framework has gained significant traction in recent years, offering valuable insights into the processes of innovation, diffusion, and transformation across various sectors.

At its core, the MLP conceptualizes transitions as the result of interactions across three analytical levels: niches (micro), regimes (meso), and landscapes (macro) (Geels, 2011). This multi-layered approach allows for a nuanced understanding of how innovations emerge, evolve, and potentially transform existing systems. At the micro-level, niches represent the breeding grounds for radical innovations that challenge established systems. These innovations are often shielded by specific contexts or policies, allowing them to develop and mature without direct competition from dominant regimes (Geels & Schot, 2007). In the context of CE, niches might include pilot projects and experimental business models that promote sustainable practices, such as zero-waste manufacturing and product-as-a-service models. Small and medium-sized enterprises (SMEs), with their inherent flexibility and adaptability, can play a pivotal role at this level by pioneering innovative circular solutions that can eventually influence larger market trends (Bocken et al., 2016).

The meso-level, or regime, comprises the existing socio-technical systems (STS) that dictate the rules, practices, and norms governing societal functions. These regimes are typically resistant to change due to their embeddedness within institutional structures and networks (Geels, 2011). For a successful transition to circular economy practices, it is crucial to address the barriers posed by existing regimes and facilitate the integration of circular principles into mainstream business operations. This requires coordinated efforts across industries, policy interventions, and stakeholder engagement to dismantle established norms and foster a more sustainable economic framework (de Jesus & Mendonça, 2018).

At the macro-level, landscapes encompass broader socio-economic, cultural, and environmental contexts that influence regime stability and niche development. These factors include global economic trends, political climates, and societal values (Geels, 2011). In the context of circular economy transitions, the increasing awareness of environmental issues and the urgency of addressing climate change have created a supportive landscape

for sustainable innovations. Policies such as the European Green Deal and the United Nations SDGs are examples of macro-level influences that drive the adoption of circular practices by setting ambitious targets and providing a roadmap for sustainable growth (European Commission, 2020; United Nations, 2023).

The MLP's strength lies in its ability to provide a systemic and dynamic view of transitions, highlighting the interactions and feedback loops between different levels. By recognizing the interplay of micro, meso, and macro-level factors, policymakers and practitioners can develop strategies that support the diffusion of circular innovations and accelerate the transition to a circular economy (El Bilali, 2019). This comprehensive approach allows for a more nuanced understanding of the barriers and enablers of change, moving beyond simplistic linear models of innovation diffusion. The interplay between niches, regimes, and the broader sociotechnical landscape, offers valuable insights into the processes, actors, and mechanisms involved in transformative changes and the emergence of sustainable STS (Chembessi et al., 2023).

In the context of studying SMEs' transition to circular economy practices, the MLP offers several advantages. Firstly, it provides a structured approach to understanding the complex interplay of factors influencing SMEs' adoption of circular practices. By examining transitions at multiple levels, researchers can identify key leverage points for intervention and support. For instance, Malik et al. (2022) used the MLP to analyze barriers to circular economy adoption in SMEs, revealing how landscape pressures, regime stability, and niche innovations interact to shape SMEs' transition pathways.

Furthermore, the MLP's emphasis on the dynamic nature of transitions aligns well with the evolving landscape of circular economy practices. As noted by Zhu et al. (2022), the transition to a circular economy is not a linear process but rather an iterative one that requires continuous adaptation and learning. The MLP's focus on the co-evolution of technologies, practices, and institutional structures provides a framework for understanding how SMEs can navigate this complex transition over time.

However, it is important to acknowledge the limitations of the MLP framework. These critiques underscore the need for complementary theoretical approaches to provide a more comprehensive understanding of transition processes. One of the primary limitations of the MLP is the ambiguity in delineating the boundaries between niches, regimes, and landscapes. In practice, these levels often exhibit significant overlap and interconnectedness, making it challenging to categorize phenomena discretely (Genus & Coles, 2008). This blurring of boundaries can lead to difficulties in accurately representing the complex dynamics of real-world transitions.

Furthermore, the MLP has been criticized for its tendency to portray transitions as predominantly bottom-up processes, with innovations emerging from niches and gradually transforming the regime. However, empirical evidence suggests that transitions are often more complex and non-linear, potentially originating from multiple levels simultaneously or even following top-down patterns (Alkemade & de Coninck, 2021). This oversimplification of transition pathways may limit the framework's ability to capture the full spectrum of change processes.

Another significant limitation of the MLP is its inadequate treatment of agency and power dynamics. Critics argue that the framework does not sufficiently account for the role of individual actors and their capacity to influence transition processes (Geels, 2020). The MLP's focus on broader structural changes may overlook the critical role that specific stakeholders play in shaping the direction and pace of transitions. This shortcoming is

particularly relevant when considering the complex interplay of interests and influences that characterize many sustainability transitions.

To address these limitations, integrating stakeholder theory and complexity theory with the MLP can provide a more nuanced and comprehensive analytical framework, which are discussed in the below sections. This integration offers a multifaceted approach that enhances our understanding of the intricate dynamics and interconnected processes inherent in SMEs' transition to circular economy practices.

1.4.2 Stakeholder Theory

Stakeholder theory provides a valuable framework for understanding and facilitating the transition of SMEs to a CE. Originally proposed by Freeman (1984), this theory suggests that organizations should consider the interests of all parties affected by their operations, including employees, customers, suppliers, communities, and regulators. This perspective moves beyond the traditional shareholder-centric model focused solely on profit maximization, encouraging businesses to account for the broader social and environmental impacts of their activities (Jones et al., 2018). In the context of sustainability, stakeholder theory has been widely applied across disciplines such as business ethics, corporate social responsibility, and environmental management.

The transition of SMEs to a CE exemplifies a context where stakeholder theory is particularly relevant, as it underscores the importance of collaboration across the value chain in achieving CE goals. Unlike large corporations, SMEs often operate with limited resources and closer relationships with their stakeholders (Klein et al., 2021). Applying stakeholder theory helps SMEs engage with diverse actors, fostering collaboration and co-creating solutions that promote circularity. This approach is crucial because the transition to a circular economy is not just an operational change but a systemic transformation requiring multi-stakeholder cooperation (Geissdoerfer et al., 2017).

Stakeholder theory shifts the focus from internal operations to the wider ecosystem in which SMEs operate. For instance, SMEs must work with suppliers to access sustainable materials, collaborate with customers who demand eco-friendly products, and align with regulatory frameworks that support CBMs (Kirchherr et al., 2018). This theory emphasizes the interconnectedness of these relationships and how co-creating circular solutions is critical. Without such collaboration, SMEs would struggle to develop closed-loop systems, which depend on coordination at all stages of the product lifecycle – from design to disposal and recycling (Boiral et al., 2020).

Partnerships play a crucial role in this context. SMEs can partner with suppliers to establish closed-loop supply chains or collaborate with customers to drive demand for sustainably designed products (Lüdeke-Freund et al., 2018). Partnerships with research institutions can facilitate access to cutting-edge technologies, while collaborations with industry associations can help SMEs navigate regulatory landscapes (Jonker et al., 2020). These collaborations align with the principles of stakeholder theory, which encourages businesses to build mutually beneficial relationships with key actors. For example, partnerships with suppliers can enable access to sustainable materials, while customers may become advocates for circular products through sustainable consumption choices (Masi et al., 2018).

Regulators and policymakers play a pivotal role as stakeholders in driving the CE transition. They establish regulatory frameworks, offer financial incentives, and provide technical assistance, which are critical for enabling SMEs to adopt sustainable practices (de Jesus & Mendonça, 2018). However, navigating complex regulations can be challenging

for resource-constrained SMEs. Proactive engagement with policymakers can help SMEs shape supportive regulations while ensuring compliance with environmental standards (Hazen et al., 2020). A study by Kirchherr et al. (2018) showed that regulatory support is crucial for encouraging circular business practices, particularly in sectors with stringent environmental regulations.

Internally, employees and management are vital stakeholders in the CE transition. Employee engagement can drive innovation and improve the implementation of circular practices. Training programs and capacity-building initiatives can enhance employees' skills, enabling them to contribute effectively to sustainability goals (Adams et al., 2016). Moreover, leadership commitment from management significantly influences organizational priorities and the integration of circular strategies (Ghadimi et al., 2021). A shared vision for sustainability among internal stakeholders fosters a culture that supports continuous improvement in environmental performance (Freudenreich et al., 2020).

Stakeholder theory is essential for fostering innovation, trust, and shared value – elements critical in overcoming the resource and capability limitations SMEs face during the transition to CE. SMEs can leverage external knowledge and resources through stakeholder collaboration, compensating for their limited internal capacities (Masi et al., 2018). Trust, a central component of stakeholder theory, is particularly relevant in circular initiatives, where long-term partnerships based on trust between SMEs and their stakeholders can lead to more effective collaboration and innovation in resource efficiency and waste reduction (Boiral et al., 2020).

Furthermore, stakeholder theory provides a framework for understanding the socio-economic and regulatory dimensions of the transition to CE. Many challenges SMEs face are external, such as market conditions, consumer demand, or the regulatory landscape (Kirchherr et al., 2017). By engaging with stakeholders, SMEs can influence these external factors. For instance, they can work with regulators to advocate for favorable policies that support CBMs or collaborate with other firms to create a secondary materials market (Kirchherr et al., 2018).

Engaging with a diverse set of stakeholders can help SMEs identify new opportunities for circular practices. For example, collaboration with local communities can lead to the discovery of novel ways to reduce waste or increase resource efficiency (Mont et al., 2021). The circular economy depends on viewing operations from a systems perspective, where waste in one part of the system can be repurposed as a resource in another (Korhonen et al., 2018). Stakeholder theory helps SMEs recognize this interconnectedness and enables them to build partnerships that close resource loops and reduce waste across the value chain (Masi et al., 2018).

To sum, stakeholder theory provides a holistic understanding of the actors involved in the transition to a circular economy by emphasizing the interconnectedness of these actors and their collective potential to drive systemic change (Lüdeke-Freund et al., 2018). For SMEs, adopting a stakeholder-centric approach allows them to move beyond short-term financial goals and consider broader environmental and societal impacts (Freudenreich et al., 2020). By fostering strong relationships and aligning stakeholder interests with circular goals, SMEs can overcome barriers and leverage opportunities for sustainable growth in their transition to a circular economy (Hazen et al., 2020).

Despite its strengths, stakeholder theory has certain limitations when applied to the complex dynamics of SMEs transitioning to a CE. One key shortcoming is its limited capacity to address the systemic and interdependent nature of CE transitions.

Stakeholder theory traditionally focuses on dyadic relationships between businesses and individual stakeholders, overlooking the broader network of interconnected actors that shape sustainability outcomes (Kirchherr et al., 2018). To address these limitations, integrating complexity theory and the MLP can enhance the applicability of stakeholder theory in studying SMEs' CE transitions.

1.4.3 Complexity Theory

Complexity theory, originally developed in disciplines such as mathematics and physics, examines the behaviour of systems comprising numerous interconnected elements. Interactions within such systems lead to emergent properties that are not easily predictable due to non-linear dynamics and feedback loops (Manson, 2001). Unlike traditional linear models, where outcomes can be directly traced to specific causes, complexity theory suggests that small changes in one system component can produce significant, often unexpected, effects in other parts due to interdependencies (Cilliers, 1998). This conceptualization offers valuable insights into socio-economic and organizational contexts, including the transition of SMEs toward CE practices.

In the context of CE transitions, complexity theory helps elucidate how diverse factors such as technological innovation, policy changes, and stakeholder behaviour interact dynamically to influence the adoption of circular practices. Feedback loops and non-linear causality are central to this framework, wherein minor adjustments in one area of an SME's operations can trigger large-scale transformations across the entire system, a phenomenon often termed the "butterfly effect" (Manson, 2001). Furthermore, complexity theory highlights emergent properties arising from these interactions, meaning that new, unanticipated behaviours and outcomes may occur that cannot be understood by analysing individual elements in isolation (Cilliers, 1998).

Adaptability and resilience are critical aspects of complexity theory, emphasizing that SMEs must adopt flexible strategies to navigate the uncertain and evolving nature of CE transitions. This perspective supports the identification of leverage points within interconnected systems, enabling targeted interventions for accelerating CE adoption (Kumar et al., 2022). By acknowledging the dynamic interplay between various internal and external elements, complexity theory fosters a holistic understanding of the transition process.

Moreover, complexity theory underscores the multi-level nature of CE transitions, involving micro (firm-level), meso (industry-level), and macro (policy-level) dynamics shaped by interdependencies and reciprocal influences (Kumar et al., 2022). This approach aligns with STS theory, which advocates for collaborative efforts across social and technical domains to address transition challenges (Sohal et al., 2022). Recognizing these multi-level interactions enables a deeper understanding of the systemic barriers and opportunities that SMEs encounter in adopting CBMs.

To further enhance analytical precision, complexity theory can be complemented by fuzzy logic, which addresses uncertainty and ambiguity inherent in complex systems. Fuzzy logic allows for degrees of membership within sets, facilitating nuanced representations of real-world phenomena where binary categorizations fall short (Zadeh, 1965). This capability proves particularly relevant for SMEs' CE adoption, which often occurs along a continuum rather than through discrete steps (Ghadimi et al., 2020). Integrating fuzzy logic with complexity theory allows for more precise modelling of gradual and uncertain transitions.

The combined application of complexity theory and fuzzy logic provides a robust framework for understanding and managing SMEs' transition to CE practices. This integrated approach supports the development of adaptive strategies that accommodate variability, enabling firms to better predict, respond to, and shape emergent properties during the transition process (Rittershaus et al., 2023). Researchers and practitioners can leverage this combined theoretical lens to devise more effective interventions, enhancing SMEs' resilience and ensuring successful transitions toward sustainable business models (Grobman, 2005; Kumar et al., 2022).

Despite its strengths, complexity theory alone may fall short in capturing the roles and motivations of individual actors within CE transitions, as it primarily focuses on systemic dynamics. This limitation can be addressed by integrating stakeholder theory, which emphasizes the interests and power dynamics among diverse actors, and the MLP, which highlights interactions across socio-technical levels. Together, these frameworks offer a comprehensive view by linking individual, organizational, and systemic dimensions, enabling a more holistic analysis of SMEs' CE transitions.

1.4.4 A Multi-Theoretical Perspective for Understanding SMEs' Transition to a CE

The transition of SMEs to CE represents a complex, multi-dimensional challenge that cannot be adequately captured by any single theoretical framework. While the MLP, Stakeholder Theory, and Complexity Theory each offer valuable insights, their individual limitations necessitate an integrated approach. This synthesis addresses the systemic, relational, and adaptive dimensions of CE transitions, providing a holistic analytical lens to unravel the interdependencies, power dynamics, and non-linear processes inherent in SMEs' sustainability journeys.

The MLP's strength lies in its systemic conceptualization of transitions across niche, regime, and landscape levels, offering a structured understanding of how macro-level policies, meso-level industry norms, and micro-level innovations interact (Geels, 2011). However, its limitations – such as ambiguous boundaries between analytical levels, neglect of agency, and oversimplified bottom-up transition pathways (Genus & Coles, 2008; Alkemade & de Coninck, 2021) – underscore the need for complementary theories. Stakeholder Theory addresses the MLP's oversight of actor-level dynamics by emphasizing the role of collaborative relationships, power asymmetries, and value co-creation among SMEs, suppliers, customers, and regulators (Freeman, 1984; Boiral et al., 2020). For instance, SMEs' reliance on stakeholder networks to overcome resource constraints (Klein et al., 2021) aligns with MLP's niche-level focus but enriches it by detailing how trust and shared goals enable circular innovations. Yet Stakeholder Theory's traditional focus on dyadic relationships risks overlooking systemic interdependencies, a gap bridged by Complexity Theory's emphasis on emergent properties and feedback loops within interconnected systems (Cilliers, 1998; Kumar et al., 2022).

Complexity Theory, with its focus on non-linear causality and adaptability, elucidates how SMEs navigate uncertainty through iterative learning and flexible strategies (Manson, 2001; Ghadimi et al., 2020). However, its systemic orientation often neglects the motivations of individual actors, a shortcoming mitigated by Stakeholder Theory's attention to divergent interests and collaboration. Meanwhile, the MLP contextualizes these dynamics within broader socio-technical landscapes, such as regulatory shifts under the European Green Deal (European Commission, 2020), revealing how macro-level pressures interact with micro-level SME practices. For example, policy incentives for circular practices (de Jesus & Mendonça, 2018) may create landscape-level momentum,

but SMEs' ability to leverage these opportunities depends on stakeholder collaboration (meso) and adaptive capacity (micro) – dynamics explicable only through theoretical integration.

The integration of these theories offers a multi-faceted framework that addresses critical gaps in transition scholarship. First, the MLP's macro-meso-micro structure provides scaffolding to map systemic influences, while Stakeholder Theory injects agency into this structure by detailing how SMEs negotiate relationships with regulators, suppliers, and communities to align circular strategies with external expectations (Kirchherr et al., 2018; Hazen et al., 2020). Complexity Theory, in turn, explains why such strategies often yield unpredictable outcomes due to feedback loops, such as how a minor supply chain adjustment might cascade into market-level shifts (Rittershaus et al., 2023). This tripartite integration resolves the MLP's linear bias by framing transitions as iterative processes where stakeholder collaboration (Stakeholder Theory) and adaptive experimentation (Complexity Theory) co-evolve with regime-level changes (MLP).

Second, the framework addresses the compartmentalization of prior research. While Stakeholder Theory highlights SMEs' partnerships for material recovery (Masi et al., 2018), Complexity Theory reveals how these partnerships form adaptive networks that enhance resilience to market disruptions (Kumar et al., 2022). Simultaneously, the MLP contextualizes these networks within niche-regime interactions, such as how pilot projects scale into industry norms (Geels & Schot, 2007). This synergy is particularly vital for SMEs, whose resource limitations make them reliant on external ecosystems for innovation and risk mitigation (Jonker et al., 2020). For example, circular design initiatives often require SMEs to collaborate with academia for R&D (Stakeholder Theory), adapt to regulatory changes (MLP), and respond to emergent consumer trends (Complexity Theory) – a convergence explicable only through a multi-theoretical lens.

Figure 4 visually demonstrates the rationale for integrating these three theories. The overlap between MLP and Stakeholder Theory bridges structural and relational dimensions of CE transitions (Systemic and Relational Interdependencies). While MLP maps the systemic landscape (e.g., policy regimes, market structures), Stakeholder Theory elucidates how SMEs navigate these structures through relationships with suppliers, customers, and regulators. For instance, MLP's regime level highlights institutional barriers to CE adoption, such as entrenched linear supply chains (Geels, 2011), but Stakeholder Theory explains how SMEs overcome these barriers by building alliances with eco-conscious suppliers or lobbying policymakers (Boiral et al., 2020). Conversely, stakeholder-driven innovations (e.g., circular product designs) can destabilize existing regimes, accelerating niche-to-regime transitions (Bocken et al., 2016). This synergy addresses MLP's neglect of agency by demonstrating how SMEs' strategic stakeholder engagement reshapes socio-technical systems.

The intersection of Stakeholder Theory and Complexity Theory highlights how SMEs leverage collaborative networks to navigate uncertainty (Collaboration and Adaptive Capacity). Stakeholder Theory emphasizes trust-building and shared value creation (Freeman, 1984), while Complexity Theory underscores the need for adaptive strategies in volatile environments (Manson, 2001). For example, SMEs collaborating with competitors to establish circular industrial symbiosis networks (Stakeholder Theory) must adapt to emergent challenges like fluctuating material flows or regulatory changes (Complexity Theory) (Kumar et al., 2022). This overlap reveals how relational resilience – rooted in stakeholder trust – enables SMEs to absorb shocks and experiment with circular practices despite systemic unpredictability.

The convergence of MLP and Complexity Theory resolves MLP's linear bias by framing transitions as iterative, non-linear processes (Non-Linear Socio-Technical Transitions). MLP's landscape pressures (e.g., climate policies) create macro-level momentum for CE, but Complexity Theory explains how SMEs' micro-level adaptations generate feedback loops that reconfigure regimes (Geels, 2020). For instance, a small-scale shift toward remanufacturing by SMEs (niche innovation) might trigger industry-wide standards (regime change) through cumulative interactions, a process MLP conceptualizes as scaling but Complexity Theory attributes to emergent, self-organizing dynamics (Zhu et al., 2022). This synergy enriches MLP's structural analysis with Complexity Theory's emphasis on path dependency and unintended consequences.

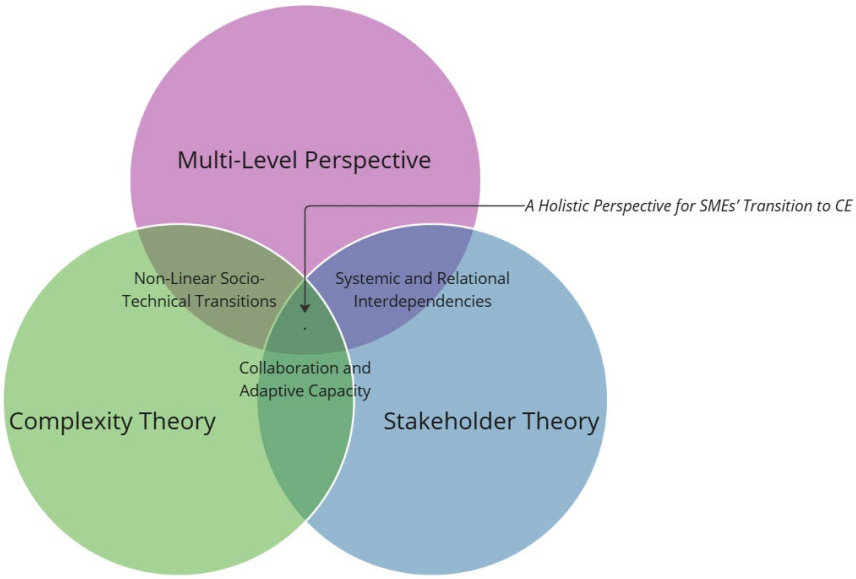

Figure 4. Integrating Theories for SMEs' Transition to CE.
Source: Composed by the author.

At the core, where all three theories converge, emerges a "Holistic Perspective for SMEs' Transition to CE." This integrated view reflects the comprehensive approach needed to thoroughly analyse the dynamics and complexities of SMEs' transition to CE. It acknowledges that the transition is not merely an operational change but a systemic transformation requiring multi-stakeholder cooperation, adaptive strategies, and an understanding of complex socio-technical interactions (Geissdoerfer et al., 2017; Korhonen et al., 2018).

While the integration of these theories is synergistic, inherent tensions arise from their epistemological differences. MLP's hierarchical levels (niche, regime, landscape) imply a structured progression of transitions, whereas Complexity Theory posits that transitions are emergent and non-linear, often bypassing "levels" altogether. For SMEs, this tension manifests in the unpredictability of CE adoption: while MLP might frame digital CE platforms as niche innovations scaling to regime dominance, Complexity Theory warns that their success depends on contingent factors like consumer behaviour or competitor responses, which may defy linear trajectories (Rittershaus et al., 2023). This tension challenges researchers to balance MLP's analytical clarity with Complexity

Theory's acknowledgment of chaos. Stakeholder Theory assumes that collaborative engagement can align divergent interests, but MLP highlights how regime-level inertia may stifle SMEs' circular initiatives regardless of stakeholder goodwill. For example, SMEs advocating for extended producer responsibility (Stakeholder Theory) may face resistance from incumbent firms entrenched in linear regimes (MLP) (de Jesus & Mendonça, 2018). This conflict underscores the need to temper Stakeholder Theory's idealism with MLP's realism about power asymmetries. Complexity Theory's focus on uncertainty and emergent outcomes can conflict with Stakeholder Theory's pragmatic emphasis on actionable strategies. SMEs require clear roadmaps for stakeholder collaboration, yet Complexity Theory suggests that outcomes are inherently unpredictable. Resolving this tension requires frameworks that blend adaptive stakeholder networks (e.g., modular partnerships) with iterative learning cycles (Ghadimi et al., 2020).

2 Methodology

This chapter details the research methodologies and approaches used in this study, highlighting the procedures involved in conducting the research for data collection and analysis purposes. Trochim and Donnelly (2001) stated that every research is governed by assumptions regarding the way the universe is perceived and understood. These assumptions are informed by various factors, including the focus area of the research and the theme under investigation (Remenyi et al., 1998). To conduct research in the hopes of finding answers to the research questions posed, research is carried out using frameworks that are proven and well-established through the guiding paradigm of research philosophies.

2.1 Research Philosophy

When discussing the foundations of research, it's important to break down the core elements that shape the study. Ontology helps define "what is out there to know" while epistemology explores "what and how can we know about it" (Grix, 2002, p. 180). Axiology, in turn, relates to the role of values and ethics in the research, guided by the ontological and epistemological perspectives, and influencing the chosen methodological approach (Geels, 2010).

Methodologies represent the approaches for acquiring knowledge, with methods and sources being the specific techniques and data collection tools (Grix, 2002). All these components are closely intertwined and stem from a philosophy of science. Therefore, in this chapter, I address the facets of the research paradigm I've adopted, linked to my beliefs about the nature of transitions (ontology), how I perceive knowledge about them (epistemology), and the role of values and ethics within my research (axiology) (Geels, 2010; Lincoln & Guba, 1985; Tashakkori & Teddlie, 2010; Zolfagharian et al., 2019). These perspectives have a profound impact on the methodologies employed in my research, the methods I've chosen to conduct the studies, and the data sources I've utilized. As a result, they significantly influence the nature of the results obtained and the subsequent interpretation. Hence, in the following subsection, I introduce the scientific philosophies that underpin my thesis research.

2.1.1 Ontology and Epistemology

My scientific philosophy primarily aligns with pragmatism, which focuses on actions and change in a constantly evolving world: "the essence of a pragmatist ontology is actions and change; humans acting in a world that is in a constant state of becoming" (Goldkuhl, 2012, p. 139). This philosophy is evident in my research goals, which prioritize not only the development of theoretical insights but also the creation of practical frameworks that can be applied directly in real-world contexts. This research, which explicitly aims to enhance analytical knowledge while creating practical, applicable frameworks, aligns well with this ontological stance. By addressing real-world applications in published articles, this thesis embodies the pragmatist commitment to linking theoretical development with actionable outcomes.

Additionally, elements of critical realism are woven into my scientific philosophy and thesis research: "the evidence we observe can come close to reality but is always a fallible, social, and subjective account of reality" (Sturgiss & Clark, 2020, p. 143). This perspective fits well with the complexity of CE implementation and change of SMEs,

where multiple interconnected factors shape outcomes. It helped address questions about how and why transitions to a circular economy progress, such as the X-curve framework (Hebinck et al., 2022), in interdisciplinary real-world contexts.

Although transitions are dynamic, we often use static categories for analytical purposes, such as the X-curve constructs: "we assert that specific patterns and mechanisms are generic and thus intransient because we assume there are 'stable' patterns in dynamic structures" (Loorbach et al., 2017). We believe some patterns and mechanisms are stable despite the fluid nature of transitions and aim to analyse these enduring patterns that lead to lock-ins and dependencies over time. My pragmatic approach involves anticipating elements that might continue while acknowledging the inherent uncertainty in dynamic transitions: "Because we live in a world in process, the future, although continuous with the past is not its bare repetition" (Dewey, 1929, p. 40).

However, this approach also faces key ontological and epistemological challenges. The commitment to a flat ontology and an open, exploratory research design introduces dilemmas regarding empirical openness versus the necessity to define practical boundaries. For instance, while striving for broad empirical inclusivity, there remains a need to establish limits in terms of sectoral focus, actor groups, and geographical scope. These choices inevitably shape how well the study captures the complexity of CE implementation in SMEs.

Additionally, despite a clear conceptual framework, the open exploration inherent in this approach can yield findings that align with diverse epistemological perspectives. Insights may emerge that speak not only to sustainability but also to technological advancements, management practices, or the social dimensions of work. This broad relevance introduces challenges of "demarcation" (Jones & Murphy, 2011), where defining the appropriate boundaries of practices as analytical objects becomes complex. In practice-oriented research, balancing this openness while maintaining conceptual clarity is critical to ensuring a coherent yet rich interdisciplinary inquiry.

2.1.2 Axiology

Axiology, which pertains to values in research, has its roots in ontology and epistemology. It involves fundamental beliefs about ethics that are deeply ingrained in research paradigms and guide researchers in their decision-making processes: "basic beliefs about what is ethical are embedded in research paradigms and guide the researcher's decision making" (Killam, 2013, p. 6). This implies that axiology encompasses the values of research, including the need for clear contextual transparency regarding the researcher's position and its implications for research methodologies (Pontoretto, 2005).

The axiology of my research, directly linked to my ontology and epistemology, blends elements of pragmatism and critical realism. The elements of my work were created, researched, and developed in alignment with my interests and values in the field of the circular economy. John Dewey, a foundational pragmatist, posited that "all human experience involves some amount of interpretation – interpreting knowledge and beliefs leads to action, and reflecting on actions leads to new ways of knowing and acting" (Kelly & Codeiro, 2020, p. 2). Similarly, critical realists acknowledge the existence of true reality but understand that it can only be imperfectly apprehended and measured: "critical realists 'accept a true reality but believe it can only be apprehended and measured imperfectly'" (Ponterotto, 2005, p. 131). While we constantly strive for transparency and objectivity in our roles as scientists and in our analytical endeavors, we acknowledge that

our backgrounds, experiences, and values can unintentionally and implicitly influence our work to some extent. Therefore, it is valuable for the reader to appreciate the contextual and background factors that underlie my research.

2.2 Research Strategy and Study Design

Building on the insights gained during the exploratory stage, which informed the identification and design of the study, this research employs an explanatory sequential mixed methods design, which involves first collecting and analysing quantitative data, followed by qualitative data to further explain or build upon the initial findings, as shown in Figure 5 (Creswell & Plano Clark, 2018). The rationale for selecting this design lies in its ability to address the complex and multi-dimensional nature of SMEs' transition to a CE by capturing both systemic patterns and contextual nuances. Mixed methods research balances the strengths of quantitative and qualitative approaches while addressing their respective limitations, enabling a more holistic analysis (Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2008).

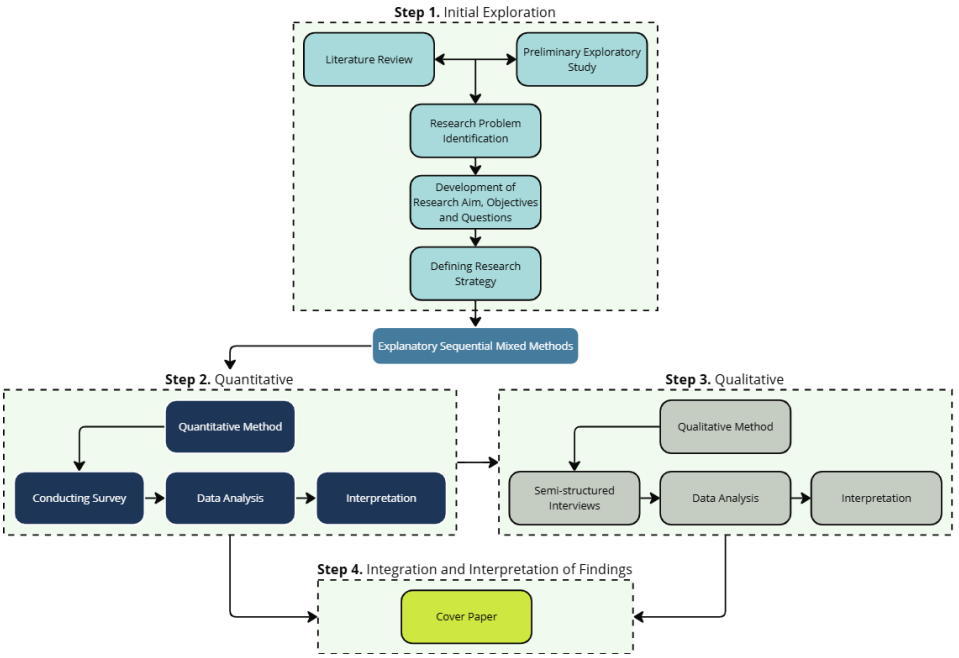

Figure 5. Explanatory Sequential Mixed Method Research Design for Investigating SMEs' Transition to a CE.
Source: Composed by the author.

Step 1. Initial Exploration Phase: The initial exploration phase focuses on identifying knowledge gaps, defining research objectives, and establishing a robust research framework. This phase includes a comprehensive literature review and a preliminary exploratory study to map the key challenges and opportunities in CE adoption.

Article 1 provides an empirical investigation into CE adoption among SMEs in Estonia, focusing on industry-specific barriers and enablers. By examining the adoption of CE practices across five stages of the product life cycle, the study highlights critical obstacles,

including limited knowledge, financial constraints, and low prioritization of CE practices. For example, the metal industry demonstrated higher levels of innovation compared to sectors like chemicals and electronics, offering sector-specific insights.

Article 2 employs the Multi-Level Perspective (MLP) framework to systematically analyze the dynamics influencing CE transitions. This study maps the micro-level (organizational practices), meso-level (industry networks), and macro-level (policy frameworks), identifying the interdependencies between these levels. The theoretical contribution addresses a key gap by linking organizational-level changes with broader systemic and policy-level influences. Together, these studies provide a critical understanding of the barriers, enablers, and systemic dynamics shaping CE transitions in SMEs. This foundational knowledge guides the design of subsequent quantitative and qualitative inquiries, ensuring a focused and coherent research trajectory.

Step 2. Quantitative Phase: The quantitative phase validates and expands upon the exploratory findings. This phase focuses on identifying patterns, relationships, and causal pathways that influence CE adoption.

Article 3 explores the impact of stakeholder pressures and managerial perceptions on CE practices. The study reveals that internal stakeholder pressures (e.g., employees and managers) have a more direct influence on CE adoption compared to external pressures (e.g., customers and regulators). However, external pressures exert an indirect effect through the mediating role of CEO, highlighting the importance of strategic alignment within organizations.

Article 4 applies fsQCA to uncover distinct causal pathways for CE adoption among international (firms that operate in international markets) and non-international (operate solely within domestic markets) micro-manufacturing firms. The study identifies five pathways, with international firms relying more on stakeholder engagement and regulatory frameworks, while non-international firms focus on internal sustainability practices. This highlights the heterogeneity of CE transitions and the need for context-specific strategies. The insights from these studies deepen the understanding of stakeholder dynamics, organizational behavior, and contextual influences, forming the basis for targeted qualitative investigations in the next phase.

Step 3. Qualitative Phase: The qualitative phase builds on the quantitative findings to provide an in-depth exploration of the complexities of CE adoption. Semi-structured interviews are used to capture the nuanced perspectives of key stakeholders.

Article 5 synthesizes insights from earlier studies to propose a holistic framework for CE adoption. By integrating MLP and complexity theory, the study examines success factors across micro-, meso-, and macro-levels. At the micro-level, factors such as organizational culture, employee training, and leadership commitment are identified as critical drivers. At the meso-level, stakeholder collaboration and industry partnerships are emphasized as key enablers, while at the macro-level, supportive regulatory environments and financial incentives are highlighted as essential for fostering systemic alignment. This study bridges theoretical insights with practical strategies, providing a comprehensive roadmap for SMEs to navigate their CE transitions. The qualitative findings add depth to the quantitative results, revealing the dynamic and adaptive processes that underpin successful CE transitions. They also highlight the interconnectedness of internal capabilities, stakeholder relationships, and systemic conditions.

Step 4. Integration and Interpretation Phase: The final phase synthesizes the insights from all previous stages into a cohesive narrative, culminating in the preparation of a cover paper. This phase integrates quantitative data and qualitative findings to address

the research objectives comprehensively. The integration of findings ensures a robust understanding of the factors influencing CE transitions at the micro (organizational), meso (industry), and macro (policy) levels.

The explanatory sequential design is particularly well-suited to this study because it allows for a phased exploration of the research problem. In the quantitative phase, broad patterns, relationships, and systemic trends are identified, providing measurable and generalizable insights. For example, surveys and statistical analysis highlight barriers, drivers, and stakeholder dynamics shaping CE transitions in SMEs. The qualitative phase then builds on these results, delving deeper into contextual and relational dynamics through semi-structured interviews. This two-phase approach ensures a comprehensive understanding, as the qualitative insights enrich and contextualize the quantitative findings (Creswell, 2002). By integrating data across phases, the study provides a robust understanding of the factors influencing CE transitions at the micro (organizational), meso (industry), and macro (policy) levels.

The rationale for this design is rooted in the complexity of CE transitions, which require an understanding of both systemic interactions and individual organizational behaviours. SMEs operate within interconnected ecosystems, where factors such as regulatory frameworks, market dynamics, and stakeholder pressures interact to shape sustainability outcomes. A single-method approach would fail to capture this complexity. The sequential mixed methods design ensures that the study addresses both the breadth and depth of the research problem, providing a nuanced perspective that is both generalizable and contextually rich (Poth & Munce, 2020).

The chosen design also aligns with the study's philosophical foundations, which integrate pragmatism and critical realism. Pragmatism focuses on practical solutions and real-world applicability, making it an ideal fit for this study's aim to generate actionable insights for SMEs, policymakers, and industry stakeholders. It allows for flexibility in research methods, ensuring that the design adapts to the demands of the research context (Biesta, 2010). Critical realism, on the other hand, emphasizes the interplay between observable phenomena and the underlying structures or mechanisms that influence them. This perspective is particularly valuable for understanding the systemic and relational dimensions of CE transitions, acknowledging that patterns identified through quantitative methods are shaped by deeper social, cultural, and economic contexts (Sturgiss & Clark, 2020).

2.3 Research Instruments and Methodological Approach

This thesis utilized a combination of quantitative and qualitative research methods as the primary data collection instruments, selected for their ability to capture both measurable trends and nuanced insights into SMEs' transition to a CE. This approach enabled the integration of large-scale, standardized insights with in-depth, contextual exploration, addressing the multifaceted nature of SMEs' transition to a CE.

The mixed methods approach ensured a comprehensive understanding of the research problem by integrating the breadth of quantitative data with the depth of qualitative insights. The sequential design allowed findings from the quantitative phase to inform the qualitative phase, creating a cohesive and iterative research process. For example, while the surveys identified broad systemic patterns, such as the role of stakeholder pressures, the interviews provided deeper insights into how SMEs experience and respond to these pressures in practice.

By combining structured survey data with nuanced qualitative narratives, the study achieved a holistic perspective on the factors influencing CE adoption among SMEs. This integration reflects the strengths of mixed methods research in addressing both generalizable trends and context-specific dynamics (Poth & Munce, 2020; Tashakkori & Teddlie, 2003). Together, these instruments and methods provided a robust foundation for achieving the study's objectives and advancing both theoretical and practical knowledge on SMEs' transition to CE.

2.3.1 Quantitative Research Method

The primary instrument for the quantitative phase was a structured survey questionnaire, designed to capture standardized data across a broad sample of SMEs. As Marczyk et al. (2005) suggest, questionnaires are highly effective for statistical analysis, allowing the identification of patterns and relationships between variables. In this study, the survey was tailored to measure constructs such as environmental awareness, stakeholder pressure, internal barriers, and CE adoption practices. Questions were derived from validated scales in existing literature to ensure methodological rigor. A five-point Likert scale was employed to quantify respondents' attitudes and practices, facilitating detailed statistical analysis.

To enhance clarity and minimize common pitfalls such as bias and ambiguity, the questionnaire adhered to established design principles (Saunders et al., 2009). A pilot test was conducted with a small sample of SMEs, following Marczyk et al.'s (2005) recommendations, to identify and address any issues with question clarity or structure before full deployment. This step ensured both the reliability and validity of the survey instrument.

The survey was distributed online to SMEs in Estonia, leveraging digital platforms to maximize accessibility and participation. Participants were recruited through industry associations, professional networks, and direct outreach, ensuring diversity in industry representation and firm sizes. Data from the survey were analysed using descriptive and inferential statistical methods to identify patterns and relationships. Additionally, fsQCA was applied to uncover complex interactions between factors affecting CE adoption, such as organizational capabilities and stakeholder influences. This advanced analytical method allowed for the identification of multiple pathways through which firms adopt CE practices, offering nuanced insights into the diversity of SME experiences (Marczyk et al., 2005).

2.3.2 Qualitative Research Method

The qualitative phase involved semi-structured interviews, recognized for their ability to explore complex issues in depth (Saunders et al., 2009). A thematic interview guide was developed based on insights from the quantitative analysis, ensuring alignment with key areas such as stakeholder pressures and internal challenges that emerged as significant factors. This iterative approach allowed the qualitative phase to complement and expand upon the findings of the quantitative phase.

The semi-structured format provided flexibility, enabling the researcher to probe deeper into participants' responses and explore emerging themes. This aligns with Marczyk et al.'s (2005) assertion that qualitative research methods allow for open-ended responses, uncovering new dimensions of the research topic. The interviews focused on Swedish SMEs, offering insights into organizational, relational, and systemic dynamics in a mature CE ecosystem.

The data were analysed using thematic analysis, a systematic approach involving the coding of transcripts to identify recurring themes and patterns (Saunders et al., 2009). The use of NVivo software facilitated the organization and systematic analysis of the qualitative data, ensuring transparency and consistency in identifying themes. These insights contextualized the quantitative findings, providing richer, more detailed understanding of how SMEs navigate CE transitions.

2.4 Sample and Data Collection

This study employed a purposive sampling strategy. The sampling criteria were designed to capture a variety of perspectives and experiences, focusing on firms engaged in manufacturing, a sector critical to CE transitions. Additional criteria included organizational size (micro, small, and medium enterprises) and varying levels of CE adoption, ensuring the inclusion of both early adopters and firms in the initial stages of CE implementation. The sample size varied across the research stages, reflecting the specific objectives and methodological requirements of each phase. Figure 6 shows a multi-stage research methodology diagram spanning from January 2021 to January 2025, spanning the four year of PhD study.

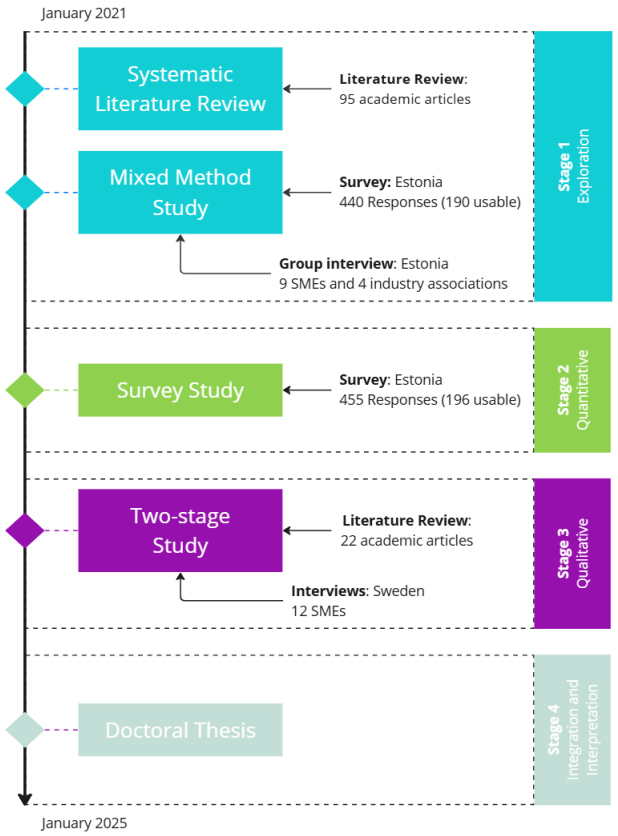

Figure 6. Four-Stage Mixed Methods Research Design: From Exploration to Integration and Interpretation.
Source: Composed by the author.

2.4.1 Stage 1: Exploration Phase

The exploration phase utilized a dual approach to data collection, combining a systematic literature review with a mixed-method study in Estonia. For the literature review, a sample of 95 academic articles was systematically selected from Web of Science and Scopus databases. The selection criteria focused on articles relevant to SMEs' transition to CE practices. This comprehensive sample provided a solid foundation for understanding the current state of research in the field (Article 2). The mixed-method study in Estonia involved both quantitative and qualitative data collection. A survey was distributed to 2,211 SMEs across four industries in Estonia between October and December 2021. The survey yielded 440 responses, of which 190 were deemed usable after screening. This represents a response rate of approximately 8.6%, which is consistent with similar studies in the field. Four group interviews were conducted, involving 9 SMEs and 4 industry associations from four sectors. These semi-structured interviews lasted approximately one hour each and were audio-recorded and transcribed for analysis (Article 1).

2.4.2 Stage 2: Quantitative Phase

The quantitative phase expanded on the exploratory findings through a comprehensive survey study in Estonia. The sampling and data collection process was rigorous and multi-faceted.

A randomized sample of 1,500 SMEs was drawn from the Orbis Europe database, ensuring representativeness across the Estonian SME landscape. The survey was administered through the Qualtrics platform on January 10th, 2023. To accommodate the diverse linguistic background of Estonian firms, the survey was made available in three languages: Estonian, Russian, and English. The data collection occurred in three phases, comprising the baseline survey and two follow-up surveys, spanning a period of three weeks. The survey yielded 455 initial responses, representing a 30.33% response rate. After rigorous data cleaning and application of inclusion criteria, 196 complete and valid responses were retained for analysis, resulting in a final response rate of 13.07%. A subset of the data focused specifically on micro-firms, yielding 128 usable responses after applying strict inclusion criteria

2.4.3 Stage 3: Qualitative Phase

The qualitative phase employed a two-stage methodology, combining a focused literature review with in-depth interviews of Swedish SMEs. A focused review of 22 academic articles was conducted, providing a theoretical foundation for the qualitative investigation. The initial sample pool consisted of 55 SMEs identified through an extensive online search of Swedish CE-focused organizations. This was narrowed down to 32 SMEs based on the extent and impact of their CBMs. Ultimately, 12 SMEs agreed to participate in the study. Semi-structured interviews were conducted with executive managers from the 12 participating SMEs. These interviews were carried out online using Microsoft Teams between January and February 2023, with an average duration of 40 minutes each. The decision to conduct 12 interviews was guided by the principle of theoretical saturation, with redundancy of information observed after the 10th interview.

2.4.4 Stage 4: Integration and Interpretation Phase

The final stage synthesizes findings across all previous phases, integrating quantitative and qualitative insights to develop a comprehensive understanding of CE implementation in manufacturing SMEs. This integration phase enables triangulation of findings and development of robust theoretical and practical implications.

2.5 Data Analysis

The analysis across the five articles reveals a diverse array of methodologies combining both quantitative and qualitative approaches. These methodologies were applied to explore various dimensions of CE implementation among SMEs.

The analysis in Article 1 employed a mixed-methods approach, combining qualitative and quantitative analysis techniques. For the qualitative component, thematic analysis was applied to the transcripts of four group interviews, identifying key themes related to CE awareness, initiatives, motivations, and barriers. The quantitative analysis of survey data from 190 complete responses was conducted using SPSS version 27, employing descriptive statistics and analysis of variance to examine constraints hindering CE innovation implementation. This integration of qualitative and quantitative findings allowed for a holistic understanding of CE innovation among Estonian SMEs.

Article 2 employed content analysis using NVIVO 14 and MS Excel to analyse 95 academic articles. The analysis followed Mayring's (2014) main steps, including review idea, operationalization, and results interpretation. The coding process adhered to the Webber protocol, involving multiple stages such as defining recording units, determining coding categories, and testing coding on sample texts. This rigorous approach allowed for both quantitative and qualitative exploration of the articles, providing insights into complex managerial phenomena related to SMEs' transition to CE.

Article 3 employed a comprehensive methodological approach to analyse survey data from 196 valid responses. Descriptive analyses were conducted to explore the main characteristics of survey items, including mean and standard deviation. To ensure robustness, reliability and validity assessments were performed on all survey items and constructs. Harman's single-factor test was used to assess common method bias (Harman, 1976). Reliability was assessed through measures such as Cronbach's alpha coefficient (Churchill, 1979; Cronbach, 1951), average variance extracted (Bagozzi & Yi, 1988), and composite reliability (Nunnally, 1978). Convergent validity was established through exploratory factor analysis (Hair et al., 2010). Correlation analysis was conducted to identify patterns of association between constructed variables. Finally, ordinary least square (OLS) regression and structural equation modelling (SEM) were employed to test hypotheses and examine complex relationships between variables, including mediation effects (Hayes & Preacher, 2013).

Article 4 utilized fsQCA to analyse data from 128 usable questionnaires. The analysis followed a three-step fsQCA process: data calibration, truth table building, and truth table minimization. In the calibration phase, indicator values were aggregated for each variable, and thresholds were computed using maximum, average, and minimum values. The truth table was constructed with a frequency threshold of 1 and a consistency level of 0.75 (Pappas and Woodside, 2021). Data minimization was performed using the standard analysis command, resulting in complex, parsimonious, and intermediate solutions. The focus was on intermediate solutions to determine causal configurations, comparing them with parsimonious solutions to identify core and peripheral conditions.

This approach allowed for a nuanced analysis of the complex interplay between factors influencing CE adoption in micro-firms.

Lastly, Article 5 employed thematic analysis following Braun and Clarke's (2006) guidelines to analyse the rich data collected through semi-structured interviews. The analysis process involved an iterative collaboration among the authors, using both inductive and deductive approaches. The Gioia method was utilized to ensure rigorous and reliable analysis, involving multiple rounds of coding and refinement (Gioia et al., 2013). NVivo software supported the analysis of manually transcribed interviews. The process involved identifying first-order concepts, categorizing them into second-order categories, and consolidating them into core categories based on the Multi-Level Perspective framework. This approach allowed for a systematic and in-depth exploration of success factors contributing to the adoption of CE practices in manufacturing SMEs.

Data Quality Assurance played a crucial role in ensuring the reliability and validity of the research findings across the studies. The researchers employed a variety of rigorous techniques to maintain high standards of data integrity and minimize potential biases.

One of the primary methods used for data quality assurance was the implementation of reliability and validity assessments. In Article 3, comprehensive reliability tests, including Cronbach's alpha coefficient, average variance extracted, and composite reliability measures conducted. Cronbach's alpha, in particular, is widely recognized as a robust measure of internal consistency, with values above 0.7 generally indicating acceptable reliability. These measures helped ensure that the constructs used in the study were consistently measuring what they were intended to measure.

To address the potential issue of common method bias, which can arise when data for both dependent and independent variables are collected from the same respondents, Harman's single-factor test was employed. This test involves conducting an exploratory factor analysis to determine whether a single factor accounts for the majority of the variance in the responses. In Article 4, the results of this test revealed that the first factor accounted for only 20.5% of the total variance, well below the 50% threshold, indicating that common method bias was not a significant concern.

Validity was another critical aspect of data quality assurance. In Article 3, convergent validity was established through exploratory factor analysis. This technique helps to confirm that items that are theoretically related to each other demonstrate high correlations. Additionally, to assess multiple relationships within an integrated framework SEM employed, allowing for a more comprehensive examination of the hypothesized relationships.

For qualitative data, rigorous thematic analysis techniques were employed. In Article 5, Braun and Clarke's (2006) guidelines for thematic analysis followed, which involves a systematic approach to identifying, analysing, and reporting patterns within the data. The use of the Gioia method further enhanced the rigor of the qualitative analysis, providing a structured approach to developing data-driven theoretical insights.

To ensure the robustness of quantitative data, the "complete case analysis" method was used to address missing data, as seen in Articles 3 and 4 (Hughes et al., 2019). This approach involves excluding cases with incomplete or missing responses from the analysis, thereby maintaining the integrity of the dataset. While this method can potentially reduce sample size, it helps to avoid the introduction of bias that can occur with some imputation methods.

In Article 4, the process of using fsQCA involved setting thresholds for full membership, non-membership, and the cross-over point for each variable, ensuring that the data was appropriately prepared for this specific analytical technique.

The use of multiple coders in Article 2's content analysis helped to ensure inter-coder reliability and validity of the data source, particularly for articles indexed in Scopus or Web of Science. This approach helps to mitigate individual biases and enhance the consistency of the coding process.

2.6 Research Ethics

Building on the empirical exploration of the significance of the CE for SMEs presented in Chapter 2, I have come to recognize that the CE fundamentally aligns with principles of environmental stewardship, societal well-being, and intergenerational fairness – key elements of an ethical society. However, through the application of critical realism and a pragmatic approach, it becomes evident that the actual implementation and reality of the CE diverge significantly from these idealistic expectations. This divergence does not, in any way, imply that ethical considerations should be diminished in CE research. On the contrary, it underscores the heightened importance of maintaining stringent ethical standards throughout the research process. Any compromise, no matter how minor, would fundamentally contradict the ethical foundations of the CE itself, resulting in an inherent paradox where unethical methods are used to study an ethical concept.

As Lincoln and Guba (1985) and Creswell (2013) suggest, a researcher's morals, values, and belief system profoundly influence the ethical considerations of their study, reflecting an axiological approach to research. This perspective becomes evident in the researcher's interactions with interviewees, the framing of the research questions, the design of the study, and the interpretation and communication of findings. Similarly, Cooper and Schindler (2008) emphasize that every stage of the research process must be conducted in a morally responsible manner. In alignment with these principles, I have rigorously adhered to the highest ethical standards at every step of this research.

Regarding the interview phase, I ensured confidentiality by limiting the disclosure of specific details about the participating organizations. Consent was obtained from all interviewees before proceeding, and they were informed that their participation was entirely voluntary, with the option to withdraw at any time. Participants were explicitly informed of the confidentiality guidelines outlined in TalTech's ethical policy[2], which governed the handling of data, including the recording of conversations and the access granted to my two supervisors.

In addition to interviews, ethical considerations were also crucial during the survey phase of this study. Participants in the survey were fully briefed on the study's purpose, and their anonymity was guaranteed. Like the interviews, informed consent was sought, and participants were made aware that they could opt out of the survey at any stage without any consequences. Data gathered from the survey was handled with the same strict confidentiality protocols, ensuring that no sensitive information could be traced back to individual respondents.

[2] TalTech's Principles of Academic Ethics (Code of Academic Ethics) provide comprehensive guidelines on confidentiality and ethical conduct in academic research. Available at: https://oigusaktid.taltech.ee/en/principles-of-academic-ethics-code-of-academic-ethics/

This research has adhered to TalTech's code of conduct, upholding ethical standards on two primary levels: (a) safeguarding the rights and interests of both interviewees and survey participants, and (b) ensuring the rigor, validity, and reliability of the research findings by avoiding biases, selective reporting, and maintaining transparency throughout. The ethical integrity maintained across both qualitative (interview) and quantitative (survey) methods ensures that the study remains consistent with the underlying ethical principles of the CE, reinforcing the importance of ethics in both the content and conduct of research.

3 Results

The central aim of this study was to explore and analyse the transition process of SMEs from traditional, linear business models to adopting CE principles. This exploration focused on how SMEs manage this journey by balancing internal organizational changes, responding to external pressures, and evolving their stakeholder relationships. The results section is structured around three key objectives:

Each of the five articles in this study contributes to one or more of these objectives, providing a comprehensive and multi-faceted analysis of the research questions. Objective 1 focuses on identifying and understanding key factors, actors, and mechanisms influencing this transition, and is primarily addressed by Articles 1, 2, and 5. Objective 2, which explores how organizational dynamics and stakeholder interactions shape CE pathways, is primarily addressed in Articles 2, 3, and 4. Lastly, objective 3, which determine the critical elements for implementing and sustaining CE practices in SMEs, is addressed by Articles 1, 4, and 5.

By organizing the results around these three objectives, rather than by individual papers, this study provides a cohesive and integrated analysis of SMEs' transition to CE. This approach allows for a more comprehensive understanding of the interconnected factors influencing this transition, while still acknowledging the unique contributions of each article to the overall research goals.

3.1 Key Drivers and Mechanisms in SMEs' Circular Economy Transition

The transition of SMEs to CE is a complex process influenced by a multitude of factors, actors, and mechanisms operating at various systemic levels. A comprehensive understanding of these factors is crucial for facilitating this transition, which has garnered increasing academic attention. Articles 1, 2, and 5 showcase a comprehensive picture of these influences, providing valuable insights into the challenges and opportunities faced by SMEs in their CE transition journey.

At the micro-organizational level, Article 1 identifies significant barriers such as the lack of knowledge regarding CE principles and technological expertise among SMEs. This knowledge gap hinders innovation and effective implementation of circular practices. The study also highlights financial constraints as a critical obstacle, limiting their ability to invest in necessary innovations for CE transition (Article 1). Complementing these findings, Article 5 emphasizes the importance of internal capabilities and resources, specifically innovation capacity, leadership commitment, and employee engagement, as crucial success factors for CE implementation at the micro level. The research suggests that firms with strong innovative capabilities and dedicated leadership support for sustainability initiatives are better positioned to successfully implement and maintain CE strategies (Article 5).

At the meso-industry level, Article 2 underscores the significance of industry associations and networks as key actors facilitating collaboration and knowledge sharing among SMEs. These entities serve as crucial intermediaries in the CE transition process. The study also highlights the importance of stakeholder engagement, including suppliers, customers, and local actors, as a key factor in successful CE implementation (Article 2). Article 5 further elaborates on the meso level, focusing on the socio-technical regime encompassing industry norms, standards, and networks. It emphasizes the importance of collaboration with supply chain partners, engagement with industry

associations, and the adoption of new technologies that facilitate circular processes. The research highlights how these inter-organizational relationships and industry-wide initiatives create an enabling environment for CE implementation (Article 5).

At the macro level, all three articles (Article 1,2 and 5) highlight the crucial role of institutional and governmental support in facilitating the transition to CE. Article 1 identifies insufficient support from governmental and public institutions as a significant impediment to the progress of SMEs in adopting CE practices, suggesting that policy interventions and supportive institutional frameworks are crucial for widespread implementation of CE principles. Article 2 reinforces this by emphasizing the role of institutional support as a significant mechanism influencing the CE transition process, highlighting the importance of institutions and policymakers in creating advocacy and awareness for CE principles. Article 5 further expands on this, emphasizing the role of broader societal and environmental factors in shaping the CE landscape. It underscores the significance of supportive regulatory frameworks, economic incentives, and public awareness campaigns in fostering a societal shift towards circular principles (Article 5).

The research also reveals the interconnected nature of these levels and the complex interplay between various factors. Article 2 employs the MLP framework to systematically map out influences at all three levels, providing a comprehensive understanding of the CE transition process. Article 5 takes this further by developing a holistic framework that integrates insights from all three levels – micro, meso, and macro. This integrated approach offers a more nuanced perspective on the challenges and opportunities associated with CE adoption, emphasizing the non-linear and interconnected nature of factors influencing CE practices (Article 5).

3.2 Organizational Dynamics and Stakeholder Roles in Circular Economy Adoption

Organizational dynamics and stakeholder interactions play a crucial role in shaping the pathways towards CE adoption in SMEs. The interplay between internal organizational processes and external pressures creates a complex landscape that firms must navigate to successfully implement CE practices. This section synthesizes insights from three articles (Article 2,3 and 4) to elucidate how these dynamics unfold and influence CE adoption strategies.

Article 2 illuminates the complex relationship between organizational dynamics and stakeholder interactions in shaping CE adoption within SMEs. The study emphasizes the critical role of organizational culture and leadership commitment as internal factors that foster an environment conducive to CE implementation. SMEs with a strong sustainability-oriented culture and ethical leadership are better positioned to overcome barriers and integrate CE principles into their strategies and operations. This finding underscores the importance of internal organizational dynamics in facilitating CE adoption (Article 2).

Furthermore, Article 2 highlights the significant role of stakeholder engagement in the CE adoption process. Active interactions with a diverse range of stakeholders, including suppliers, customers, and industry associations, serve as conduits for knowledge sharing and collaboration. The study identifies collaboration and co-creation as critical mechanisms in the CE adoption process, enabling SMEs to leverage external expertise and resources.

studies such as Austin and Rahman (2022) acknowledge the role of international market exposure in fostering innovation and sustainability, they generally fall short in identifying how these contextual factors translate into distinct CE adoption strategies. The pathways identify – such as stakeholder pressure offsetting internal barriers for international firms or the integration of CEO and environmental awareness in non-international firms – complicate the overly generalized frameworks of studies like Frishammar and Parida (2019). By articulating these nuanced strategies, the results from Article 4 not only addresses the heterogeneity of SMEs but also offers a blueprint for tailored interventions based on organizational context.

However, while the findings provide a robust understanding of CE adoption, they also invite critique in light of certain gaps and oversights. First, the emphasis on stakeholder engagement predominantly centres around formal, externally defined relationships, such as those with suppliers, customers, and regulators. This perspective, while aligned with Kirchherr et al. (2017), risks marginalizing the informal and community-based networks that often play a pivotal role in SME ecosystems. For instance, local collaborations rooted in community knowledge and shared resources, as noted by Harrison et al. (2023), could offer additional pathways for fostering CE transitions, particularly for non-international firms with limited access to global markets.

4.3 Critical Components for Sustaining CE Practices in SMEs

The implementation and sustainment of CE practices in SMEs require the alignment of critical components across organizational, relational, and systemic dimensions. The findings from Articles 1, 4, and 5 provide a nuanced understanding of these components, which align with and expand upon existing literature on the multifaceted challenges and enablers of CE adoption.

Knowledge dissemination and capacity building emerge as foundational elements for CE adoption, as highlighted in Article 1. The emphasis on knowledge and awareness aligns with Kirchherr et al. (2018), who argue that insufficient understanding of CE principles often deters SMEs from engaging in circular practices. Dey et al. (2019) similarly note that technical expertise is a significant barrier, particularly for smaller firms lacking robust R&D capabilities. This underscores the need for targeted training programs and educational initiatives to bridge knowledge gaps, as advocated by Maher et al. (2023). Furthermore, the integration of CE principles into organizational culture, as emphasized in Article 4, resonates with Gallardo-Vázquez et al. (2024), who highlight the importance of a CEO in fostering strategic and operational alignment with sustainability goals.

Financial constraints remain a persistent challenge for SMEs transitioning to CE, as noted in Article 1. The high upfront costs associated with circular innovations are well-documented in the literature (Austin & Rahman, 2022; Lahti et al., 2018). Restricted access to external funding exacerbates this issue, with complex grant application processes and stringent eligibility criteria often sidelining SMEs (Mura et al., 2020). Article 5's emphasis on supportive macro-level policies aligns with calls for government-backed financial mechanisms, such as tax incentives and green bonds, to alleviate these barriers (Rodriguez-Espindola et al., 2022; Zhu et al., 2022). Additionally, public procurement policies that prioritize circular products can create market demand and incentivize SMEs to invest in sustainable practices (Massari & Giannoccaro, 2023).

5.1 Theoretical Contribution

The theoretical contributions of this doctoral thesis are significant in advancing the understanding of SMEs' transition to CE by synthesizing and extending existing frameworks while addressing critical gaps in the literature. Through the integration of the MLP, stakeholder theory, and complexity theory, this thesis provides a comprehensive lens for analysing the systemic, relational, and adaptive dimensions of CE transitions. These contributions not only refine existing theoretical constructs but also offer new insights into the unique challenges and opportunities faced by SMEs in navigating this complex process.

One of the key contributions lies in the application and refinement of the MLP framework to the context of SMEs' CE transitions. While previous studies have employed MLP to examine sustainability transitions broadly (Geels, 2011; El Bilali, 2019), its application to SMEs has been limited, particularly in understanding how smaller firms manage interactions across micro (organizational), meso (industry), and macro (policy and societal) levels. This thesis demonstrates that SMEs CE transition is interconnected and complex, and necessitate multi-perspective view, rather than isolated view. Findings showed that CE practices are constrained by misalignments with meso-level industry regimes and macro-level policy environments. For example, fragmented supply chains or inconsistent regulatory frameworks can hinder SMEs' ability to scale their circular innovations, highlighting the importance of multi-level coordination. This nuanced understanding extends the MLP by emphasizing that successful CE transitions require alignment across all three levels, addressing critiques that MLP often underrepresents the dynamic interplay between levels (Trevisan et al., 2023; Malik et al., 2022).

The integration of stakeholder theory further deepens the theoretical discourse by emphasizing the interactive and relational dimensions of CE transitions. Unlike larger corporations, SMEs operate within closer proximity to their stakeholders, including suppliers, customers, regulators, and local communities (Klein et al., 2021). This research highlights that stakeholder relationships are not isolated but are embedded within broader socio-technical systems. For instance, meso-level dynamics such as industry norms and collaborative networks significantly shape SMEs' ability to align their stakeholder interactions with broader CE objectives. By demonstrating how internal organizational attributes – such as leadership commitment and CEO – mediate stakeholder pressures, this study enriches stakeholder theory by linking external pressures with internal processes. This perspective addresses a key limitation in stakeholder theory, which often overlooks systemic factors influencing stakeholder dynamics (Kirchherr et al., 2018; Boiral et al., 2020).

A particularly novel contribution is the introduction of CEO as a mediating factor that bridges external stakeholder pressures with internal organizational strategies. This concept provides a more granular understanding of how SMEs internalize external demands for sustainability and translate them into actionable practices. For example, SMEs with strong CEO are better positioned to respond to customer demands for eco-friendly products or regulatory requirements for resource efficiency. These finding challenges traditional assumptions in stakeholder theory that external pressures alone drive organizational change (Govindan & Hasanagic, 2018) and instead underscores the importance of internal cultural and strategic alignment.

These insights enable SMEs to make informed decisions about their growth strategies by preparing for both the challenges and opportunities associated with international operations.

A key contribution of this research is its focus on why certain industries are more amenable to CE practices. For example, sectors such as metals demonstrate higher levels of innovation due to factors like supply chain integration and regulatory incentives, whereas industries like chemicals or electronics face greater challenges due to fragmented supply chains or complex product designs. These insights suggest that targeted policy interventions should consider industry-specific dynamics. Policymakers could develop sector-specific CE roadmaps that align efforts across industries while providing tailored support mechanisms, such as subsidies for recycling infrastructure in manufacturing or incentives for industrial symbiosis in textiles. By addressing sectoral nuances, these interventions can enhance the scalability and effectiveness of CE adoption.

For large companies, this research offers significant implications by demonstrating how lessons from SMEs' agility and innovative approaches can inform their own CE strategies. Large firms often face bureaucratic inertia that slows down sustainability transitions; however, they can draw inspiration from SMEs' ability to rapidly adapt to stakeholder pressures and implement circular innovations at smaller scales. Additionally, large companies can benefit from collaborating with SMEs within circular ecosystems by leveraging their flexibility and localized knowledge. Partnerships with SMEs can enable large firms to test pilot projects, co-develop circular products, or establish industrial symbiosis networks that reduce waste and optimize resource use across supply chains.

For industry networks, this research underscores the pivotal role of collaboration in facilitating CE transitions. Industry associations and networks are identified as critical enablers that can act as knowledge hubs by disseminating best practices, fostering cross-sector partnerships, and pooling resources for shared infrastructure like recycling facilities or remanufacturing systems (Susanty et al., 2020; Centobelli et al., 2021). The findings emphasize the importance of developing sector-specific CE roadmaps that align efforts across industries while providing clear guidelines for SMEs. For instance, action plans tailored to specific sectors – such as manufacturing or textiles – can help firms identify opportunities for industrial symbiosis, where waste from one company becomes a resource for another (Hull et al., 2021). Industry networks can also facilitate local and regional circular ecosystems by connecting firms with complementary resource needs or waste outputs. These ecosystems create opportunities for SMEs to participate in closed-loop systems without requiring substantial individual investment in infrastructure.

The research also highlights the value of cross-sector collaborations involving academia, non-profits, and government agencies. Such partnerships provide SMEs with access to specialized knowledge, funding opportunities, and new markets for circular products (Holzer et al., 2021). Additionally, digital platforms are identified as transformative tools that enable resource sharing and foster new business models within circular value chains (Neri et al., 2023). Industry networks can play a crucial role in scaling these innovations by creating digital ecosystems that connect waste generators with potential users or facilitate secondary material markets.

For policymakers, this thesis offers evidence-based recommendations to design effective support mechanisms that address the unique challenges faced by SMEs. Financial incentives such as tax benefits, grants, subsidies, or green bonds are highlighted

Third, future research could broaden the organizational focus to include larger enterprises, non-profit organizations, social enterprises, and public sector entities. Comparative analyses between SMEs and larger corporations could illuminate how organizational scale and resource availability impact CE adoption strategies. For example, large firms may have greater capacity for innovation but face bureaucratic inertia, whereas SMEs may excel in agility but struggle with resource constraints. Additionally, examining CE transitions in non-profit or public sector organizations could provide a holistic understanding of sustainability transitions across various organizational forms. Such studies would help identify cross-sectoral synergies and collaborative opportunities for advancing CE practices.

Fourth, there is an opportunity to extend the focus beyond CE to investigate alternative sustainability frameworks such as regenerative business models. Unlike CE's emphasis on closing material loops, regenerative models aim to create net-positive environmental and social impacts by restoring natural systems and enhancing biodiversity. Future research could examine how SMEs can integrate regenerative practices into their operations, such as adopting agroecological methods in agriculture or designing products that actively regenerate ecosystems. This shift would provide a broader perspective on sustainability transitions by addressing critiques of CE's limitations in achieving full circularity.

Fifth, sector-specific studies are essential to uncover why certain industries are more amenable to CE practices than others. For instance, this research found that sectors like metals demonstrated higher levels of innovation compared to chemicals or electronics. Future work could analyse how industry-specific factors such as supply chain complexity, regulatory requirements, or market demand influence CE adoption pathways. In-depth case studies of successful implementations could identify best practices for overcoming barriers like entrenched linear business models or fragmented supply chains.

Sixth, longitudinal studies tracking SMEs' CE adoption over extended periods would address the limitations of cross-sectional data by capturing the dynamic nature of sustainability transitions. Such research could explore how policy interventions or industry collaborations influence SMEs' ability to sustain circular practices over time. For example, tracking firms' progress could reveal how the importance of R&D capabilities shifts during different phases of CE implementation or how firms adapt their strategies in response to evolving regulatory landscapes.

Seventh, further refinement of theoretical frameworks is needed to capture the nuanced interactions between systemic structures (as analysed through MLP), stakeholder dynamics (Stakeholder Theory), and adaptive processes (Complexity Theory). Scholars could develop more precise constructs to measure these interactions while integrating complementary perspectives such as Institutional Theory or Resource-Based View. These additions would address gaps related to power dynamics and resource management in CE transitions while providing a more comprehensive understanding of multi-level influences.

Eights, future research should explore the transformative role of emerging technologies – such as artificial intelligence, blockchain, and IoT – in facilitating SMEs' transition to CE. These technologies have shown potential to enhance resource tracking, enable closed-loop supply chains, and support new circular business models like product-as-a-service. However, empirical studies are needed to investigate how SMEs can overcome barriers such as high implementation costs or limited technical expertise to adopt these technologies effectively. Research could also examine how digital

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Appendix 3

Publication III

Ahmadov, T., Durst, S., Nguyen, Q., Foli, S., & Gerstlberger, W. (2024). Circular Economy Practices in Manufacturing SMEs: Exploration of Stakeholder Pressure, Managerial Perception, and the Mediating Role of Circular Economy Orientation. Accepted in *Journal of Circular Economy.*

Appendix 5

Publication V

Ahmadov, T., Durst, S. & Gerstlberger, W. (2025). Unveiling success factors for implementing and sustaining circular economy practices in small and medium-sized firms: multi-level perspective. *The Bottom Line*, Vol. 38 No. 1, pp. 71–98. https://doi.org/10.1108/BL-12-2023-0320

Note: The final accepted manuscript version, prior to the transfer of author rights to publishing house, has been incorporated as an appendix in my doctoral thesis.

Curriculum vitae

Personal data

Name:	Tarlan Ahmadov
Date of birth:	05.12.1996
Place of birth:	Baku, Azerbaijan
Citizenship:	Azerbaijan

Contact data

E-mail:	tarlan.ahmadov@taltech.ee

Education

2021–2025	Tallinn University of Technology, PhD
2018–2020	Master of Science (M.Sc.) in Environmental Engineering and Management, Tallinn University of Technology, Estonia
2014–2018	Bachelor of Business Administration (BBA) in Industrial Engineering, Joint program with Siegen University (Germany) and Azerbaijan State Oil and Industry University (Azerbaijan)
2003–2014	School No. 151, Baku, Azerbaijan

Language competence

English	Fluent
Azerbaijani	Native language
Turkish	Fluent

Professional employment

01.04.2024–30.09.2024	Visiting Researcher, Research Institute of Sweden (RISE), Gothenburg, Sweden
01.05.2020–30.01.2021	Research Assistant at Tallinn University of Technology, Tallinn, Estonia
01.06.2019–30.01.2020	Research Trainee at ORTHEX, Helsinki, Finland

Elulookirjeldus

Isikuandmed

Nimi:	Tarlan Ahmadov
Sünniaeg:	05.12.1996
Sünnikoht:	Baku, Aserbaidžaan
Kodakondsus:	Aserbaidžaani

Kontaktandmed

E-post:	tarlan.ahmadov@taltech.ee

Hariduskäik

2021–2025	Tallinna Tehnikaülikool, PhD
2018–2020	Magistrikraad (M.Sc.) keskkonnatehnika ja juhtimise erialal, Tallinna Tehnikaülikool, Eesti
2014–2018	Ärijuhtimise bakalaureusekraad (BBA) tööstustehnika erialal, koostööprogramm Siegeni Ülikooli (Saksamaa) ja Aserbaidžaani Riikliku Nafta- ja Tööstusülikooli (Aserbaidžaan) vahel
2003–2014	Kool nr 151, Baku, Aserbaidžaan

Keelteoskus

Inglise keel	Sujuv
Aserbaidžaani keel	Emakeel
Türgi keel	Sujuv

Teenistuskäik

01.04.2024–30.09.2024	Rootsi uurimisinstituudi (RISE) külalisteadur, Göteborg, Rootsi
01.05.2020–30.01.2021	Teadusassistent Tallinna Tehnikaülikoolis, Tallinn, Eesti
01.06.2019–30.01.2020	Teadustrainee ORTHEX-is, Helsingi, Soome