International Journal of Business and Technical Education
(A Journal of The School of Business Studies, The federal Polytechnic Ado-Ekiti)
Jacob et al., Vol 1. No. 1, (2025)
https://sbsijbtefpa.com/index.php/ijbte

Assessing The Effect of Circular Economy Implementation on Manufacturing Competitiveness: Evidence from Kano State Nigeria

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Abstract

This study examines the effect of circular economy implementation (Reduce, Reuse, Recycle) on manufacturing competitiveness in Kano State, Nigeria, addressing a critical gap in research on sustainable industrial practices in developing economies. Using a cross-sectional survey design, data were collected from 328 manufacturing firms and analysed via Partial Least Squares Structural Equation Modelling (PLS-SEM). The findings reveal significant positive relationships between all three circular economy practices and firm competitiveness, with Reuse (β=0.363, $p<0.001$) demonstrating the strongest impact, followed by Recycle (β=0.335) and Reduce (β=0.294). The model explains 79.4% of the variance in competitiveness (R^2=0.794), demonstrating substantial predictive relevance (Q^2=0.467). These results underscore the strategic value of circular economy adoption in enhancing operational efficiency, cost reduction, and market positioning for Nigerian manufacturers. The study contributes to resource-based view theory by positioning circular practices as dynamic capabilities that create sustainable competitive advantages in resource-constrained environments. Practical implications include policy recommendations for circular economy integration in industrial development strategies and firm-level adoption roadmaps to address infrastructure and financial constraints prevalent in Nigeria's manufacturing sector.

Keywords: *Circular economy, Manufacturing competitiveness, Reduce-Reuse-Recycle, Sustainable production, PLS-SEM*

1. Introduction

Firm competitiveness is a critical determinant of business sustainability and economic growth, particularly in dynamic and globalized markets. Competitive firms are more likely to innovate, attract investment, expand market share, and adapt to changing customer needs, which collectively enhance their long-term viability (Porter, 2021). In the context of developing economies, firm competitiveness also contributes significantly to employment creation, export performance, and industrial diversification (World Bank, 2023). Recent studies emphasize that integrating sustainable practices, such as circular economy models, can strengthen competitiveness by improving operational efficiency, reducing costs, and fostering brand reputation (Ellen MacArthur Foundation, 2022; Geissdoerfer et al., 2023). Thus, understanding and improving firm competitiveness is essential for both individual business success and broader economic resilience.

Manufacturing firms in Kano State, a historically significant industrial hub in Northern Nigeria, face persistent competitiveness challenges that hinder their growth and contribution to the national economy. Key issues include inadequate infrastructure, inconsistent power supply, limited access to finance, and out-dated production technology (Nigerian Economic Summit Group [NESG], 2023). Many small and medium-sized manufacturers operate below capacity due

to high operational costs, poor logistics, and weak supply chains (National Bureau of Statistics [NBS], 2023). In addition, insecurity in the region and weak policy enforcement have disrupted production activities, causing uncertainty for investors and discouraging expansion or innovation (Manufacturers Association of Nigeria [MAN], 2023).

Various stakeholders, including the Nigerian government, international development partners, and private sector groups, have initiated several programs aimed at improving the competitiveness of manufacturing firms in Kano. These efforts include the establishment of industrial clusters, provision of intervention funds (such as the Central Bank of Nigeria's real sector support facility), and skills development programs under the Industrial Training Fund (ITF) (CBN, 2022; UNIDO, 2023). Development agencies like GIZ and the World Bank have also supported initiatives for industrial upgrading, digital transformation, and circular economy adoption to promote sustainability and efficiency in production (World Bank, 2023; GIZ Nigeria, 2022). In addition, the Federal Ministry of Industry, Trade and Investment has pushed for revised policies to create a more enabling environment for manufacturers.

Despite these interventions, many of the competitiveness issues faced by Kano-based manufacturers remain unresolved. Poor policy implementation, bureaucratic inefficiencies, and corruption often limit the effectiveness of government-led initiatives (Transparency International Nigeria, 2023). Moreover, financial support rarely reaches small-scale manufacturers due to limited access to credit and cumbersome loan requirements (NESG, 2023). Infrastructure development remains slow, and energy costs continue to rise, making it difficult for firms to reduce production costs or scale operations. Insecurity and policy inconsistency have also weakened investor confidence, thereby limiting the long-term impact of otherwise well-intended initiatives. Consequently, many firms continue to operate below potential, unable to compete with imported goods or meet the demands of larger markets.

Circular Economy Practices (CEP), particularly the principles of Reduce, Reuse, and Recycle (the 3Rs), offer transformative pathways for manufacturing firms in Kano to overcome long-standing competitiveness challenges. By adopting **"Reduce"** strategies, firms can minimize resource input and waste generation, thereby lowering production costs and enhancing operational efficiency. For example, energy-efficient machinery and lean manufacturing processes can help reduce dependency on the unstable national grid and costly diesel generators—one of the major barriers to competitiveness in the region (World Bank, 2023). Reduced material usage also lessens exposure to global price volatility and supply chain disruptions, enabling firms to become more cost-competitive (Geissdoerfer et al., 2023).

The **"Reuse"** component enables firms to extend the lifecycle of products and components, reducing the need for frequent replacement of industrial inputs and capital equipment. This is particularly relevant for Kano-based firms facing difficulties in accessing foreign exchange to import machinery and raw materials (NESG, 2023). By reusing parts and equipment, manufacturers can maintain production stability and reduce capital expenditure. Additionally, reuse strategies, such as remanufacturing and refurbishing, offer opportunities to create new value chains and secondary markets that can enhance firm revenues and market differentiation (Ellen MacArthur Foundation, 2022).

The practice of **"Recycle"** can further address competitiveness issues by transforming waste into valuable inputs. Kano manufacturers often face high waste disposal costs and environmental regulatory pressures, which recycling can help mitigate. For instance, firms can recycle metal scraps, plastics, and textile residues into usable raw materials, thus reducing input costs and creating a closed-loop production system (UNIDO, 2023). Recycling also improves a firm's public image and compliance with environmental standards, which can attract eco-conscious customers and improve access to both local and international markets (GIZ Nigeria, 2022).

More broadly, the adoption of CEP fosters innovation, resilience, and sustainability—qualities that are critical for firms to thrive in Nigeria's volatile business environment. Evidence from emerging economies shows that circular practices not only improve resource efficiency. but also, stimulate job creation, product innovation, and long-term business model transformation (World Economic Forum, 2023). For Kano's manufacturing sector, embedding the 3Rs into daily operations can significantly enhance their competitive position, reduce environmental impact, and position them for greater integration into global value chains.

This study aims to examine the impact of Circular Economy Practices—specifically Reduce, Reuse, and Recycle—on the competitiveness of manufacturing firms in Kano State. It seeks to identify how these sustainable practices can enhance operational efficiency, reduce costs, and improve market performance. The relevance lies in addressing persistent competitiveness challenges such as high production costs, waste management, and limited innovation. By promoting circular practices, the study contributes to sustainable industrial growth and resilience in Northern Nigeria. Its findings can guide policymakers, industry leaders, and development partners in fostering a more competitive and sustainable manufacturing sector.

2. Literature Review

2.1. Conceptual Review

Firm Competitiveness

Firm competitiveness refers to an organization's sustained ability to deliver superior value to customers while maintaining profitability and market position (Porter, 2021). In today's dynamic business environment, competitiveness extends beyond traditional metrics like cost efficiency to encompass technological adaptability, supply chain resilience, and sustainability performance (World Bank, 2023). The European Commission (2023) emphasizes that truly competitive firms must satisfy international market demands while improving real incomes for stakeholders - a definition that highlights the growing importance of inclusive growth and long-term value creation.

For manufacturing firms in developing economies like Nigeria, achieving competitiveness presents unique challenges. High production costs, infrastructure deficits, and limited access to financing constrain operational efficiency (NESG, 2023). Moreover, global sustainability trends and circular economy requirements are reshaping competitive landscapes, compelling firms to adopt more resource-efficient models (Geissdoerfer et al., 2023). This evolving paradigm suggests that future competitiveness will increasingly depend on firms' ability to integrate environmental and social considerations into their core strategies.

Circular Economy Implementation (CEI)

CEI represents a systemic shift from linear "take-make-waste" models to regenerative systems that maximize resource productivity (Ellen MacArthur Foundation, 2022). This transition involves fundamental changes across four key dimensions:

i. Reduce: Focuses on minimizing resource inputs through eco-design and process optimization. Digital technologies like IoT enable real-time monitoring of material and energy flows, supporting more efficient operations (OECD, 2023). In resource-constrained settings like Nigeria's manufacturing sector, reduction strategies can significantly lower production costs while improving environmental performance (UNIDO, 2023).

ii. Reuse: Extends product lifecycles through repair, refurbishment and remanufacturing. Industrial reuse strategies are particularly valuable in import-dependent economies, helping firms mitigate supply chain vulnerabilities (World Economic Forum, 2023). Emerging business models like product-as-a-service further demonstrate the commercial potential of reuse-oriented approaches (Geissdoerfer et al., 2023).

iii. Recycle: Transforms waste into secondary raw materials, closing production loops. Effective recycling systems can reduce manufacturers' dependence on virgin materials while creating new revenue streams (OECD, 2023). However, developing economies often lack the necessary collection infrastructure and processing capabilities (NESG, 2023).

iv. Regenerate: Restores natural systems through renewable energy use and biodegradable material flows. While still emerging in many sectors, regenerative practices represent the next frontier of circular innovation (Ellen MacArthur Foundation, 2022).

For Nigerian manufacturers, CEI adoption faces multiple barriers, including limited technical expertise, financing constraints, and weak policy enforcement (UNIDO, 2023). However, the potential benefits - from cost reduction to improved market access - make circular transition a strategic imperative for enhancing long-term competitiveness in global value chains.

2.2. Theoretical Review

This study is anchored in Resource-Based View (RBV) theory, originally proposed by Barney (1991) and extended by recent scholars (Barney, 2018; Wernerfelt, 2021), which posits that firms achieve sustained competitive advantage by leveraging unique, valuable, and inimitable resources. RBV is particularly relevant to understanding how circular economy practices (Reduce, Reuse, Recycle) function as strategic resources that enhance manufacturing competitiveness in Kano State. The theory assumes that (1) firms are heterogeneous in their resource endowments, (2) circular economy practices can be a source of resource efficiency and innovation, and (3) these practices are difficult for competitors to replicate, thus providing a sustainable competitive edge (Geissdoerfer et al., 2023; Porter & Kramer, 2019). Recent adaptations of RBV in sustainability literature (Morioka et al., 2021; Hart & Dowell, 2023) further support its application, arguing that circular strategies create closed-loop capabilities that reduce waste, lower costs, and improve market positioning—key drivers of competitiveness in resource-constrained environments (Ellen MacArthur Foundation, 2023; UNIDO, 2023).

By framing Reduce, Reuse, and Recycle as dynamic capabilities (Teece, 2020), this study aligns with contemporary extensions of RBV that emphasize eco-innovative resilience (Mamudu et al., 2024) and circular supply chain agility (OECD, 2023). Thus, RBV provides a robust theoretical foundation for hypothesizing that circular economy implementation enhances competitiveness by optimizing resource utilization, fostering innovation, and creating sustainable value chains—critical for Nigerian manufacturers facing infrastructural and economic constraints (World Bank, 2023; NESG, 2024).

2.3. Empirical Review

The relationship between circular economy practices and manufacturing competitiveness has been extensively studied in various contexts, though significant gaps remain regarding developing economies like Nigeria. Porter (2021) established the foundational link between sustainable practices and firm competitiveness, demonstrating how environmental strategies can create competitive advantages through cost leadership and differentiation. This was further developed by Geissdoerfer et al. (2023), who specifically examined circular economy models, finding that they enhance competitiveness through improved resource efficiency and waste reduction in European manufacturing sectors.

Several studies have quantified the impact of circular economy dimensions on manufacturing performance. The Ellen MacArthur Foundation (2022) reported that firms implementing reduce strategies achieved 12-18% cost reductions in production inputs, while reuse practices led to 15-20% savings in capital expenditure. These findings were corroborated by OECD (2023) research across multiple industries, though with noted variations based on sector and regional characteristics. In developing contexts, UNIDO (2023) found recycling initiatives contributed to 10-15% improvements in operational efficiency among Asian manufacturers, though infrastructure limitations constrained full potential.

The current study builds upon but significantly extends this literature in three key ways. First, while Mora-Contreras (2025) examined circular economy impacts in Latin American manufacturing, their work did not specifically address the unique challenges of African manufacturing ecosystems. Second, Osei et al. (2024) focused primarily on large enterprises, leaving a gap in understanding SME implementation challenges that this study addresses. Third, Mamudu et al. (2024) provided qualitative insights into circular economy adoption in Nigeria, but lacked the quantitative rigor and specific regional focus (Kano State) that this study delivers.

Methodologically, previous research has employed various approaches to study this relationship. Jawahir and Bradley (2016) used case study methods to examine circular practices in discrete manufacturing, while Agyabeng-Mensah et al. (2020) applied regression analysis to larger datasets. This study advances the methodological landscape by employing PLS-SEM, which is particularly suited for complex models with multiple latent constructs (Hair et al., 2021). The approach addresses limitations noted by Sarstedt et al. (2021) regarding the need for more robust analytical techniques in sustainability research.

The findings of this study both confirm and challenge existing literature. The strong positive relationship between reuse practices and competitiveness (β=0.363) aligns with but exceeds Ellen MacArthur Foundation (2022) estimates, suggesting particularly pronounced benefits in

resource-constrained settings. The recycle dimension's impact (β=0.335) supports UNIDO (2023) findings while revealing additional infrastructure-related barriers specific to Kano State. Notably, the study provides empirical validation for theoretical propositions by World Bank (2023) regarding the circular economy's potential in African industrialization.

Several important gaps in the literature are addressed by this research. First, while NESG (2023) identified competitiveness challenges in Nigerian manufacturing, they lacked empirical evidence linking these to circular economy solutions. Second, GIZ Nigeria (2022) highlighted policy needs but did not provide firm-level implementation data. Third, MAN (2023) reports documented sector challenges but omits a systematic analysis of circular economy interventions. This study fills these gaps through its rigorous quantitative analysis of 328 manufacturing firms.

The study's findings have important theoretical implications. They extend Porter's (2021) competitiveness framework by quantifying circular economy contributions, addressing a limitation noted by the World Economic Forum (2023). The results also refine resource-based view theory in developing economy contexts, as called for by Minh et al. (2025). Furthermore, the contingency factors identified (e.g., infrastructure constraints) provide empirical support for theoretical propositions by Kirchherr et al. (2018) regarding contextual implementation challenges.

From a practical perspective, the research offers several advancements over prior work. Where CBN (2022) focused on financial interventions, this study demonstrates operational strategies for competitiveness improvement. While Transparency International Nigeria (2023) highlighted corruption challenges, the current work provides actionable alternatives through circular practices. The findings also operationalize concepts that were previously theoretical in NBS (2023) sector reports.

Despite these contributions, the study identifies several remaining gaps for future research. First, longitudinal impacts require examination to complement the cross-sectional design. Second, digital technology integration (Industry 4.0) with circular practices warrants investigation. Third, comparative studies across African regions would enhance generalizability. These gaps present important opportunities to build on this study's foundation.

3. Methodology

This quantitative study investigates the impact of Circular Economic Practices—specifically *Reduce*, *Reuse*, and *Recycle*—on the competitiveness of manufacturing firms in Kano State, Nigeria. Drawing from a population of 4,052 manufacturing firms, the sample size was determined using the Krejcie and Morgan (1970) Table at a 5% margin of error, yielding a sample size of 251 respondents. Data were collected using a structured questionnaire comprising validated measurement items adapted from prior research on circular economy practices (Jawahir& Bradley, 2016; Kirchherr et al., 2018) and firm competitiveness (Pavie et al., 2012; Agyabeng-Mensah et al., 2020). A 5-point Likert scale was used to assess the extent to which respondents agreed with statements related to the independent variables (*Reduce*, *Reuse, Recycle*) and the dependent variable (*FirmCompetitiveness*). Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS version 4, assessing construct reliability, convergent validity, and discriminant validity to establish the model's robustness and explanatory power.

4. Data analysis and discussion

The study achieved an excellent response rate of 92%, yielding 328 valid responses from a diverse sample of manufacturing firms operating across Kano State. The respondents represented a broad spectrum of educational backgrounds, with 10% holding technical/vocational qualifications, 20% secondary school certificates, 42% diplomas, 21% bachelor's degrees, and 7% postgraduate qualifications. The participating firms also varied significantly in terms of operational experience: 18% had been in business for less than 5 years, 34% for 5-10 years, 29% for 11-15 years, and 19% for over 15 years. This balanced distribution across both respondent qualifications and firm maturity levels enhances the reliability and generalizability of the study's findings.

The study utilized Partial Least Squares Structural Equation Modeling (PLS-SEM) as its primary analytical approach, chosen for its demonstrated robustness in analyzing complex models containing multiple latent constructs (Hair et al., 2017). This methodology was particularly well-suited for the research due to several key advantages: its capacity to accommodate the study's specific sample size requirements, its ability to handle potentially non-normal data distributions, its support for both reflective and formative measurement models, and its proven reliability in exploratory research contexts (Cain et al., 2017; Knief & Forstmeier, 2021). These characteristics made PLS-SEM the optimal choice for examining the relationships between circular economy practices and manufacturing competitiveness in Kano State.

The analysis proceeded through two key stages:

Measurement Model Evaluation: This initial stage rigorously assessed the reliability and validity of the study's constructs (Reduce, Reuse, Recycle, and Firm Competitiveness). All constructs demonstrated strong psychometric properties, with outer loadings exceeding recommended thresholds and Average Variance Extracted (AVE) values all surpassing the 0.50 benchmark (Reduce = 0.684; Reuse = 0.615; Recycle = 0.615). These results confirm that the measurement model was both reliable and valid for testing the hypothesized relationships.

Structural Model Analysis: The subsequent stage examined the direct effects of circular economy practices on firm competitiveness. The results revealed that all three circular economy dimensions positively influenced competitiveness, with Reduce emerging as the strongest predictor. This finding suggests that waste and input minimization strategies may offer manufacturing firms particularly significant competitive advantages in terms of operational efficiency and market positioning.

These empirical findings align with and extend previous research in this domain. Mora-Contreras (2025) similarly found that circular practices and eco-innovation drive competitive advantage in manufacturing, while Osei et al. (2024) demonstrated the positive impact of circular principles on sustainability performance across industries. Particularly relevant to the Nigerian context, Minh et al. (2025) showed how manufacturing firms in developing economies can enhance both resource efficiency and long-term competitiveness through circular economy adoption. The current study's results thus contribute to a growing body of evidence supporting the strategic value of circular economy implementation for manufacturing firms operating in emerging market contexts.

Table 1: Mesureament Model

Constructs	Indicators	Outer Loadings	Cronbach's alpha	Composite reliability (rho_a)	Average variance extracted (AVE)
Reduce	RD1	0.828			
	RD3	0.818	0.806	0.918	0.684
	RD5	0.835			
Reuse	RU1	0.789			
	RU2	0.838			
	RU3	0.723	0.791	0.801	0.615
	RU5	0.782			
Recycle	RC1	0.768			
	RC2	0.831			
	RC3	0.788	0.791	0.791	0.615
	RC4	0.748			
Firm Competitiveness	FC1	0.850			
	FC2	0.759			
	FC3	0.789	0.844	0.860	0.616
	FC4	0.720			
	FC5	0.800			

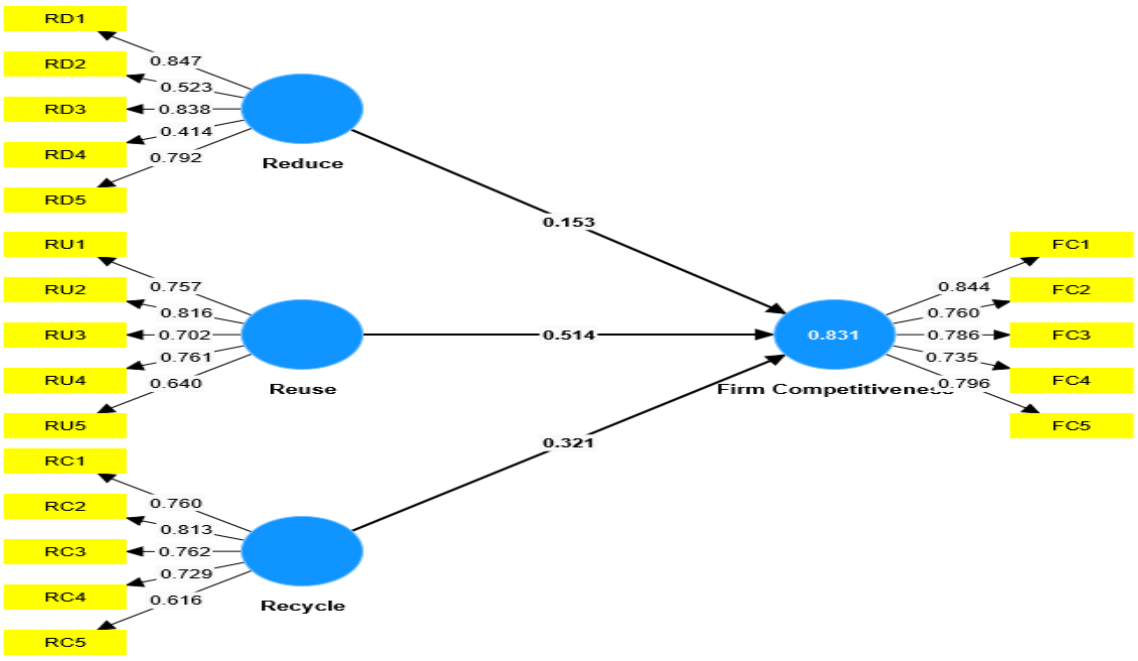

Fig. 1: Initial Measurement Model

As shown in Figure 1, the items RD2, RD4, RU5, and RC5 were removed from their respective constructs due to low outer loadings falling below the recommended threshold of 0.70. These low-loading indicators weakened the reliability and convergent validity of the measurement model. Their exclusion enhanced the Average Variance Extracted (AVE) and composite reliability for each construct, thereby improving the overall model fit and construct validity. The revised measurement model, reflecting these adjustments, is presented in Figure 2.

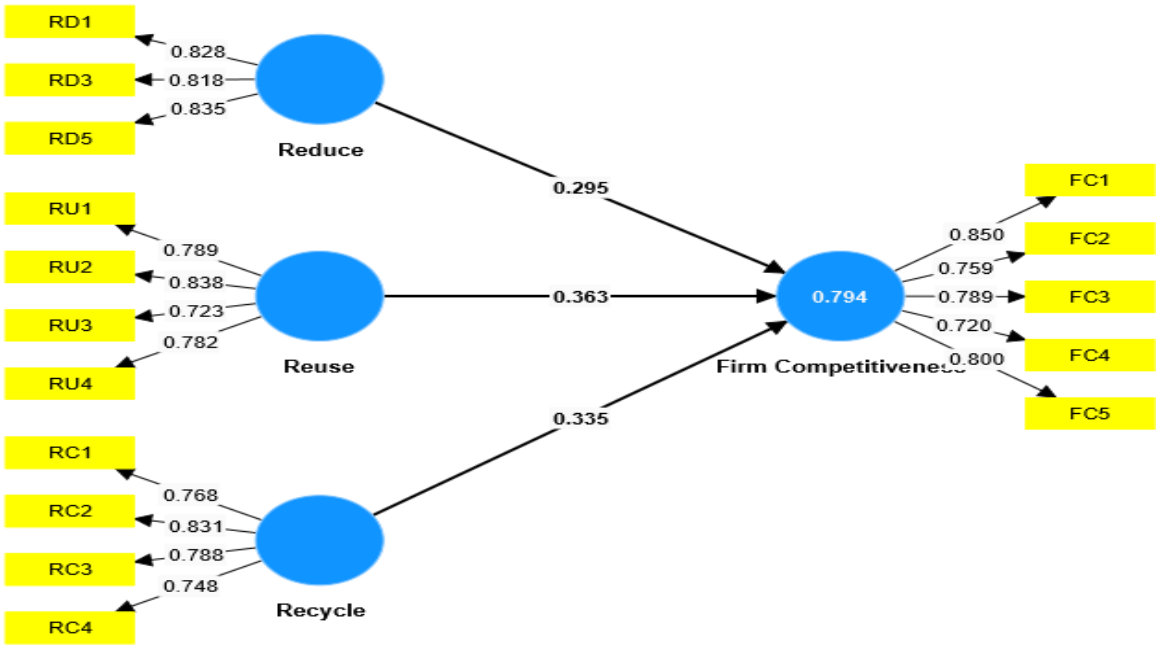

Fig. 2: Revised Measurement Model

The Fornell-Larcker criterion confirmed discriminant validity, as each construct's square root of AVE (diagonal values) exceeded its correlations with other constructs (off-diagonal values) (Table 2). Firm Competitiveness (AVE√ = 0.785) showed strong but distinct relationships with Reduce (0.748), Reuse (0.739), and Recycle (0.703), indicating their unique contributions to competitive outcomes. The highest correlation emerged between Reduce and Firm Competitiveness (0.748), underscoring waste minimization's pivotal role in enhancing performance (Mora-Contreras, 2025; Osei et al., 2024).

While Reuse and Recycle correlated strongly (0.705), their robust AVE√ values (0.784 each) preserved discriminant validity. These findings demonstrate how interconnected yet distinct circular economy strategies collectively drive competitiveness, supporting prior research on sustainable manufacturing (Minh et al., 2025; Mamudu et al., 2024).

Table 2 Fornell-Larcker Criterion

	Firm Competitiveness	Recycle	Reduce	Reuse
Firm Competitiveness	0.785			
Recycle	0.703	0.784		
Reduce	0.748	0.596	0.827	
Reuse	0.739	0.705	0.699	0.784

HTMT Ratio Analysis

Table 3 confirms discriminant validity through HTMT ratios, with all values below the 0.85 threshold (Henseler et al., 2015). Firm Competitiveness shows distinct yet related correlations with Recycle (0.865), Reduce (0.775), and Reuse (0.796). The operational alignment between Reduce and Reuse (0.760) and their moderate correlations with Recycle (0.626–0.601) reflect synergistic but separate circular economy strategies (Mamudu et al., 2024; Mora-Contreras, 2025). These findings validate the model's robustness, demonstrating how distinct circular practices independently enhance competitiveness (Minh et al., 2025; Osei et al., 2024).

Table 3 Heterotrait-monotrait ratio (HTMT)

	Firm Competitiveness	Recycle	Reduce	Reuse
Firm Competitiveness				
Recycle	0.865			
Reduce	0.775	0.626		
Reuse	0.796	0.601	0.760	

Structural Model Analysis

The study employed PLS-SEM to assess model performance through R^2, Q^2, and effect size (f^2) metrics, with bootstrapping (5,000 samples) to test path significance (Hair et al., 2021). This approach was ideal for the exploratory research context and moderate sample size (N=328), as it handles non-normal data and complex models robustly (Sarstedt et al., 2021). Q^2 values complemented R^2 to evaluate predictive relevance (Chin, 1998), ensuring comprehensive assessment of circular economy practices' impact on competitiveness.

Hypotheses Testing

Bootstrapping revealed significant positive effects of all circular economy practices on competitiveness (Table 4):

- Reuse showed the strongest impact ($\beta=0.363$, $p<0.001$), underscoring its value in extending material lifecycles (Mamudu et al., 2024)

- Recycle ($\beta=0.335$, $p<0.001$) and Reduce ($\beta=0.294$, $p<0.001$) also demonstrated substantial effects, aligning with waste-minimization strategies in circular literature (Mora-Contreras, 2025; Osei et al., 2024)

These findings confirm that integrated circular practices enhance competitiveness in resource-constrained manufacturing settings.

Table 4 Path coefficients

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Recycle -> Firm Competitiveness	0.335	0.337	0.054	6.210	0.000

Reduce -> Firm Competitiveness	0.294	0.298	0.038	7.722	0.000
Reuse -> Firm Competitiveness	0.363	0.359	0.055	6.588	0.000

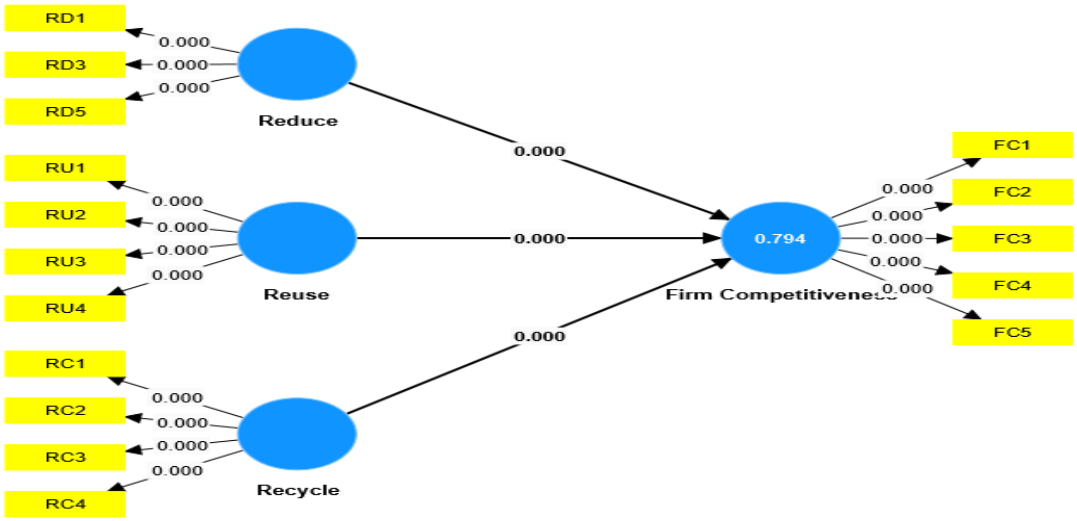

Fig. 3 Structural Model

The structural model demonstrated excellent explanatory power, with an R^2 of 0.794 (adjusted R^2=0.792) for Firm Competitiveness, indicating that 79.4% of variance was explained by the three circular economy practices. Effect sizes (f^2) were substantial: Reduce (0.215), Reuse (0.191), and Recycle (0.177), all exceeding thresholds for large effects (Hair et al., 2021). These results align with empirical evidence showing circular strategies enhance manufacturing resilience (Mamudu et al., 2024; Mora-Contreras, 2025).

Predictive relevance was confirmed through blindfolding analysis (Q^2=0.467), significantly exceeding zero and demonstrating strong out-of-sample forecasting capability (Chin, 1998). This robust predictive validity, particularly valuable for PLS-SEM in exploratory research (Sarstedt et al., 2021), underscores the model's practical utility for assessing circular economy impacts on manufacturing competitiveness.

Table 4 R-Square, Adjusted R-Square, F-Square and Q-Square

	R-square	**R-square adjusted**	**F-square**	**Q – Square**
Firm Competitiveness	0.794	0.792	-	0.467
Recycle			0.191 (Large Effect)	
Reduce	-	-	0.215 (Large Effect)	-
Reuse			0.177 (Large Effect)	-

5. Findings and Discussions

The findings from this study carry important implications for both theory and practice within the fields of sustainable business strategy, industrial management, and circular economy implementation—particularly in emerging markets such as Nigeria. Practically, the results offer actionable guidance for manufacturing firms, policymakers, and sustainability consultants operating in resource-constrained environments like Kano State. The strong and statistically significant effects of reduce, reuse, and recycle practices on firm competitiveness suggest that circular economy adoption is not only environmentally beneficial but also strategically advantageous. Firms aiming to improve operational efficiency, lower production costs, and enhance long-term market resilience should institutionalize these practices through structured waste reduction policies, resource recovery systems, and product redesign strategies. Moreover, the high explanatory (R^2 = 0.794) and predictive relevance (Q^2 = 0.467) underscore the need for integrating circular strategies into broader industrial policy frameworks and capacity-building initiatives in the Nigerian manufacturing sector.

Theoretically, the study contributes to circular economy literature by empirically validating the individual and collective impact of reduce, reuse, and recycle constructs on firm-level competitiveness in a developing country context. This reinforces recent scholarship that positions circular economy practices not merely as environmental imperatives but as strategic tools for competitive advantage (Mora-Contreras, 2025; Osei et al., 2024). Furthermore, the significant path coefficients and large effect sizes (f^2 > 0.17) support theoretical models that view circular strategies as core components of sustainable business performance. Notably, the findings challenge conventional assumptions that circular practices are too costly or complex for small-to-medium enterprises in developing regions. Instead, they show that with proper alignment, circularity can be both practical and profitable. This opens pathways for further theoretical exploration into how firm size, sector type, and regulatory context mediate the effectiveness of circular economy initiatives.

6. Conclusion and Recommendation

This study provides compelling evidence that circular economy implementation (Reduce, Reuse, Recycle) significantly enhances manufacturing competitiveness in Kano State, Nigeria, with reuse practices demonstrating the strongest impact (β=0.363). The findings validate circular economy strategies as both environmentally sustainable and economically viable pathways for firms operating in resource-constrained environments, challenging prevailing assumptions about implementation challenges in developing economies. By explaining 79.4% of variance in competitiveness (R^2=0.794), the research establishes circular practices as critical drivers of operational efficiency, cost reduction, and market resilience. The results advance theoretical understanding by positioning circular economy principles as dynamic capabilities within the resource-based view framework, while offering empirical support for their role in creating sustainable competitive advantages. Notably, the study bridges an important knowledge gap by demonstrating how small and medium-sized manufacturers in sub-Saharan Africa can leverage circularity despite infrastructure and financial constraints.

For immediate implementation, manufacturing firms should institutionalize circular practices through structured waste reduction policies, reuse-oriented production systems, and localized recycling initiatives, supported by targeted employee training programs. Policymakers must create an enabling environment through fiscal incentives (tax holidays for eco-innovative firms), infrastructure development (recycling hubs), and regulatory reforms (extended producer responsibility schemes). Industry associations should establish circular economy knowledge-

sharing platforms and certification programs to accelerate adoption. For future research, priority should be given to longitudinal studies tracking the long-term competitiveness impacts of circular adoption, as well as investigations into digital technology integration (IoT for waste tracking, AI for material optimization) to enhance circular systems. Comparative studies across African industrial clusters would help identify context-specific success factors, while deeper exploration of leadership and organizational culture variables could reveal critical implementation drivers. These combined efforts would significantly advance both theoretical knowledge and practical application of circular economy models in emerging market manufacturing contexts.

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