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Optimizing Sustainable Resource Efficiency: A Fuzzy-Set Qualitative Comparative Analysis of Sustainable Practices in SMEs

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ABSTRACT

This study examines the influence of sustainability practices on resource efficiency in Ghana's small and medium-sized enterprises (SMEs), utilizing a comprehensive framework that integrates environmental and social dimensions, enabling conditions, innovative practices, and technological advancements. Through a survey of 462 manufacturing SMEs, the research uncovers the complex interrelationships between sustainability practices and their impact on resource efficiency. The findings reveal four distinct sustainability pathways: the first underscores the critical importance of environmental dimensions and enabling conditions without robust social dimensions and innovative practices. The second highlights the significance of environmental and enabling conditions, even when technological innovativeness is limited. The third and fourth pathways emphasize the pivotal role of social dimensions and technological innovation, with innovative practices as supportive elements. Additionally, two typologies emerge, illustrating the integration of environmental and social dimensions with enabling conditions and the synergy between technological innovation, social dimensions, and innovative practices. This research advances the discourse on sustainability within SMEs, emphasizing the necessity for reduced resource consumption, conservation, efficient production, circular economy principles, and waste minimization. The findings suggest that achieving SDG 8.4 by 2030, which targets global resource efficiency, hinges on adopting these sustainable pathways with emphasis on Ghanaian SMEs. This study provides a deeper understanding of sustainability practices among developing economy SMEs, shedding light on the intricate dynamics that enhance resource management. It offers critical insights for policymakers and practitioners seeking to promote sustainability in local SMEs, particularly in Ghana, advocating for a holistic approach that considers the multifaceted nature of sustainability.

1 | Introduction

Small and medium-sized enterprises (SMEs) are increasingly becoming pivotal to economic development across both developed and developing nations. According to a recent World Bank report (accessed on May 2, 2023), formal SMEs contribute up to 40% of gross domestic product (GDP) in most emerging markets, and they are projected to generate 600 million jobs by 2030.

These enterprises are crucial not only for job creation but also for fostering sustainable economic development, particularly in regions where they play a dominant role in both formal and informal employment sectors (Westman, Moores, and Burch 2021).

Despite the undeniable contributions of SMEs, their long-term sustainability hinges on the adoption of sustainable practices. While large corporations have progressively integrated

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sustainability into their core strategies, SMEs often lag in this area. The reasons for this lag include limited resources, lack of awareness, and insufficient support systems. As highlighted by Madrid-Guijarro and Duréndez (2024), the concept and implementation of sustainability within SMEs remain underexplored globally, creating a significant gap in both academic and practical knowledge. Unlike larger firms, which employ multifaceted sustainability drivers to meet regulatory demands and achieve long-term objectives, SMEs often struggle to integrate comprehensive sustainability strategies. Environmental, social, and economic dimensions are critical components of sustainability, and these are further supported by innovative practices, technological advancements, and enabling conditions (Asongu and Odhiambo 2020; Chowdhury and Shumon 2020; Madrid-Guijarro and Duréndez 2024).

From a systems thinking perspective, sustainability within SMEs can be viewed as a configuration of business practices that simultaneously promote resource efficiency and profitability. These practices align with key dimensions—environmental, social, technological, and innovative—that are essential for achieving sustainable development goals (SDGs) (Demirkan, Srinivasan, and Nand 2022; Adam and Alarifi 2021). However, the extent to which SMEs can effectively integrate these dimensions to optimize resource efficiency remains an area requiring further exploration.

Given this context, there is a critical need for SMEs to adopt sustainable practices that enhance resource efficiency. Empirical evidence suggests that a holistic approach, considering both environmental and social sustainability alongside technological innovation and enabling conditions, can lead to optimal resource utilization (Hariyani et al. 2023; Arias, Feijoo, and Moreira 2023). Although large firms have increasingly adopted such approaches, the full benefits for SMEs are not yet fully realized or understood. This presents a significant challenge as well as an opportunity, particularly in light of SDG Goal 8.4, which emphasizes the importance of improving global resource efficiency to support inclusive and sustainable economic growth. Inefficient resource use, particularly of raw materials, poses a substantial barrier to achieving these goals, making it imperative for SMEs to identify and adopt key practices that enhance resource efficiency.

This study addresses a critical gap in the literature by mapping and examining the sustainability practices of SMEs concerning resource efficiency. Employing a systems thinking approach combined with qualitative comparative analysis (QCA), this research explores how various factors, including environmental and social dimensions, technological innovation, and enabling conditions, interact to influence resource efficiency. QCA's embrace of equifinality allows the identification of multiple pathways leading to the same outcome, offering a nuanced understanding of the core and peripheral conditions that contribute to sustainable resource management in SMEs. The objective is to uncover and articulate the pathways through which SMEs can optimize resource efficiency, thereby advancing both their sustainability practices and the broader goal of global resource efficiency. Consistent with the study objective, the fuzzy-set QCA (fsQCA) methodology considers variables as independent in a configurational investigation, identifying sufficient pathways

for achieving a specific outcome (dependent variable). Unlike regression analysis, which often examines factors in isolation, fsQCA captures the combined effects of multiple variables. This approach is particularly useful in understanding SME sustainability practices towards resource efficiency, as single-variable effects may not provide a complete explanation.

Theoretically, fsQCA employs a configurational model to demonstrate how multiple factors interact to produce an outcome. It highlights that the influence of some factors depends on the presence or absence of others. Additionally, configurational theories are rooted in the principle of causal asymmetry, where conditions leading to the presence of an outcome can differ from those leading to its absence. This nuanced perspective is crucial for uncovering the complex dynamics driving sustainable practices for resource efficiency.

2 | Literature Review

2.1 | Sustainability Practices

Sustainability development seeks to create a balanced ecosystem that integrates social, economic, and environmental considerations, essential for the long-term viability and resilience of firms. Once regarded as a niche concept, sustainability practices have now become central to business operations globally. Firms are increasingly adopting these practices to drive innovation, enhance competitiveness, and create value (Das, Kundu, and Bhattacharya 2020; Chege and Wang 2020). The significant impact of sustainable practices on firm policies and operations is well-documented, particularly as they align with the United Nations SDGs (Jagani, Marsillac, and Hong 2024; Permatasari and Gunawan 2023). For instance, Jagani, Marsillac, and Hong (2024) found that a firm's commitment to sustainability significantly influences brand attitudes and customer loyalty. Similarly, Kitsis and Chen (2021) highlight the critical role of sustainability practices in ensuring strategic and operational competence within supply chains.

Ngo et al. (2024) surmise that internal sustainability practices, such as green supply chain management and pollution prevention, are crucial for reducing environmental risks and costs, ultimately generating wealth for firms. External sustainability practices, including green product development, reassure stakeholders of a firm's legitimacy and goodwill (Sharma et al. 2024; Wang, Heugens, and Wijen 2024). By integrating both internal and external sustainability practices, firms can demonstrate a comprehensive commitment to sustainable development, fostering positive transformations across their value chains (Ngo et al. 2024). Robust internal sustainability practices, in particular, improve resource efficiency and waste reduction within organizations.

The emergence of green entrepreneurship, as discussed by Schaper (2010), marked a paradigm shift towards sustainability practices within entrepreneurial ventures. Sustainable business strategies contribute to environmental preservation and present lucrative revenue-generating opportunities. For example, in the fashion sector, entrepreneurial ventures are exploring innovative initiatives that prioritize sustainability as a

distinctive quality. Adding the Social Dimension of the Circular Economy et al. (2024) advocate for a more data-driven approach to uncover patterns and forces that drive creative and sustainable business strategies in this industry. In sustainable manufacturing enterprises, integrating sustainable manufacturing capabilities and practices is shown to improve performance (Kannan, Gholipour, and Bai 2023). Narayanan and Das (2022) further underscore the importance of marketing and brand innovation, product quality, and strategic planning and implementation in achieving efficient, sustainable development.

This synthesis of the literature underscores the multifaceted nature of sustainability practices within the global economic landscape, emphasizing the critical role of innovation, entrepreneurship, and strategic management in driving sustainable development. However, while a holistic approach to sustainability practices is essential for firms of all sizes, the extent to which SMEs excel in these practices remains unclear. Basit et al. (2024) identified several obstacles hindering sustainability practices among SMEs, including a lack of expertise and high initial capital costs. To address these barriers, Journeault, Perron, and Vallières (2021) propose a collaborative approach involving government intervention to create enabling conditions for stakeholders to enhance sustainability practices within SMEs.

2.2 | Drivers of Sustainable Practices

An increasing number of sustainability practices and theories have emerged to understand the underlying factors driving sustainability. The application of the triple bottom line (TBL) framework, which encompasses environmental dimensions, social dimensions, and economic dimensions, has become a fundamental approach to analyzing sustainability practices. Over time, due to the multidimensional nature of sustainability, considerable factors have been aligned with these three dimensions to examine sustainability objectives effectively (Jain and Mohapatra 2023; Eisenmenger et al. 2020; Sala 2019). Effective sustainability practices therefore are premised on key drivers to address the complexity of sustainable measures. This study identifies five key drivers, thus environmental, social, technological innovativeness, facilitating conditions, and innovative practices, which collectively support sustainable practices towards resource efficiency. The interplay of these drivers raises the urgency of emerging sustainable practices and their implications for sustainability transformation (Voulvoulis et al. 2022). Existing studies have pushed for firms concentrating on the environment and social dimensions of TBL, as these significantly impact resource efficiency within the emerging circular economy (Kristensen and Mosgaard 2020; Hristov et al. 2021).

2.2.1 | Environmental Dimensions

Awareness of environmental considerations is crucial in firms' strategic planning for sustainability (Bhattacharyya 2019). The correlation between environmental dimensions and various initiatives has been shown to improve firm performance. For instance, Trianni et al. (2019) posited that linking sustainability adoption to improve manufacturing processes should emphasize environmental and social dimensions. Similarly, Chege and

Wang (2020) revealed that firms tend to maximize financial outcomes when they dedicate environmental consciousness to community engagement. These insights suggest that manufacturing SMEs can significantly enhance resource efficiency by adopting environmental responsiveness. Effective sustainable resource management requires awareness of environmental innovations such as waste control strategies, circular economy thinking, smart production processes, and adherence to environmental regulations. Cainelli, D'Amato, and Mazzanti (2020) emphasized that achieving resource efficiency involves continuous efforts to "reduce materials use per unit of output, recycle waste, water, or materials and improve recycling of post-use." Theoretically, high environmental considerations lead to improved resource efficiency, highlighting the relationship between environmental dimensions and resource efficiency (Krishnan et al. 2020; Javaid et al. 2022).

2.2.2 | Social Dimensions

Broadly, social dimensions of sustainability encompass enablers such as safety, diversity, equity, governance, labor rights, and human health (Rostamnezhad and Thaheem 2022). Social sustainability promotes societal well-being, particularly for those susceptible to social justice and environmental issues. For many manufacturing firms focused on social sustainability, integrating specific indicators should result in products that enhance societal well-being (Ajmal et al. 2018). The holistic scope of social dimensions indicates that firms' life cycles are intertwined with society and the natural environment. Manufacturing SMEs should approach social dimensions activities within a social system that integrate stakeholders' perspectives on the overall resource usage. Achieving resource efficiency through social dimensions activities involves "reducing material inputs and substituting primary resources" to mitigate negative environmental impacts (Mayer et al. 2019; Zink and Geyer 2019; Mies and Gold 2021). Accordingly, Eisenmenger et al. (2020) highlight that SMEs in the manufacturing sector should carefully monitor activities to ensure absolute resource management, as outlined in SDGs 8. Prioritizing social dimensions in manufacturing processes improves resource efficiency and establishes a clear relationship between social sustainability dimensions and resource efficiency.

2.2.3 | Technological Innovation

Accelerating sustainability goals for sustainable business processes requires the robust deployment of digital technologies. Empirical studies have extensively documented the transformation of business processes and efficiencies through digital technology deployment (Felsberger et al. 2022; Raut et al. 2019). For instance, Raut et al. (2019) highlighted the impact of big data analytics capabilities on sustainable business practices. More recently, smart manufacturing applications and platforms have revolutionized sustainable manufacturing processes (Kannan, Gholipour, and Bai 2023). Consequently, SMEs are increasingly considering key smart technologies aiding the improvement of sustainable practices. Given the significant impact of technological innovation, Chege and Wang (2020) identified the use of technology to improve both products and processes assembled

within the manufacturing enterprises, thereby enhancing environmental and social sustainability. In practice, manufacturing SMEs must leverage emerging technologies to develop new and enhanced production processes aimed at optimizing resource utilization. Integrating technological innovations such as digital twins, automation, additive manufacturing, Internet of Things (IoTs), and emerging sustainable manufacturing technologies significantly supports sustainable practices. The integration, in turn, enhances resource efficiency in manufacturing processes.

2.2.4 | Facilitating Conditions

For most SMEs, the adoption of sustainable practices is incentivized by the presence of enabling conditions within their operational ecosystem. Facilitating conditions necessitate that regulatory agencies supporting sustainability engagements provide comprehensive guidance for green initiatives. SMEs often require regular stakeholder engagement on new green manufacturing practices and incentives for adopting such processes. For example, Yong et al. (2020) observed that initiatives such as green training, green rewards, and green performance assessment raise awareness and incentivize actors to adopt positive attitudes towards sustainability goals. Journeault, Perron, and Vallières (2021) further emphasized that SMEs ability to fully integrate sustainability goals requires collaboration with regulatory agencies, which support through training, coordination, and funding for sustainability practices. Governments must also play a crucial role in facilitating and developing stakeholder networks to promote the adoption of sustainable manufacturing practices among SMEs. The impact of the facilitation condition on green practices, through collaboration with agencies on green manufacturing practices, enhances resource efficiency and promotes sustainable development.

2.2.5 | Innovative Practices

Embracing innovative practices towards sustainability is a continuous effort involving the deployment and implementation of new methods, technologies, and strategies to achieve targeted environmental and social well-being objectives. Innovative practices are significantly linked to the sustainability of enterprises in contemporary and competitive open markets (Adam and Alarifi 2021). These practices span strategic, tactical, and operational levels of decision-making and actionable processes within enterprises (Kneipp et al. 2019; Battisti et al. 2020). Over time, substantial investment in innovations such as developing new models, integrating skills among functional units, green manufacturing, raw material management, and cost reduction significantly contribute to sustainable practices, even with scarce resources (Loučanová et al. 2023; Demirkan, Srinivasan, and Nand 2022; Battisti et al. 2020). Encouraging SMEs to engage in sustainable frugal innovation leads to the satisfaction of resource efficiencies (Endres, Bican, and Wöllner 2022; Albert 2022). Overall, the integration of innovative practices within SMEs not only enhances their competitiveness but also ensures the achievement of sustainability goals. The holistic approach to innovation enables firms to adapt to changing market conditions and regulatory environments while promoting sustainable development and resource efficiency. Embracing innovative practices necessitates the implementation of green innovation initiatives in the short term to enhance

resource management among SMEs. Castellano et al. (2022) emphasize the importance of facilitating conditions to support SMEs that lack the capacity to independently develop green innovation initiatives, ensuring their future sustainability.

2.3 | Configural Paths of Sustainability Practices and Resource Efficiency

Navigating the complex web of sustainability challenges while maintaining resource efficiency is crucial for the long-term viability of firms. Researchers and scientists are faced with the formidable task of establishing sustainable product and service models that balance economic and resource imperatives with environmental stewardship (Jauhar et al. 2021). An integral part of sustainability practices, particularly through SDG 8.4, is the improvement of resource efficiency in production. Achieving this goal requires a comprehensive consideration of sustainability dimensions that are key to resource efficiency. Rather than accessing these dimensions independently, a system thinking approach advocates for integrating these dimensions, marking a paradigm shift towards a holistic perspective. Achieving SDG 8.4 necessitates a combinatorial approach to sustainability practices, providing a robust framework for manufacturing processes. The study proposed a configural outlook that links the five sustainable dimensions—environmental, social, technological innovation, facilitating conditions, and innovative practices—to resource efficiency. The system thinking and configural approach offers to understand the pathways for addressing resource efficiency through various sustainability considerations among manufacturing SMEs. Figure 1 presents the configural linkage between the five sustainability practices that can be applied to achieve resource efficiency. The integrative model underscores the importance of a multidimensional strategy in fostering sustainable development and resource optimization in the manufacturing sector. By adopting this approach, SMEs can better navigate the complexities of sustainable practices and resource management, ultimately enhancing their sustainability and long-term success. The theoretical framework provides a comprehensive approach to promoting sustainable practices among SMEs in Ghana. It emphasizes government-led incentives, tailored environmental regulations, and leveraging digital tools to enhance resource efficiency. Collaboration is encouraged through partnerships between SMEs, government agencies, and industry associations, with a focus on knowledge-sharing and mentorship. Policies support green product development and sustainable supply chains while addressing challenges such as limited access to finance and technical expertise. Networking opportunities connect SMEs with stakeholders, fostering collaboration and investment for an inclusive and scalable transition to a green economy.

2.4 | Summary of Research Gaps

The literature review identifies several research gaps that warrant further investigation. Firstly, while sustainability practices have been widely explored, the specific application and effectiveness of these practices within SMEs, particularly in the manufacturing sector, remain underexplored. The literature emphasizes the importance of both internal and external sustainability practices, yet there is limited understanding of how SMEs navigate these practices compared with larger enterprises (Sharma et al. 2024; Wang

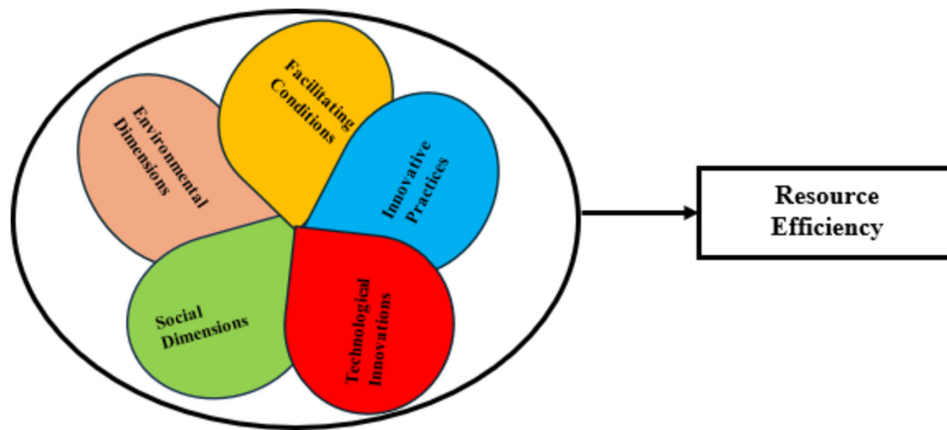


FIGURE 1 | Configurational model.

et al. 2024). The challenges SMEs face, such as limited expertise and high capital costs, highlight a need for more focused studies on the unique barriers and opportunities for sustainable development within smaller firms (Ngo et al. 2024).

Secondly, the review underscores the multidimensional nature of sustainability, particularly through the lens of the TBL framework, which includes environmental, social, and economic dimensions. Despite the growing body of research on the drivers of sustainability, there is a notable gap in the literature regarding the integration of these dimensions, particularly in the context of SMEs. Existing studies primarily focus on individual drivers, such as environmental considerations or technological innovation, without adequately addressing how these drivers interact and influence each other within the SME context (Passaro et al. 2023). This gap points to the need for research that adopts a systems thinking approach, examining how various sustainability drivers collectively contribute to resource efficiency and overall sustainability outcomes in SMEs.

Lastly, the review identifies a gap in the exploration of configurational pathways that link sustainability practices to resource efficiency (Khizar et al. 2024). While the literature acknowledges the importance of a holistic approach to sustainability, there is limited empirical evidence on how different sustainability dimensions can be integrated to form effective pathways for resource efficiency (Wang, Li, and Razzaq 2023; Lutfi et al. 2024), especially in SMEs. The proposed configurational outlook, which links environmental, social, technological, and innovative practices, offers a promising framework but lacks empirical validation. Further research is needed to explore these configurational pathways in different contexts, particularly in resource-constrained environments typical of SMEs, to better understand how they can be leveraged to achieve SDGs.

3 | Methodology

3.1 | Research Design and Sampling

To comprehensively address the study's objectives, a mixed-methods approach was adopted, combining a survey methodology with an extensive literature review. The survey methodology

involved the distribution of questionnaires, while the literature review focused on examining sustainability practices in depth.

The study targeted manufacturing SMEs located in Ghana, specifically within the Greater Accra Region. This region was selected due to its diverse and concentrated SME activities. The study population included owners, managers, and other senior officials in the manufacturing sector. A purposive non-probability sampling technique is employed to ensure the inclusion of participants who possess in-depth knowledge relevant to the study (Kumar et al. 2023). This sampling method was chosen to specifically target individuals directly involved in strategic sustainability practices within their organizations. A preliminary pilot study was conducted to ensure that participants had a clear understanding of sustainability concepts, resource efficiency, and the implications of the SDGs on sustainability practices.

A total of 102 manufacturing SMEs were surveyed in the capital city, involving 500 participants comprising owners, managers, and supervisors. Out of the 500 questionnaires distributed, 462 were fully completed, yielding a response rate of 92%.

3.2 | Data Collection Method and Analysis

The data for this study were collected using a mixed-method approach involving online questionnaires administered through Google Forms and in-person interactions. The questionnaire was structured into two sections: the first section gathered demographic information, including the type of manufacturing SMEs, the number of employees, and the nature of the products produced. The second section assessed sustainability parameters related to resource efficiency using a 5-point Likert scale, ranging from "strongly agree" to "strongly disagree," to capture respondents' levels of agreement. Six key constructs were evaluated: facilitating conditions (FAC), technological innovativeness (TECIN), social dimensions (SOCD), environmental dimensions (END), innovative practices (INOP), and resource efficiency (RESEF) as the outcome variable.

The data analysis was conducted using partial least squares structural equation modeling (PLS-SEM) to assess the reliability

and validity of the constructs, ensuring the robustness of the proposed model. This analysis provided an initial examination of the relationships among the constructs. Subsequently, fsQCA was employed using R software to further analyze the data. FsQCA was selected due to its ability to handle the non-binary nature of the data and to offer a detailed understanding of the complex relationships between the various factors (Emami, Vakil Alroaia, and Zargar 2023; Dogra et al. 2023). The fsQCA process involved data calibration, construction of a truth table, and minimization of the truth table to develop membership set scores ranging from “0” to “1,” thereby capturing the intricacies of the data.

This methodological approach allowed for a nuanced exploration of the interrelationships among the constructs and their impact on SMEs' resource efficiency. By integrating PLS-SEM and fsQCA, the study provided comprehensive insights into the pathways through which sustainability practices influence resource efficiency, offering valuable implications for enhancing the agility and sustainability of manufacturing SMEs.

3.3 | Data Analysis and Results

The data analysis followed a three-stage approach: demographic analysis, confirmatory factor analysis (CFA), and fsQCA analysis, each aligned with the research objectives. The demographic analysis provided a comprehensive overview of the workforce and types of manufacturing businesses represented in the study, offering insights into the operational context of these SMEs. Table 1 summarizes the sample statistics, detailing key characteristics such as SME size and the types of manufacturing products produced. SMEs were categorized by employee count, showing that most Ghanaian SMEs are medium enterprises with 30–99 employees, followed by small enterprises with 6–29 employees, and micro-enterprises with 1–5 employees. This classification highlights the varied scale of manufacturing activities within the SME sector in Ghana.

3.4 | CFA and Reliability Testing

To ensure the robustness and validity of the study's constructs, CFA was performed using PLS-SEM. This analysis aimed to assess the reliability and significance of the variables, thereby validating the constructs utilized in the research (Dogra et al. 2023). The CFA evaluated key metrics, including path coefficients, Cronbach's alpha, average variance extracted (AVE), composite reliability (CR), heterotrait–monotrait ratio (HTMT), latent correlations, and overall model fit.

The results, presented in Table 2, indicate that all constructs met the established benchmarks: path coefficients were equal to or greater than 0.70, Cronbach's alpha values were ≥ 0.70 , AVE values were ≥ 0.50 , and CR values were ≥ 0.50 (Henseler, Ringle, and Sarstedt 2015; Hair et al. 2022). These results confirm the internal consistency and reliability of the measurement scales. Discriminant validity was also confirmed through HTMT ratios in Table 3, affirming the distinctiveness of each construct (Henseler, Ringle, and Sarstedt 2015; Ringle et al. 2023).

TABLE 1 | Sample statistics.

	Frequency	Percentage
Number of workforce		
Number		
1–5	71	15.37
6–29	137	29.65
30–99	254	54.98
Types of manufacturing business		
Products		
Food and beverages	213	46.10
Leather, wood, and related products	83	17.97
Chemical	28	6.06
Electronic and computer devices	36	7.79
Rubber, plastics, and non-metallic mineral products	102	22.08
Total	462	100

Table 4 further details the significance tests for the path coefficients and the overall variance explained in the outcome variable. The analysis revealed that all constructs were statistically significant predictors of resource efficiency, with an R^2 value of 54%, indicating that the model explains 54% of the variance in resource efficiency. Additionally, the normed fit index (NFI) was calculated at 0.81, suggesting an acceptable model fit.

Overall, the CFA results provide strong evidence that the variables related to sustainability practices and their impact on resource efficiency are reliable and valid, offering robust support for the proposed configurational model.

3.5 | fsQCA and Sustainable Pathways

To further investigate the sustainable pathways that lead to enhanced resource efficiency among SMEs, fsQCA was utilized. FsQCA was selected due to its strength in handling nuanced, non-binary data and its capacity to uncover complex causal configurations that drive the desired outcomes (Dogra et al. 2023). The analysis was conducted in two main stages: data calibration and truth table analysis.

Stage 1. Data Calibration

In the first stage, raw Likert scale responses were transformed into fuzzy set membership scores ranging from 0 to 1. This calibration process involved converting the responses of each variable into fuzzy values, thereby reducing potential biases associated with subjective responses. This transformation enabled a more precise measurement of the degree to which each

TABLE 2 | Constructs validity, reliability, and collinearity test.

Constructs	Items	Loadings	VIF	CA	CR	AVE
Environmental dimension	END1	0.83	1.93	0.84	0.88	0.61
	END2	0.80	1.82			
	END3	0.77	1.71			
	END4	0.79	1.72			
	END5	0.71	1.46			
Facilitating conditions	FAC1	0.80	1.97	0.85	0.90	0.63
	FAC2	0.80	2.03			
	FAC3	0.76	1.65			
	FAC4	0.85	2.20			
	FAC5	0.77	1.68			
Social dimensions	SOCD1	0.77	1.98	0.87	0.90	0.65
	SOCD2	0.82	2.14			
	SOCD3	0.81	1.90			
	SOCD4	0.81	1.92			
	SOCD5	0.87	2.01			
Technological innovativeness	TECIN1	0.85	2.77	0.91	0.93	0.69
	TECIN2	0.86	2.96			
	TECIN3	0.83	2.33			
	TECIN4	0.80	2.74			
	TECIN5	0.82	2.97			
	TECIN6	0.83	2.25			
Innovative practices	INOP1	0.77	1.74	0.84	0.89	0.61
	INOP2	0.78	1.78			
	INOP3	0.79	1.79			
	INOP4	0.85	2.17			
	INOP5	0.81	1.56			
Resource efficiency	RESEF1	0.73	1.59	0.86	0.90	0.64
	RESEF2	0.83	2.82			
	RESEF3	0.85	2.82			
	RESEF4	0.81	2.23			
	RESEF5	0.78	1.98			

case belongs to a particular set (Rasoolimanesh, Valaei, and Rezaei 2023).

Stage 2. Truth Table Construction and Minimization

The second stage involved constructing a truth table using the Quine–McCluskey algorithm to identify various causal pathways leading to resource efficiency. Both parsimonious and intermediate solutions were examined, following fsQCA guidelines, to identify logical combinations of causal

conditions that influence resource efficiency (Rasoolimanesh, Valaei, and Rezaei 2023). This approach aligns with fsQCA literature by embracing the concept of equifinality, which recognizes that multiple pathways can lead to the same outcome (Dogra et al. 2023).

The fsQCA analysis revealed four distinct sustainable pathways contributing to resource efficiency among SMEs, as presented in Table 5. The reliability and empirical relevance of these pathways were validated by an overall consistency score of 0.901 and

TABLE 3 | Heterotrait–monotrait ratio matrix.

Constructs	END	FAC	TECIN	INOP	SOCD	RESEF
END						
FAC	0.82					
TECIN	0.67	0.85				
INOP	0.72	0.83	0.71			
SOCD	0.81	0.74	0.64	0.69		
RESEF	0.59	0.80	0.75	0.66	0.61	

TABLE 4 | Path significance test.

Paths	Original sample (O)	Standard deviation (STDEV)	T statistics (O/STDEV)	p values
END → RESEF	0.26	0.05	5.75	0.00*
FAC → RESEF	0.38	0.06	6.78	0.00*
TECIN → RESEF	0.33	0.05	6.78	0.00*
INOP → RESEF	0.16	0.05	3.23	0.00*
SOCD → RESEF	0.18	0.05	3.52	0.00*

Note: $R^2 = 0.54$, normed fit index (NFI) = 0.81.

*p-value < 0.05.

TABLE 5 | Truth table and sustainable paths.

Constructs	Sustainable paths			
	1	2	3	4
Environmental dimensions	●	●	●	∅
Social dimension	∅	●	●	●
Facilitating condition	●	●		
Technological innovativeness		∅	●	●
Innovative practices	∅		●	●
Raw coverage	0.813	0.780	0.810	0.736
Unique coverage	0.029	0.018	0.266	0.015
Consistency	0.834	0.860	0.813	0.914
Overall solution coverage		0.876		
Overall consistency coverage		0.901		
Overall PRI		0.951		

Note: Black circles “●” indicate the presence of a condition, and circles with “∅” indicate its absence or low condition. Large circles depict core conditions, and small circles represent peripheral conditions. Blank spaces indicate that the condition is redundant in a given path to achieve an outcome (Pappas and Woodside 2021; Thomann and Maggetti 2020; Fiss 2011).

a solution coverage of 0.876. Moreover, the proportional reduction in inconsistency (PRI) was 0.951, confirming the acceptability and robustness of the identified pathways (Nikou et al. 2024).

These findings underscore the diverse ways in which SMEs can achieve resource efficiency, highlighting the importance of tailored strategies that account for the unique conditions and capabilities of individual firms.

3.6 | Sustainable Pathways Identified

3.6.1 | Sustainable Pathway 1

This pathway indicates that strong environmental dimensions serve as a core condition, supported by social dimensions and facilitating conditions as peripheral factors. This combination effectively enhances resource efficiency.

3.6.2 | Sustainable Pathway 2

This pathway demonstrates that high environmental dimensions coupled with robust facilitating conditions are essential for achieving resource efficiency. Even when social dimensions and technological innovativeness are low, the presence of strong environmental and facilitating conditions can sustain resource efficiency.

3.6.3 | Sustainable Pathway 3

Here, the presence of environmental dimensions, social dimensions, and technological innovativeness as core conditions, along with innovative practices as a peripheral condition, supports resource efficiency.

3.6.4 | Sustainable Pathway 4

This pathway reveals that even with low environmental dimensions, the integration of social dimensions with technological innovativeness and innovative practices as core conditions can lead to improved resource efficiency.

These findings highlight the significance of adopting a holistic and integrated approach to sustainability within manufacturing SMEs. The identified pathways illustrate how different combinations of environmental, social, technological, and innovative practices can collectively drive resource efficiency. Such insights are instrumental for policymakers and business leaders seeking to promote sustainable development in the SME sector, as they underscore the necessity of tailored sustainability strategies that leverage multiple dimensions of sustainability.

The results from the PLS-SEM and fsQCA analyses collectively demonstrate that sustainability practices are reliably and significantly associated with resource efficiency in SMEs. The multiple sustainable pathways identified through fsQCA provide a nuanced understanding of how various factors can be configured to achieve optimal resource management, reinforcing the importance of flexibility and adaptability in sustainability strategies.

4 | Discussion of Findings

In alignment with the SDGs and the critical need for optimal resource utilization among firms, this study explores the sustainability practices of SMEs and their long-term implications for the future job market. The primary objective was to elucidate how the interplay of various sustainable constructs collectively drives resource efficiency in SMEs. While much of the existing literature has focused on sustainability practices in large firms, often analyzing sustainability variables or dimensions in isolation, this study specifically examined the combined roles of environmental dimensions, social dimensions, facilitating conditions, technological innovativeness, and innovative practices in achieving resource efficiency within SMEs. By doing so, it extends the discourse on the role of SMEs in advancing sustainable practices, particularly in resource-constrained settings.

The empirical results, supported by reliability measures and hypothesis testing, confirmed the significance of all the constructs considered for evaluating sustainability practices towards resource efficiency. The fsQCA analyses uncovered four distinct pathways through which SMEs can achieve resource efficiency, highlighting the critical role of environmental dimensions as core conditions in three out of the four identified configurations. This suggests that SMEs with strong environmental dimensions can enhance resource efficiency even in the absence of robust social dimensions, provided there is adequate support from regulatory bodies on resource management. This finding resonates with the work of Journeault, Perron, and Vallières (2021), who emphasized the importance of collaborative stakeholder engagement in integrating environmental concerns into sustainability practices, thereby improving resource management. The first sustainable pathway identified in this study suggests that SMEs lacking in technological innovativeness and innovative

practices can still achieve resource efficiency with the support of local stakeholders (Dal Maso et al. 2018; Shubham, Charan, and Murty 2018).

The results further indicate that prioritizing environmental dimensions as core, alongside social dimensions and governmental support as peripheral conditions, can significantly reduce resource wastage during manufacturing processes, as highlighted in the second sustainable pathway. This pathway underscores the pivotal role of environmental sustainability, social sustainability, and enabling conditions in resource management, even with minimal technological application (Lehmann et al. 2022). Additionally, the third pathway reveals that combining environmental dimensions, social dimensions, and technological innovativeness as core conditions, along with innovative practices, fosters resource efficiency. Although SMEs may lack the extensive capabilities of larger firms, integrating sustainable innovative practices into operational processes, business models, and ethical frameworks can significantly enhance resource efficiency. Kneipp et al. (2019) and Castellano et al. (2022) have similarly identified that embedding innovative sustainable practices within other sustainability dimensions positively impacts resource efficiency. This finding underscores the critical importance of sustainable innovative engagements for the survival and competitiveness of manufacturing SMEs (Adam and Alarifi 2021; Loučanová et al. 2023). For instance, Loučanová et al. (2023) observed that frugal innovations—focusing on cost minimization, adherence to standards and laws, and optimization of manufacturing inputs—can be a key driver of resource efficiency among SMEs. The study suggests that resource efficiency can be achieved through the combinatorial effects of technological innovativeness and innovative practices as core conditions, with social dimensions serving as peripheral conditions, even in scenarios where environmental dimensions are less emphasized.

The analysis identified two key topologies of configurational paths that enhance resource efficiency. The first topology, which combines Pathways 1 and 2, integrates environmental dimensions as core, with social dimensions and facilitating conditions as peripheral, even under conditions of low technological innovativeness (Hristov et al. 2021; Felsberger et al. 2022). The second topology considers the combinatorial effects of technological innovativeness and social dimensions as core conditions, with innovative practices as peripheral conditions, in contexts where environmental sustainability is not the primary focus. Nara et al. (2021) argued that the integration of Industry 4.0 technologies into sustainability practices contributes to improvements in green sustainability, reflecting the importance of digital innovativeness in resource management. This is consistent with the findings of Ambaye et al. (2023), who highlighted the significance of technology integration with sustainable strategies to minimize waste in manufacturing processes.

Finally, the study's outcomes underscore the support for fsQCA analysis in revealing the combinatorial effects of different sustainable paths to resource efficiency in SMEs. This suggests that multiple sustainability practices can interact to enhance overall resource efficiency, providing valuable insights for SMEs seeking to improve their sustainable strategies. The identification and implications of Topologies 1 and 2 signal a significant paradigm

shift in sustainability strategies for SMEs, as emphasized by Voulvoulis et al. (2022). For instance, Voulvoulis et al. (2022) stress the importance of adopting a systems thinking approach to integrate key sustainable dimensions and goals, thereby facilitating the transition towards achieving SDG objectives. These findings are consistent with those of the present study, which also highlights the critical role of synergies in sustainability strategies as guiding principles for advancing future sustainability methodologies (Mariyate and Bera 2023; Cheng et al. 2024).

This study contributes to the ongoing discourse on sustainability practices among SMEs by elucidating the nuanced interactions between different paths that enhance resource management. Beyond merely identifying sustainable pathways, the findings prioritize strategies to reduce resource consumption, conserve resources, enhance production efficiency, implement circular economy principles, and minimize waste. Ultimately, the results suggest that achieving SDG 8.4 by 2030, which targets global resource efficiency in consumption and production among SMEs in Ghana, hinges on the adoption and sustained implementation of these identified pathways.

5 | Implications and Conclusion of Study

5.1 | Theoretical Implications

This study significantly advances theoretical discourse in sustainability research by employing a systems thinking approach, offering a transformative perspective on the interconnected dynamics influencing resource efficiency in SMEs. The integration of multiple constructs and dimensions, rather than examining them in isolation, provides a robust analytical framework that enriches our understanding of sustainability practices, especially within the manufacturing sector. These implications contribute to a more nuanced, holistic view of sustainable development, addressing critical gaps in existing scholarship.

5.1.1 | Advancing Systems Thinking in Sustainability Research

The adoption of systems thinking challenges traditional reductionist methodologies by emphasizing the interconnectedness and interplay of sustainability dimensions. This study underscores the necessity of examining environmental, social, technological, and policy-related factors as an integrated whole, offering a holistic lens to analyze sustainability practices. By utilizing fsQCA, this research introduces a paradigm shift from linear, single-variable analysis to a configurational perspective, highlighting the synergistic effects of multiple factors. This innovative approach pushes theoretical boundaries, promoting a deeper understanding of the complexity inherent in sustainability transitions.

5.1.2 | Strengthening Configurational Theories in Sustainability

5.1.2.1 | Unveiling Configurational Pathways. The study identifies four distinct sustainable pathways and two

critical typologies that SMEs can adopt to achieve resource efficiency. These findings validate causal asymmetry, emphasizing that sustainability outcomes are not achieved through uniform conditions but rather through diverse, context-specific combinations of drivers. This enriches theoretical discussions on how multi-factorial configurations produce sustainable outcomes.

5.1.2.2 | Interplay of Sustainability Dimensions. By integrating environmental, social, and technological dimensions with enabling conditions, this research bridges a significant gap in the literature, which often treats these dimensions in silos. The study elucidates how these factors converge to produce effective sustainability outcomes, offering a more comprehensive understanding of their interdependencies and collective impact.

5.1.3 | Expanding SME-Centric Sustainability Frameworks

This study addresses the underrepresentation of SMEs in sustainability discourse, presenting them as pivotal actors in resource efficiency and sustainable development. It emphasizes the foundational role of environmental considerations while showcasing the indispensability of facilitating conditions such as policy support, innovation access, and collaborative networks. These findings extend the scope of existing frameworks by providing actionable insights tailored to the unique challenges and opportunities of SMEs in the manufacturing sector, thereby enhancing their theoretical relevance and practical utility.

5.1.4 | Reframing Sustainability Measurement

The application of fsQCA in this study redefines how sustainability is conceptualized and measured. Instead of relying on isolated metrics, this approach focuses on dynamic interactions and configurational pathways, providing a more sophisticated lens for understanding complex sustainability phenomena. This methodological advancement sets a new standard for future research, equipping scholars with tools to explore and theorize about sustainability in its multifaceted entirety.

5.2 | Policy Implications

The findings of this study highlight the critical need for policymakers to adopt a systems thinking approach to effectively support SMEs in achieving resource efficiency. This approach necessitates the development of integrative policies that address the interconnected dimensions of sustainability, thus, environmental, social, and technological, while aligning with the objectives of the SDGs. By recognizing the multifaceted nature of resource efficiency, policymakers can craft strategies that not only target sustainability but also enhance the operational resilience of SMEs.

A key recommendation is the provision of targeted incentives designed to encourage SMEs to adopt sustainable practices. Tailored support mechanisms such as tax benefits, grants, and subsidized loans can enable SMEs to invest in

environmentally friendly technologies and smart manufacturing systems, bridging the gap between sustainability goals and technological capabilities. This financial encouragement can play a transformative role in making sustainable practices more accessible to resource-constrained businesses. Additionally, capacity building emerges as a vital pillar in promoting sustainable development. Policymakers should focus on fostering the adoption of digital tools and innovative solutions through training programs and platforms for knowledge sharing. These initiatives can equip SMEs with the necessary skills and resources to enhance their operational efficiency and sustainability performance.

The study also underscores the importance of designing holistic policy frameworks that integrate environmental and social considerations alongside economic objectives. Utilizing methodologies like fsQCA allows for evidence-based policymaking, ensuring that policies are both dynamic and responsive to the nuanced challenges faced by SMEs. Such frameworks should align closely with sustainability goals, particularly those emphasizing responsible consumption, production, and improved resource efficiency. Cross-sector collaboration further amplifies the impact of sustainability initiatives. Policymakers should encourage partnerships among government agencies, industry stakeholders, academic institutions, and international organizations. These collaborations can pool resources, share expertise, and foster collective action to drive sustainable development within the SME sector. The synergistic efforts of diverse stakeholders can accelerate the adoption of sustainable practices and amplify their long-term impact.

Finally, embedding circular economy principles into policy strategies is essential. By encouraging waste reduction, recycling, and resource conservation, policymakers can promote sustainable production processes that prioritize efficiency. Integrating frugal sustainability and achieving sustainability goals with minimal resources ensures that SMEs, especially those with limited financial capacity, can participate in the broader sustainability agenda.

Ultimately, policymakers play a pivotal role in shaping an ecosystem that empowers SMEs as key agents of sustainability. Bridging the gap between policy design and implementation is critical to fostering resilient, competitive, and sustainable SMEs. By addressing their unique challenges and leveraging their potential, such policies not only contribute to global sustainability objectives but also bolster the long-term viability and competitiveness of SMEs in a rapidly evolving global economy.

5.3 | Conclusions, Limitations, and Future Study Directions

This study investigates sustainable practices among SMEs in the manufacturing sector, with a focus on aligning with the SDGs and optimizing resource utilization. By analyzing various sustainable constructs—including environmental dimensions, social dimensions, facilitating conditions, technological innovativeness, and innovative practices—the research identifies key pathways that drive sustainability and resource efficiency in SMEs.

The findings underscore the importance of integrating environmental considerations, social dimensions, and governmental support to enhance resource efficiency. Four sustainable pathways are identified, highlighting the pivotal roles of technological innovativeness and innovative practices alongside environmental and social dimensions. Additionally, the study outlines two key topologies that bolster resource efficiency, emphasizing the integration of emerging technologies and a systemic approach to sustainability strategies. These insights provide valuable guidance for policymakers and practitioners in promoting sustainable development and achieving SDG objectives.

While this study underscores the importance of synergistic sustainability strategies and the interplay of diverse factors in fostering resource efficiency among SMEs, it is not without limitations. Acknowledging these limitations is essential to contextualize the findings and guide future research endeavors.

One limitation is the specificity of the study's context, focusing primarily on SMEs in the manufacturing sector. This narrow scope restricts the generalizability of the findings to SMEs in other industries or geographic regions. Future research should explore how the identified pathways and topologies apply to SMEs in diverse sectors and cultural contexts, thus broadening the theoretical and practical applicability of the framework.

Another limitation concerns the behavioral dimension of sustainability practices. This study does not account for the impact of employees' behaviors and decision-making processes on resource management. Investigating these human factors could offer deeper insights into how internal organizational dynamics influence the adoption and success of sustainability strategies. Additionally, the study's reliance on configurational pathways derived from fsQCA, while robust, may oversimplify the nuanced interactions among variables in real-world scenarios. Future studies could complement these findings with qualitative methodologies, such as in-depth case studies or interviews, to capture the complexities and contextual subtleties of sustainability practices.

The cross-sectional nature of the research presents another limitation, as it captures sustainability configurations at a single point in time. Longitudinal studies could address this gap by examining how pathways and topologies evolve over time, providing insights into the adaptability and longevity of sustainable practices under changing market, regulatory, and environmental conditions. Moreover, the study focuses on a limited set of dimensions influencing sustainability: environmental, social, technological, and facilitating conditions. Future research could incorporate additional factors such as cultural influences, global supply chain pressures, and market dynamics, which are increasingly relevant in today's interconnected world. These dimensions could offer a more comprehensive understanding of the forces shaping sustainability in SMEs.

In summary, while this study makes significant contributions to advancing sustainable development and resource efficiency in SMEs, addressing these limitations in future research will further enhance the robustness and applicability of its findings. Expanding the scope, incorporating qualitative insights, and exploring additional dimensions and temporal dynamics will

deepen the theoretical understanding of sustainability configurations and their practical implications.

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