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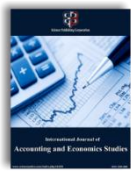

# Forging Circuits and Bytes: The Mediator with Moderating Effects of Digital Transformation on The Circular Economy and Sustainable Entrepreneurship

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**Abstract**

Focusing on Micro, Small, and Medium Enterprises (MSMEs) in India, this study examines the intricate connections between Circular Economy (CE), Digital Transformation (DT), and Sustainable Entrepreneurship (SE). A quantitative approach was employed, analyzing survey data from 326 entrepreneurs using Structural Equation Modelling (SEM) to understand how digital transformation mediates and moderates these relationships. The results clearly show that CE positively impacts SE, both directly and indirectly through the influence of DT. However, DT's moderating effect on the CE-SE relationship proved significantly negative, pointing to potential implementation hurdles when these two strategies are pursued concurrently. This research offers valuable theoretical insights into the dual role of digital technologies as either facilitators or barriers within sustainable business models. From a practical standpoint, the findings highlight the importance of integrating digital tools in phases, and policy recommendations are put forth to aid MSME transitions. Ultimately, the study contributes significantly to interdisciplinary literature by creating a bridge between sustainability, entrepreneurship, and digital transformation, particularly relevant for emerging economies.

***Keywords***: *Circular Economy; Digital Transformation; Sustainable Entrepreneurship; 5-Point Likert Scale; Structural Equation Modelling.*

## 1. Introduction

Robust growth of digital technologies has rehabilitated the landscape of business, sustainability, and entrepreneurship. Artificial intelligence, blockchain, and the Internet of Things (IoT) are profoundly transforming how firms operate, innovate, and interact within their business ecosystems. As we traverse this evolving crossroads, recognizing how digitization impacts circular economy practices and sustainable entrepreneurship becomes more crucial than ever.
The term "sustainability" has become more popular, highlighting how sustainable practices may be incorporated into the innovation process. Driven by the growing global urgency for sustainability, Circular Economy (CE) practices have emerged, focusing on waste reduction, material reuse, and resource regeneration. It is at the intersection of these shifts that Sustainable Entrepreneurship (SE) is found as the commitment to entrepreneurial ventures that are not only profitable but also environmentally protective and socially beneficial.

### 1.1. Statement of The Problem

The combined force of digital transformation, circular economy principles, and sustainable entrepreneurship presents a crucial opportunity in the rapidly changing field of business and sustainability. Prior research illuminates the essential nature of digital transformation, circular economy practices, and sustainable entrepreneurship; however, a thorough understanding of their complex interactions and reciprocal effects between these components remains elusive. The literature is deficient in offering a thorough understanding of the way in which digital transformation acts as a mediator, directing the connection between the prosperity of sustainable entrepreneurs and the adoption of circular economy practices. In addition, to fulfil the paucity of the study of the moderating effect of digital transformation on the effectiveness of circular economy practices in promoting sustainable entrepreneurship is the succeeding aim of this effort. This study aims to bridge that gap by exploring how digital transformation shapes the relationship between circular economy and sustainable entrepreneurship outcomes, acting as both a mediator and a moderator.

### 1.2. Research Questions

In light of the above frailties, the following research questions are motivated:
1) Does digital transformation act as a mediator between sustainable entrepreneurship and circular economy practices?
2) Does the moderation of digital transformation have an impact on the ability of circular economy practices to stimulate sustainable entrepreneurship?

## 2. Theoretical Fortifications and Development of Hypotheses

### 2.1. Circular Economy and Sustainable Entrepreneurship

Sustainable entrepreneurship refers to the process of starting and running an enterprise that puts social and environmental objectives ahead of financial success. It means integrating environmental responsibility, social equity, and economic viability into how businesses operate and make decisions. The aim of sustainable entrepreneurs is to seek a positive, beneficial influence on the environment and society without sacrificing their financial security.

By encouraging environmentally friendly behaviours, lowering carbon footprints, and avoiding resource depletion, sustainable entrepreneurship helps achieve environmental goals (Schaltegger & Wagner, 2011). Sustainable entrepreneurs address societal issues, advance ethical labour practices, and aid in community development by integrating social responsibility into their business plans (Shepherd & Patzelt, 2011). According to Dean and McMullen (2007), enterprises that prioritize sustainability tend to reassure innovation and obtain a competitive advantage in the market by crafting eco-friendly goods and services. Businesses that practice sustainable entrepreneurship frequently strengthen their bonds with stakeholders, which promotes increased trust and a favourable image for the enterprise (Fernandes et al., 2023; Bansal & DesJardine, 2014).

A system attempting to reduce waste, repurpose resources, and replenish natural resources is conveyed by the idea of the circular economy. It contrasts with the traditional linear model of production and consumption, which incorporates the acquisition, application, and eventual disposal of materials. Entrepreneurs can practice circular design, business strategies, and techniques that make value out of waste, extend product life, and improve resource efficiency for the sustainability of entrepreneurship (Ali et al, 2024). Remanufacturing, biodegradable packaging, and sharing platforms are examples of the circular economy in action.

The circular economy, with its focus on waste reduction and resource efficiency, has drawn interest as a means of achieving sustainable development (Ellen MacArthur Foundation, 2015; Stahel, 2016). Prior research indicated that implementing circular economy principles can have positive effects on the economy, the environment, and society (Geissdoerfer et al., 2017; Ghisellini et al., 2016). Sustainable entrepreneurship is directly impacted by the Circular Economy (CE), which is supported by a number of theoretical stances.

According to the Resource-Based View (RBV), enterprises can obtain a competitive advantage by strategically deploying their unique resources and capabilities. This includes CE practices such as waste reduction and resource optimization (Barney, 1991). On the other hand, CE plays a crucial part in sustainability transitions, as highlighted by Transition Management Theory, which makes entrepreneurs who practice CE significant contributors to the sustainable entrepreneurship agenda (Loorbach, 2007). Innovation Diffusion Theory provides a clear explanation for CE breakthroughs, similar to closed-loop production systems, since they have the power to spread throughout ecosystems and industries, motivating entrepreneurs to establish companies that actively advance sustainability (Rogers, 1995). However, CE practices have a direct impact on sustainable entrepreneurship since they are strongly related to environmental entrepreneurship, which is the pursuit of novel circular solutions to ecological problems (Hockerts & Wüstenhagen, 2010). Last but not least, CE's importance of rethinking supply chains for sustainability as a component of supply chain management offers business owners chances to support supply chain management through innovative supply chain solutions (Pagell & Wu, 2009). Sustainable entrepreneurship is directly impacted by environmental entrepreneurship and sustainable supply chain management, which are features of CE (Schaper, 2002).

Hypothesis 1 (H1): Circular Economy directly influences Sustainable Entrepreneurship.

### 2.2. Circular Economy and Digital Transformation

The linear economy is based upon the “take-make-dispose” design. This is nothing but the process of resource extraction (take), production, consumption, and distribution (make), and disposal (waste) at the end of their useful lives (Riesener et al., 2019; Lieder& Rashid, 2016). A continuously revolving and regenerating loop of materials and resources characterizes the circular economy (CE). There is no waste, and the energy that powers the cycle is renewable. The Ellen MacArthur Foundation (2016) defined the five cycle phases of CE as follows: make, use, reuse, remake, and recycle. The transition to a CE is unavoidable given the global problem of waste disposal and waste-related contamination (Riesener et al., 2019). Digital transformation is recognized as a key asset for transforming industries into more sustainable businesses. This objective is achieved through an iterative process of data modelling, with the underlying strategies grouped according to Bocken’s eight archetypes: maximize material and energy efficiency; create value from ‘waste’; substitute with renewables and natural processes; deliver functionality rather than ownership; adopt a stewardship role; encourage sufficiency; re-purpose the business for society/the environment; and develop scale-up solutions (Colombi, & D’Itria, 2023).

The study of digital technology with CE is a fast-growing research field in terms of data architecture and integration infrastructure (Pagoropoulos et al., 2017). Digitalization of products and processes with a focus on stakeholders and virtualization of those processes are two substantial possibilities for a CE approach (Antikainen et al., 2018). Studies exhibiting how digital technologies facilitate resource usage optimization and monitoring examine the relationship between digital transformation and the circular economy (Al-Khatib, 2024; Geng et al., 2019; Rizos et al., 2016). IoT devices, for instance, play a crucial role in tracking and managing resources within a circular economy framework (Wang et al., 2021). Digital transformation involves the integration of digital technologies into various aspects of business operations to enhance efficiency, innovation, and competitiveness (Okorie et al,2023; Westerman et al., 2014; Berman, 2012). In changing conventional business models, the scholars highlight the revolutionary impact of technologies like blockchain, artificial intelligence (AI), and the Internet of Things (Schallmo et al., 2017; Brynjolfsson & McAfee, 2014).

Hypothesis 2 (H2): The relationship between digital transformation and circular economy is significant.

### 2.3. Digital Transformation and Sustainable Entrepreneurship

One particularly important factor in the development and advancement of innovative businesses is the digital transformation. It is the application of digital methods and gadgets to improve efficiency, strengthen client relations, and promote competitiveness across a range of enterprises (Vares etal al.,2024). With the use of digital transformation, entrepreneurs can create new products, services, and innovations that meet the needs and expectations of the market. E-commerce, cloud computing, AI, blockchain, and the internet of things are all included in the concept of digital transformation (Agal et al.,2025).
Digital technology may overturn conventional organizational structures, opening the door for creative and long-lasting entrepreneurial initiatives that defy accepted wisdom, according to the Theory of Disruptive Innovation (Christensen, 2006). According to Social Cognitive Theory, exposure to and education in the digital sphere can foster entrepreneurs' confidence in their abilities to advance sustainability through digital methods (Bandura, 1986). According to research on digital entrepreneurship, digital technologies increase productivity, accessibility, and reach, which makes it possible to launch ecologically and socially conscious businesses (Morakanyane et al., 2017). Finally, the theory of the digital ecosystem highlights how digital transformation encourages ecosystem actors to collaborate and become more interconnected, opening doors for sustainable entrepreneurship in digital ecosystems (Jacobides et al., 2018).
Hypothesis 3 (H3): Digital Transformation directly drives Sustainable Entrepreneurship.

### 2.4. The Mediator Role of Digital Transformation

Literature suggests that digital transformation acts as a mediator in the relationship between circular economy practices and sustainable entrepreneurial success (Kirchherr et al., 2017; Hernandez et al., 2018). The theoretical framework proposed by Sundarakani et al. (2019) highlights how digital technologies enable and enhance circular economy practices, influencing entrepreneurial outcomes positively. Prior studies on digital transformation have primarily examined its influence on economic productivity, environmental outcomes, and corporate strategies (Gimpelan & Roglinger,2015). This transformation has boosted overall factor productivity (Zeng & Lei,2021). Existing scholarship has utilized digital transformation as a mediating factor to scrutinize the effects of the digital economy on innovation (Li et al., 2022). Digitalization is characterized as the application of digital technologies and digitized data to modify working methods, change the way customers and firms interact, and establish new digital income sources. Digital transformation parallels digitalization. The entrepreneurial orientation mediates the relationship between digital transformation and competitive advantage ominously (Shehadeh et al., 2023).
Hypothesis 4 (H4): The mediating role of Digital Transformation between circular economy and sustainable entrepreneurship is substantial.

### 2.5. Moderating Effects of Digital Transformation

External factors, including regulatory environments and market conditions, can moderate the effects of digital transformation on sustainable entrepreneurial success (Boons et al., 2013). However, organizational factors like leadership commitment and organizational culture play a crucial role in shaping the impact of digital initiatives on sustainability outcomes (Dangelico & Pujari, 2010; Wiengarten et al., 2017). At the same time, the World Economic Forum (WEF) has developed various strategies focusing on the role of digital transformation as part of the action to improve the future of the digital economy and society (Pappas et al., 2023). Digitalization of care, participants, communication within the organization, tools, and integration of organizations offers new models for information management that will have a positive impact on human performance and organizational performance, but also create problems related to privacy and security, responsibility. The often conflicting dynamic and digital environment of ecosystems requires a better understanding of the logic of many virtual tools and the opportunities to match them with daily needs (Trocin et al., 2022).
Hypothesis 5 (H5): Digital Transformation holds a strong moderation effect between Circular Economy and Sustainable Entrepreneurship.

## 3. Research Methods

The research design for this study adopts a quantitative approach to explore the complex relationships among circular economy, digital transformation, and sustainable entrepreneurship success. Data collection relies on surveys and questionnaires with eighteen items, facilitated in collaboration with the MSME-Development and Facilitation Office (MSME-DFO), Cuttack. Utilizing a 5-point Likert scale, the surveys capture respondents' perceptions and opinions on the variables of interest. The study employs a random sampling method to estimate a sample size of 326, ensuring a representative participant group. The data analysis phase incorporates statistical methods such as correlation analysis, regression analysis, and structural equation modelling (SEM), employing software like SPSS and Smart PLS on the 5-point Likert scale responses. The electronic survey includes self-assessment, is open to participant discussion and analysis, and potential problems are identified and corrected through empirical observations. A 5-point rating scale ranging from strongly agree to strongly disagree allows a consensus to be reached. Initial distribution to 420 entrepreneurs achieved a response rate of 78%, and 326 completed surveys were considered suitable for further analysis. Structural equation modelling(SEM), an advanced statistical method, is used and selected for its effectiveness in revealing the interaction between work and success. We conducted a rigorous evaluation of validity and reliability and, for the sake of transparency, made the completed survey available for future replication. The study's methodology includes details on the random sampling process and the achieved response rate, contributing to a comprehensive understanding of the research approach.

### 3.1. Measurement Instruments

During the scale-development process, a comprehensive eighteen-item scale was created to measure the three dimensions of entrepreneurship. The scale utilized a five-point Likert scale, with participants indicating their agreement or disagreement on each item. Six items for Circular Economy, five items for Digital transformation, and seven items for Sustainable entrepreneurship are the dimensions and corresponding item counts. To ensure the scale's validity and relevance, items were carefully chosen from prior research that closely matched the specific variables of interest.

#### 3.1.1. Circular Economy

The study developed a six-item scale, using a 5-point scale, spanning from "1: strongly disagree" to "5: strongly agree". Elevated scores indicate greater levels of entrepreneurial pioneering, whereas lower scores indicate lesser levels of entrepreneurial pioneering. Sample

items included “I actively seek ways to reduce, reuse, and recycle materials in my business or daily life to enhance the sustainability of my entrepreneurial ventures”. “How likely are entrepreneurs to adopt Circular Economy principles when starting or running a business?”, “Social responsibility is a fundamental aspect of my business, alongside financial considerations”., “The circular economy contributes significantly to cost savings for my organization”., “Collaboration with community organizations is a regular practice in my entrepreneurial endeavours to contribute to positive social change”., and “I believe that circular economy principles can lead to sustainable business and economic growth”. The scale has been validated in multiple studies, with Cronbach's alpha values fluctuating from 0.6 to 0.8 (Hirschi, 2009). Cronbach's alpha of 0.889 is achieved for this scale, indicating good internal consistency.

#### 3.1.2. Digital Transformation

Digital transformation was assessed using a six-item scale, utilizing a five-point Likert scale for justification. The sample items from the scale were "I actively explore and leverage digital technologies to enhance the efficiency and long-term success of my entrepreneurial activities.", "In my business, I consistently incorporate digital tools for marketing and sales purposes.", "I continuously monitor and adapt to emerging digital trends to stay competitive in the market.", "I am open to experimenting with new and emerging digital technologies to maintain competitiveness.", "Recognizing the importance of digital security, I prioritize measures to protect my business in the digital landscape.", and “I believe that digital technologies, like e-commerce and digital marketing, enable entrepreneurs to create sustainable ventures with a broader societal impact”. The scale confirmed good internal consistency, yielding a Cronbach's Alpha value of 0.932.

#### 3.1.3. Sustainable Entrepreneurship

A 5-point Likert scale was used to measure seven items for the validation of the Sustainable Entrepreneurship Instrument. Sample items included "In my entrepreneurial activities, I actively incorporate friendly practices that contribute to environmental sustainability.", "I am committed to creating a positive social impact through my entrepreneurial ventures.", "I actively seek and implement innovative solutions to address social and environmental challenges in my industry.", "The success of my business is measured not only in financial terms but also by its positive social responsibility and environmental outcomes.", "Collaboration with community organizations is a regular practice in my entrepreneurial endeavours to contribute to positive social change.", “The integration of digital technologies positively influences my commitment to sustainable entrepreneurship,” and “My commitment to sustainable entrepreneurship is strengthened through the adoption of circular economy practices." However, 0.904 is the Cronbach's alpha for the scale, indicating even higher internal consistency.
Building upon the theoretical fortifications discussed above, we have illustrated the study’s hypothetical model in Figure 1.

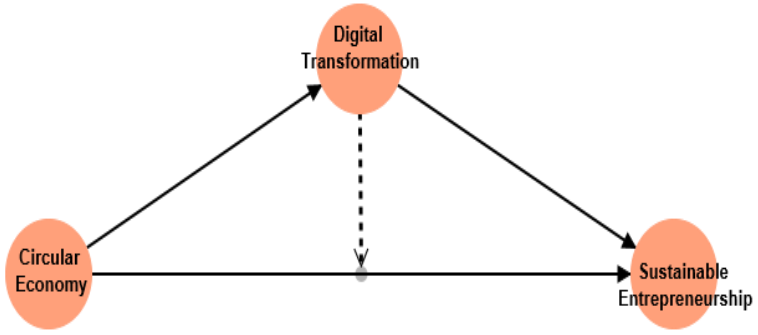


**Fig. 1:** Hypothetical Model.

Source: The Authors.

## 4. Data analysis and Interpretations of Results

The data gathered from the questionnaires underwent analysis through SPSS 26 and SmartPLS PLS4 software. All the construct values set the satisfactory cut-off value of 0.7, as suggested by Nunnally (1978). The seven-item Sustainable entrepreneurship (SUSENT), six-item Circular Economy (CIRECO), and five-item Digital transformation (DIGTRA) produce the Cronbach’s alpha values for scale as 0.889, 0.899, and 0.932, respectively, as given in Table 2. The scale was prepared to commence the acquisition of comprehensive empirical data for the research investigation.
The primary goal of this research was to predict the dependent variable Sustainable Entrepreneurship(SUSENT), widely used in SEM research (Hussain, N., & Li, B., 2022). This was achieved using a two-stage SEM approach, following the model proposed by Hair, Ringle, and Sarstedt (2013). In the first stage, a thorough measurement model assessment was performed to evaluate construct validity and goodness of fit. After confirming a satisfactory measurement model, the study proceeded to the second stage, employing Structural Equation Modelling (SEM) to empirically represent the structural relationships between different constructs through path estimates.

### 4.1. Exploratory Factor Analysis

Kaiser-Meyer-Olkin (KMO) and Bartlett's Sphericity tests are applied to assess sample adequacy for factor analysis, and the obtained values were deemed adequate. The approximate chi-square value was 4510.288 with 153 degrees of freedom, significant at the 5 percent level of significance. The Kaiser-Meyer-Olkin (KMO) statistic yielded a value of 0.901, which exceeds the suggested threshold of 0.50 (Hair et al., 2013) as presented in Table 1.

**Table 1:** KMO and Bartlett's Test

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .901 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 4510.288 |
| | Df | 153 |
| | Sig. | .000 |

Source: Author’s estimation.

## 4.2. Measurement Model Assessment

The measurement model in the factor analysis displays the relationship between constructs and indicators, incorporating Composite Reliability (CR) to assess internal consistency and reliability, and Average Variance Extracted (AVE) to evaluate convergent validity (Hair et al., 2012; Sarstedt et al., 2014).

**Table 2:** Convergent Validity Test of Measurement Mode-Cronbach's Alpha, Composite Reliability (rho_c), and Average Variance Extracted (AVE)

| Constructs | Cronbach's alpha | Composite reliability (rho_a) | Composite reliability (rho_c) | Average variance extracted (AVE) |
|---|---|---|---|---|
| Digital transformation | 0.932 | 0.933 | 0.948 | 0.786 |
| Sustainable Entrepreneurship | 0.889 | 0.895 | 0.913 | 0.601 |
| Circular Economy | 0.899 | 0.905 | 0.922 | 0.664 |

Source: Authors' estimation.

According to Gaskin and Lim (2016, the model is considered excellent if the values of AVE are greater than 0.5 and CR exceeds 0.7. As observed in Table 2, the standards of CR and AVE meet these criteria, affirming the model's reliability and validity. The convergent validity of each critical success factor was assessed using AVE, while reliability was tested using CR. For individual item reliability, each item's outer loadings are evaluated, and it is found that outer loadings values are higher than 0.70 (Sarstedt et al., 2014). Table 3 provides the outer loading values for each item, indicating the strength of the relationship between the observed variables (items) and their respective latent constructs (Digital transformation, Sustainable entrepreneurship, and Circular Economy) in the structural equation model. It is also found that each item's outer loadings are more than 0.70, indicating the sufficiency of the standards of the item's loading.

**Table 3:** Items Outer Loading

| Items | Circular Economy (CIRECO) | Digital Transformation (DIGTRA) | Sustainable Entrepreneurship (SUSENT) |
|---|---|---|---|
| CIRECO1 | 0.794 | | |
| CIRECO2 | 0.801 | | |
| CIRECO3 | 0.826 | | |
| CIRECO4 | 0.821 | | |
| CIRECO5 | 0.816 | | |
| CIRECO6 | 0.830 | | |
| DIGTRA1 | | 0.857 | |
| DIGTRA2 | | 0.893 | |
| DIGTRA3 | | 0.898 | |
| DIGTRA4 | | 0.898 | |
| DIGTRA5 | | 0.886 | |
| SUSENT1 | | | 0.801 |
| SUSENT2 | | | 0.759 |
| SUSENT3 | | | 0.740 |
| SUSENT4 | | | 0.743 |
| SUSENT5 | | | 0.780 |
| SUSENT6 | | | 0.802 |

Source: Author's Estimation.

For Circular Economy (CIRECO), items CIRECO1 to CIRECO6 also demonstrate notable outer loading values, ranging from 0.794 to 0.830, indicating a significant relationship between these items and the Circular Economy construct. For Digital Transformation (DIGTRA), items DIGTRA1 to DIGTRA5 have high outer loading values ranging from 0.857 to 0.898. These values suggest a strong association between these items and the Digital transformation construct.

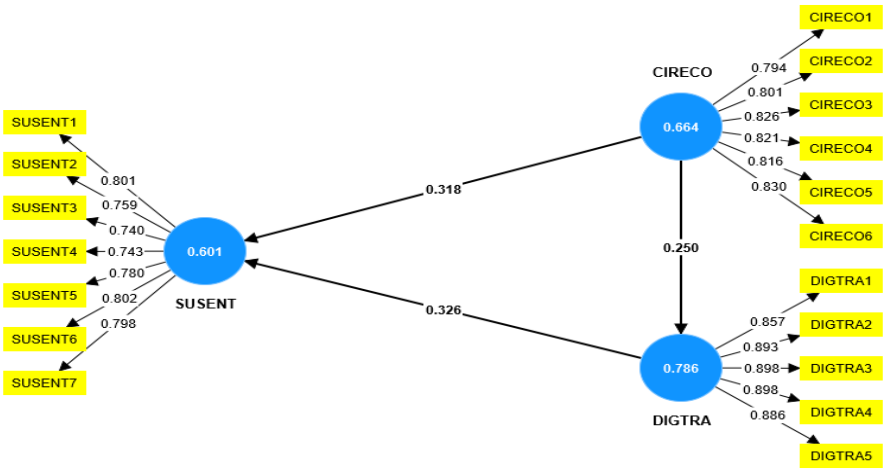


**Fig. 2:** Three Factor Measurement Model with AVE and Outer Loading.

Similarly, for Sustainable entrepreneurship (SUSENT), items SUSENT1 to SUSENT7 exhibit substantial outer loading values, ranging from 0.740 to 0.802. These values indicate a robust connection between these items and the Sustainable entrepreneurship construct. The items selected for each construct (Digital transformation, Sustainable entrepreneurship, and Circular Economy) are meaningful and contribute significantly to measuring their respective constructs. The three-factor measurement model and structural model are depicted in Figure 3 and Figure 4, respectively.

## 4.3. Discriminant Validity

Discriminant validity is evident among all the study constructs. To validate this, the Heterotrait-Monotrait (HTMT) technique proposed by Fornell and Larcker (1981) was utilized, which evaluates discriminant validity by analyzing the intercorrelations between a specific construct of interest and all other indicators in the model. Values below 0.85 indicate the achievement of discriminant validity (Kline, 2015).

**Table 4:** A) HTMT Ratio-Coefficients

| The latent variables | Coefficients of Heterotrait-monotrait ratio (HTMT) |
|---|---|
| DIGTRA <-> CIRECO | 0.271 |
| SUSENT <-> CIRECO | 0.436 |
| SUSENT <-> DIGTRA | 0.438 |

Source: Author's estimation.

HTMT values close to 1 indicate a lack of discriminant validity. Table 4a fulfils the HTMT ratio procedure, with all values in the matrix being less than 0.85 for inter-construct correlations. The HTMT Ratio-coefficients associated with each of the latent variables varied from 0.271 to 0.438, all of which are below the threshold value of 0.85, given in Table 4a.

**Table 4:** B) Fornell and Larcker Criterion for Discriminant Validity

| | CIRECO | DIGTRA | SUSENT |
|---|---|---|---|
| CIRECO | 0.815 | | |
| DIGTRA | 0.25 | 0.887 | |
| SUSENT | 0.4 | 0.406 | 0.775 |

Source: Author's estimation.

The correlations between latent variables and the diagonal values, presented as bold off-diagonal numbers, were evaluated based on the Fornell and Larcker criteria in Table 4 b (Ab Hamid et al., 2017). There were no indications of any issues or concerns with this HTMT analysis (in Table 4a and 4b, as specified by Gaskin and Lim (2016).

## 4.4. Structural Model Assessment

The structural model describes the path relationships between the endogenous and exogenous variables in the conceptual research model. In the structural modelling, we assessed the presence of multicollinearity using the Variance Inflation Factor (VIF) values, a measure that quantifies the degree of correlation among predictor variables. According to established literature, multicollinearity is considered problematic when VIF exceeds a threshold of 5 (Hair, Ringle, and Sarstedt, 2013). VIF values for Digital Transformation (DIGTRA) items (DIGTRA1 to DIGTRA5) range from 2.63 to 3.608, indicating a moderate to high level of multicollinearity among these variables. Similarly, VIF values for Sustainable entrepreneurship (SUSENT) items (SUSENT1 to SUSENT7) range from 1.906 to 2.394, suggesting a moderate degree of correlation among the SUSENT items without reaching an alarming extent. The VIF values for Circular Economy (CIRECO) items (CIRECOf1 to CIRECO6) range from 1.892 to 2.709, demonstrating a moderate level of multicollinearity among these variables, akin to the pattern observed in Sustainable entrepreneurship, given in Table 5.

**Table 5:** Collinearity Matrix of Items of the Outer Model

| Items | VIF |
|---|---|
| CIRECO1 | 1.892 |
| CIRECO2 | 2.060 |
| CIRECO3 | 2.310 |
| CIRECO4 | 2.486 |
| CIRECO5 | 2.645 |
| CIRECO6 | 2.709 |
| DIGTRA1 | 2.630 |
| DIGTRA2 | 3.343 |
| DIGTRA3 | 3.317 |
| DIGTRA4 | 3.608 |
| DIGTRA5 | 3.334 |
| SUSENT1 | 2.322 |
| SUSENT2 | 2.145 |
| SUSENT3 | 1.906 |
| SUSENT4 | 1.922 |
| SUSENT5 | 2.329 |
| SUSENT6 | 2.394 |

Source: Author's estimation.

Variance Inflation Factors (VIF) for collinearity statistics among constructs in the inner model are examined in Table 6. The VIF values close to 1 indicate that there is little to no multicollinearity among the constructs in the inner model. This is a positive finding that the relationships between Digital transformation, Sustainable entrepreneurship, and Circular Economy can be independently examined without the interference of high multicollinearity.

**Table 6:** Collinearity Statistics of Constructs of the Inner Model

| | VIF |
|---|---|
| DIGTRA -> SUSENT | 1.067 |
| CIR ECO -> DIGTRA | 1.000 |
| CIR ECO -> SUSENT | 1.067 |

Source: Author's estimation.

The structural relationships within our model are stoutly supported by the statistical analyses. The path coefficients reveal significant positive associations between Digital transformation and Sustainable entrepreneurship (0.326), Circular Economy and Digital transformation (0.250), and Circular Economy and Sustainable entrepreneurship (0.318), given in Figures 1 and 2. The t-values, such as 6.537, 4.802, and 6.663, are notably high, reinforcing the statistical significance of these relationships (all p-values = 0). These results affirm that increases in Digital transformation and Circular Economy are strongly linked to corresponding increases in Sustainable entrepreneurship.
A standard bootstrapping technique is used to determine the implications of path coefficients, p-values, t-values, and the value of $R^2$. The approach involved employing 5000 bootstrap samples methodologies (Reinartz et al., 2009; Hair et al., 2014). A good model should have an SRMR value of less than 0.08 (Henseler et al., 2016; Hair et al., 2014), given in Table 7. In this study, the SRMR value is 0.058, which is lower than the threshold, signifying a good model fit. SRMR (Standardized Root Mean Square Residual) is a statistic that measures the discrepancy between the estimated model and the observed data. A lower SRMR indicates better model fit. In this case, both the saturated and estimated models have the same SRMR of 0.058, suggesting a good fit.

**Table 7:** Structural Model Fit Indices

| | Saturated model | Estimated model |
|---|---|---|
| SRMR | 0.058 | 0.058 |
| d_ULS | 0.575 | 0.575 |
| d_G | 0.250 | 0.250 |
| Chi-square | 580.539 | 580.539 |
| NFI | 0.874 | 0.874 |

Source: Author's estimation.

The d_ULS (Unweighted Least Squares) value of 0.575 measures the discrepancy between observed and predicted matrices. Smaller values indicate a better fit. The identical values for both models suggest that they have the same level of fit according to this index. The d_G (GFI Incremental Fit Index) of 0.250 is another measure of the incremental fit of the estimated model compared to a baseline model. A value of 0.250 suggests that the identical values for both models suggest a consistent level of fit. The chi-square value of 580.539 is a statistic used to assess how well the estimated model fits the data. Lower chi-square values indicate a better fit. In both cases, the chi-square values are the same, indicating that the estimated model does not significantly differ from the saturated model. However, the chi-square test is sensitive to sample size, so other fit indices are often considered alongside it.
The NFI (Normed Fit Index) value of 0.874 is a normed fit index that measures how well the estimated model reproduces the observed data. Values closer to 1 indicate a better fit. The identical NFI values for both models suggest a good fit. A value of 0.874 suggests that the model provides a reasonable fit to the data, although higher values are generally desired. The estimated model appears to provide a relatively good fit to the data. The SRMR, d_ULS, d_G, and NFI values all suggest that the model is fitting the data reasonably well (Table 7).

### 4.5. Model Fit with The Bayesian Information Criterion

The Bayesian Information Criterion (BIC) is a statistical criterion used for model selection. The BIC is calculated using the likelihood function and a penalty term based on the number of parameters in the model. The model with the lower BIC is considered a better fit. A BIC less than 0 favours the hypothesized model (Bauldry,2015).

**Table 8:** Model Fit with The Bayesian Information Criterion

| The latent variables | BIC (Bayesian information criterion) |
|---|---|
| Digital transformation (DIGTRA) | -14.026 |
| Sustainable entrepreneurship (SUSENT) | -99.3 |

Source: Author's estimation.

#### 4.5.1. Digital Transformation Model

Table 8 depicts the BIC value of -14.026, which suggests a relatively good fit for the Digital Transformation model. Lower BIC values indicate a better trade-off between model fit and complexity.

#### 4.5.2. Sustainable Entrepreneurship Model

The BIC value of -99.300 is substantially lower than the BIC for the Digital transformation model (-14.026). This implies that, based on the BIC criterion, the Sustainable entrepreneurship model is a better fit (Table 8).
To sum up, the Sustainable entrepreneurship model, with a BIC of -99.300, is considered to have a better fit according to the BIC criterion compared to the Digital transformation model with a BIC of -14.026. Lower BIC values generally indicate better-fitting models, considering both goodness of fit and model complexity.

## 5. Hypothesis Testing

To ascertain the significance and relevance of the relationships in the structural model, t-values are compared to the critical t-values for a significance level of 0.05(given in Table 9). Bias-corrected confidence intervals play a crucial role in assessing the precision and reliability of estimated path coefficients in structural modelling. These intervals provide a more accurate range for the true population parameters by addressing potential biases in the estimation process. Interpretation of bias-corrected confidence intervals involves considering both the point estimate and the range within which the true parameter is likely to fall. Path Coefficients- Confidence intervals, bias corrected, and it interpretations are given in Table 10.

### 5.1. Hypothesis 1 (H1)

There is a direct and substantial positive relationship between the Circular Economy and Sustainable entrepreneurship.

**Table 9:**

| Path coefficients | Hypothesis | Original sample (O) | Standard deviation (STDEV) | T statistics (\|O/STDEV\|) | p- values |
|---|---|---|---|---|---|
| CIRECO -> SUSENT | H1 | 0.318 | 0.048 | 6.663 | 000 |
| CIRECO -> DIGTRA | H2 | 0.250 | 0.052 | 4.802 | 000 |
| DIGTRA -> SUSENT | H3 | 0.326 | 0.05 | 6.537 | 000 |
| CIRECO -> DIGTRA -> SUSENT (Mediating) | H4 | 0.082 | 0.023 | 3.535 | 000 |
| DIGTRA x CIRECO -> SUSENT(Moderating) | H5 | -0.165 | 0.045 | 3.648 | 000 |

Source: Author's estimation.

The path coefficient for " Circular Economy -> Sustainable entrepreneurship " is 0.318, indicating the relationship from Circular Economy to Sustainable entrepreneurship. The t-value of 6.663 is highly significant (p-value = 0), suggesting that this relationship is statistically significant(Table 9). Similar to the other relationships, a positive coefficient implies that an increase in Circular Economy is associated with a significant increase in Sustainable entrepreneurship. The estimated path coefficient is 0.318, and the bias-corrected confidence interval suggests that the true population parameter is likely to fall between 0.224 and 0.408 with 95% confidence. The bias correction helps provide a more accurate range for the parameter. (Table 10).

## 5.2. Hypothesis 2 (H2)

There is a significant positive relationship between the Circular Economy and Digital transformation.
The path coefficient for " Circular Economy -> Digital transformation " is 0.250, representing the relationship from Circular Economy to Digital transformation. The t-value of 4.802 is highly significant (p-value = 0), indicating that this relationship is statistically significant (Table 9). A positive coefficient suggests that an increase in the Circular Economy is associated with a significant increase in Digital transformation. The estimated path coefficient is 0.250, and the bias-corrected confidence interval suggests that the true population parameter is likely to fall between 0.141 and 0.345 with 95% confidence. The bias correction addresses potential biases in the estimation process (Table 10).

## 5.3. Hypothesis 3 (H3)

There is a positive and statistically significant relationship between Digital transformation and Sustainable entrepreneurship.
The path coefficient for "Digital transformation -> Sustainable entrepreneurship" is 0.326, indicating the strength and direction of the relationship from Digital transformation to Sustainable entrepreneurship. The t-value of 6.537 is highly significant (p-value = 0), suggesting that this relationship is statistically significant. The effect is positive, indicating that an increase in Digital transformation is associated with a significant increase in Sustainable entrepreneurship (Table 9). The estimated path coefficient is 0.326, and the bias-corrected confidence interval suggests that the true population parameter is likely to fall between 0.223 and 0.42 with 95% confidence(Table 10). The bias correction accounts for potential biases in the estimation.

**Table 10:** Path-Coefficients Confidence Intervals Bias Corrected

| The latent variables | Original | Sample | Bias | 2.50% | 97.50% |
|---|---|---|---|---|---|
| CIRECO -> SUSENT | 0.318 | 0.321 | 0.002 | 0.224 | 0.408 |
| CIRECO -> DIGTRA | 0.250 | 0.255 | 0.005 | 0.141 | 0.345 |
| DIGTRA -> SUSENT | 0.326 | 0.328 | 0.001 | 0.223 | 0.420 |
| CIRECO -> DIGTRA -> SUSENT (Mediating) | 0.082 | 0.084 | 0.002 | 0.041 | 0.130 |
| DIGTRA x CIRECO -> SUSENT(Moderating) | -0.165 | -0.160 | 0.005 | -0.249 | -0.073 |

Source: Author's estimation.

## 5.4. Mediating Effect

The mediation propositions evaluate the significant associations between the independent-dependent variable, independent-mediating variable, and mediating-dependent variable by using Baron and Kenny's (1986) technique.

### 5.4.1. Hypothesis 4 (H4)

Digital transformation (DIGTRA) mediates the relationship between Circular Economy and Sustainable entrepreneurship (SUSENT) significantly.
The hypothesis (4) test for the path "Circular Economy -> Digital transformation -> Sustainable entrepreneurship" yields a highly significant result (p-value = 0). Therefore, there is strong evidence to reject the null hypothesis, indicating that there is a statistically significant relationship between Circular Economy, Digital transformation, and Sustainable entrepreneurship. The positive point estimate (0.082) suggests a positive association, and the t-statistic of 3.535 further reinforces the statistical significance of this relationship (Table 9).
The total indirect effect (path coefficient) from Circular Economy to Sustainable entrepreneurship via Digital transformation is estimated to be 0.082 in the original sample. The bias-corrected confidence interval (0.041 to 0.130) suggests that we can be 95% confident that the true population parameter for this indirect effect falls within this range (Table 10). The sample mean and bias help contextualize the point estimate. The positive point estimate indicates a positive indirect effect, suggesting that higher levels of Circular Economy contribute to increased Sustainable entrepreneurship through the mediator Digital transformation.

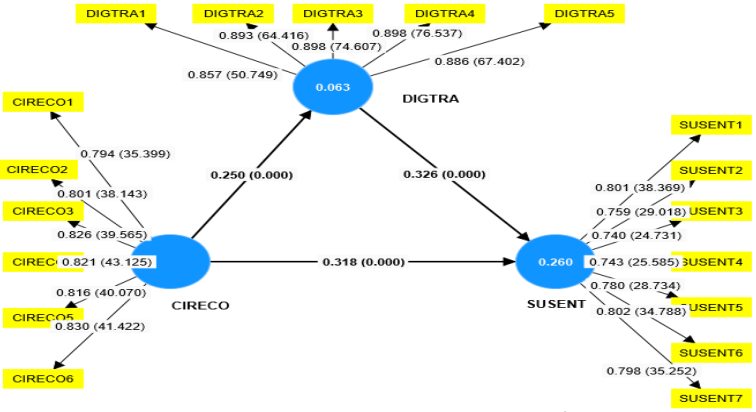


**Fig. 3:** Three Factor Structural Model with $R^2$.

Source: Author's estimation.

## 5.5. Moderation Effect

The moderating effect (H5) represented by the interaction term DIGTRA x CIRECO -> SUSENT reveals valuable insights.
Hypothesis 5 (H5): Digital Transformation holds a strong moderation effect between Circular Economy and Sustainable Entrepreneurship. The path coefficient of -0.165, with a significant T-value of 3.648 ($p < 0.001$), suggests that the combined influence of Digital Transformation (DIGTRA) and Circular Economy (CIRECO) practices hurts Sustainable Entrepreneurship (SUSENT) (Table 9 & Figure 4). This implies that the simultaneous emphasis on both digital and circular strategies is associated with a reduction in sustainable entrepreneurial success. The refined interpretation is substantiated by the tight confidence interval (CI) of -0.160 to -0.073, reinforcing the robustness of the finding(Table 10). In practical terms, organizations should approach the integration of digital and circular initiatives judiciously, recognizing potential complexities or trade-offs that might affect the desired sustainable outcomes. Regular monitoring and strategic adaptation are paramount to navigating this nuanced relationship effectively.

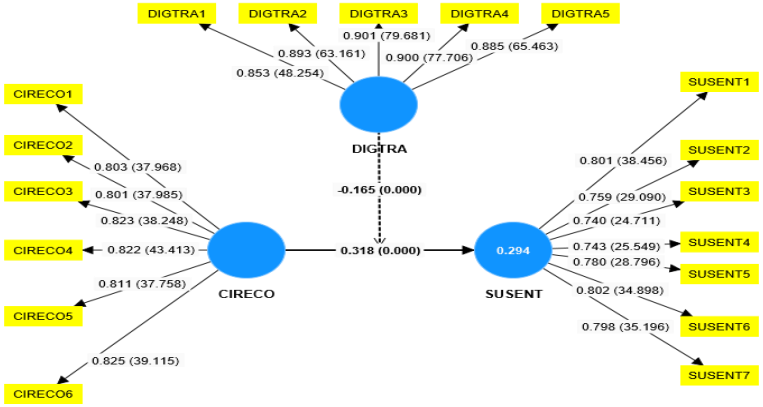


**Fig. 4:** Three Factor Moderation Effect Structure Model.

Source: Author's estimation.

Digital Transformation(DIGTRA) moderates the relationship between Circular Economy(CIRECO) and Sustainable entrepreneurship(SUSENT) such that higher levels of Digital Transformation(DIGTRA) are associated with high levels of Circular Economy(CIRECO) are associated with high levels of Sustainable entrepreneurship(SUSENT) when Circular Economy(CIRECO) increases from low to high.

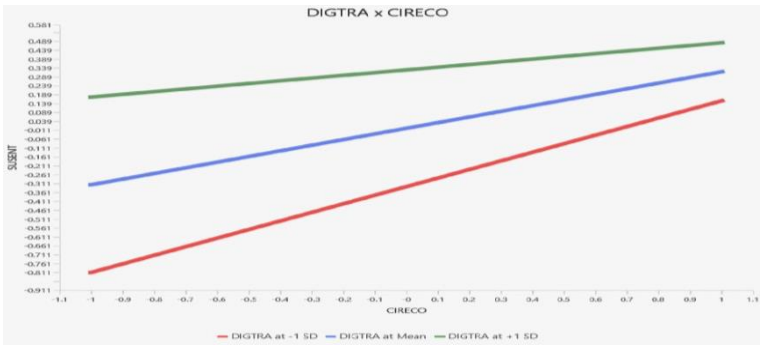


**Fig. 5:** Significance of Moderation Effect with Simple Slope Analysis.

Source: Author's estimation.
To follow-up on this interaction, we calculate the Estimated Marginal Means (EMMs) of sustainable entrepreneurship at different levels (-1 SD/ mean/ +1 SD) of circular economy, and at different levels (-1 SD/ mean/ +1 SD) of digital transformation, and test for the effect

of circular economy at different levels of digital transformation with simple slopes analysis. Figure 5 demonstrates how digital transformation (DIGTRA) moderates the relationship between circular economy practices (CIRECO) and sustainable entrepreneurship (SUSENT) among MSMEs. The three lines illustrate this effect at different DIGTRA levels:

- Low DIGTRA (Red line, −1 SD, Slope = 0.483): MSMEs with low digital adoption show the strongest positive effect. Here, circular practices efficiently translate into sustainable entrepreneurship without complex digital demands.
- Mean DIGTRA (Blue line, Slope = 0.318): This represents the average positive effect for MSMEs with moderate digital transformation.
- High DIGTRA (Green line, +1 SD, Slope = 0.153): MSMEs with extensive digital adoption exhibit the weakest direct effect. Extensive digitalization appears to diminish the immediate benefits of circular practices.

This pattern confirms the negative moderating effect (H5): excessive digital transformation can initially weaken the direct positive impact of CE practices on MSMEs' sustainable entrepreneurship. A significant p-value substantiates this finding. This supports our theoretical premise that resource strain, technological complexity, and capability gaps in MSMEs can limit short-term CE benefits under heavy digitalization.

## 5.6. R2 and f2 Effect Size

The value of $R^2$ is employed to evaluate the portion of variability in the dependent variable that can be accounted for by one or multiple independent variables (Fassott et al., 2016). In this study, the value of $R^2$ is found to be acceptable based on the study's requirements. Falk and Miller (1992) suggest that a value above 0.10 is acceptable for $R^2$. Conversely, $R^2$ values are categorized into three ways: 0.60 as good, 0.33 as moderate, and 0.19 as weak (Chin et al., 2003).

**Table 11:** R-Square and R-Square Adjusted

| | R-square | R-square adjusted |
|---|---|---|
| Digital transformation | 0.063 | 0.06 |
| Sustainable entrepreneurship | 0.26 | 0.256 |

Source: Author's estimation.

The model's explanatory power is examined through the R-squared and adjusted R-squared values. Table 11 represents the R-squared of 0.063, suggesting that 6.3% of its variance is explained by the model, with an adjusted R-squared of 0.06, considering model complexity for Digital transformation. In the case of Sustainable entrepreneurship, the R-squared of 0.26 indicates that approximately 26% of its variance is accounted for by the predictors, and the adjusted R-squared is 0.256. While the model demonstrates a moderate ability to explain the variability in Sustainable entrepreneurship, both adjusted R-squared values imply that other factors not included in the model contribute to these constructs.

Cohen's f2 is a measure of the proportion of variance in the dependent variable that is explained by a predictor variable, relative to the unexplained variance. An f2 of 0.02, 0.15, and 0.35 is considered small, medium, and large, respectively (Cohen,1992). The f-square values provide a practical measure of the contributions of Digital transformation and Circular Economy to the variance in Sustainable entrepreneurship and Digital transformation, respectively. These effect sizes support the notion that both Digital transformation and Circular Economy are meaningful predictors, substantiating their relevance in understanding and explaining the observed variability in Sustainable entrepreneurship and Digital transformation, represented in Table 12.

**Table 12:** Cohen's $F^2$ and Effect Size

| | f-square | Effect |
|---|---|---|
| Digital transformation -> Sustainable entrepreneurship | 0.135 | Moderate impact |
| Circular Economy -> Digital transformation | 0.067 | Moderate impact |
| Circular Economy -> Sustainable entrepreneurship | 0.128 | Moderate impact |

Source: Author's estimation.

Digital transformation -> Sustainable entrepreneurship: The f-square of 0.135 indicates that 13.5% of the variance in Sustainable entrepreneurship is explained by the predictor Digital transformation(Table 12). This effect size suggests a moderate impact, indicating that the inclusion of Digital transformation in the model contributes significantly to explaining the variability in Sustainable entrepreneurship.
Circular Economy -> Digital transformation: The f-square of 0.067 suggests that 6.7% of the variance in Digital transformation is explained by the predictor Circular Economy (Table 12). This effect size indicates a moderate impact, highlighting the meaningful contribution of the Circular Economy to the variability in Digital transformation.
Circular Economy -> Sustainable entrepreneurship: With an f-square of 0.128, approximately 12.8% of the variance in Sustainable entrepreneurship is explained by the predictor Circular Economy(Table 12). This effect size suggests a moderate impact, emphasizing the significant role of the Circular Economy in accounting for the variability in Sustainable entrepreneurship.

## 5.7. Discussion and Findings

This study set out to uncover the intricate connections linking Circular Economy (CE), Digital Transformation (DT), and Sustainable Entrepreneurship (SE) among MSMEs in an emerging economy. Our core findings confirm that CE positively influences both SE (H1) and DT (H2), and importantly, DT itself significantly contributes to sustainable entrepreneurial outcomes (H3). These results resonate with prior research (Schaltegger & Wagner, 2011; Al-Khatib, 2024), underscoring how digital and circular strategies collectively propel sustainability-focused ventures.

A pivotal theoretical discovery is the validation of DT's mediating role (H4) between CE and SE. This means that when digital capabilities are present, circular practices are far more effective in translating into entrepreneurial success. This insight supports both the Resource-Based View (RBV) and Innovation Diffusion Theory, showing that technology acts as a strategic engine for disseminating circular innovation through entrepreneurial avenues.

Intriguingly, the study also revealed a significant negative moderating effect of DT (H5) on the direct CE–SE relationship. This counter-intuitive finding indicates that, surprisingly, high levels of digitalization can actually dilute the direct positive impact of circular practices on sustainable entrepreneurship. Successful integration of digital and CE orientations boosts SME innovation, whereas poor integration hinders it (Arroyabe,2024). This unexpected outcome could stem from:

- The added complexity of managing both CE and DT initiatives concurrently.

- The strain on limited resources for MSMEs with nascent digital maturity.
- Gaps in critical skills or infrastructure that impede seamless DT integration.

This result highlights a crucial paradox within Transition Management Theory: while digitalization is vital for long-term transitions, it can inadvertently hinder short-term value creation if not carefully implemented and supported.

#### 5.7.1. Generalizability of Findings

While our investigation centred on MSMEs in Cuttack, India, its implications extend to similar developing economies globally. Countries such as Bangladesh, Vietnam, and Kenya share comparable MSME characteristics – including scarce financial and digital resources, a rising interest in sustainability, and increasing exposure to digital technologies (Nath et al.,2024; Vo Thai et al.,2025; Tyson et al.,2020; Vu & Nguyen,2022; Mutegi et al., 2023). Therefore, the identified mediating and moderating roles of digital transformation in circular economy-driven entrepreneurship likely hold broad relevance, though specific outcomes might be shaped by local regulatory support and digital infrastructure. Future research is encouraged to validate these results through cross-country comparative studies to bolster their generalizability.

## 6. Implications and Limitations of The Study

### 6.1. Theoretical Implications

The research study unveils several critical findings, each bearing substantial implications for theory, practice, and entrepreneurial endeavours. First, the positive and significant relationship between Circular Economy and Sustainable Entrepreneurship (H1) (Path Coefficient = 0.318, $p < 0.001$) establishes a crucial theoretical linkage. This result supports the theoretical framework, suggesting that the adoption of circular economy principles positively influences the development of sustainable entrepreneurial practices. Organizations aligning their operations with circularity are more likely to foster sustainable entrepreneurship, contributing to environmental and social objectives.

The second hypothesis, Circular Economy -> Digital Transformation (H2) (Path Coefficient = 0.250, $p < 0.001$), reveals a noteworthy connection between circular economy practices and digital transformation initiatives. The theoretical implication is that businesses committed to circularity are also inclined to undergo digital transformations. This suggests a synergistic relationship where organizations, in embracing circular economy principles, concurrently leverage digital technologies to enhance operational efficiency and innovation.

The third hypothesis, Digital Transformation -> Sustainable Entrepreneurship (H3) (Path Coefficient = 0.326, $p < 0.001$), underscores the role of digital transformation in shaping sustainable entrepreneurial practices. The positive and significant association suggests that organizations undergoing digital transformation are more likely to engage in sustainable entrepreneurial activities. This finding contributes to the theoretical understanding that digital technologies act as enablers, facilitating the integration of sustainability into entrepreneurial ventures.

The fourth hypothesis introduces a mediating relationship, Circular Economy -> Digital Transformation -> Sustainable Entrepreneurship (H4, Mediating) (Path Coefficient = 0.082, $p < 0.001$). This result implies that the influence of circular economy on sustainable entrepreneurship is partially explained by the mediating role of digital transformation. The theoretical implication is that digital technologies serve as a conduit through which circular economy practices translate into sustainable entrepreneurial success.

### 6.2. Practical Implication

The practical implications of the study are twofold. First, the positive and significant relationship between Circular Economy and Digital Transformation (H2) suggests a strategic opportunity for organizations to align their operations with circularity while simultaneously leveraging digital technologies. Practically, this implies that companies embracing circular economy practices can explore the adoption of digital solutions, such as IoT and AI, to optimize resource usage and enhance overall operational efficiency.

Second, the positive association between Digital Transformation and Sustainable Entrepreneurship (H3) emphasizes the practical importance of technological advancements in fostering sustainability within entrepreneurial activities. Organizations undergoing digital transformations are encouraged to explicitly integrate sustainability goals into their strategies, leveraging digital tools for eco-friendly product development, supply chain optimization, and energy efficiency. These practical insights provide a roadmap for businesses to simultaneously pursue circularity, digital transformation, and sustainable entrepreneurial success.

Policy Implications: In addition to the strategies pursued by individual firms, governments and development agencies possess a crucial role in expediting the CE–DT–SE transition. This acceleration can be achieved through various forms of targeted assistance, such as offering subsidies for the adoption of IoT and AI technologies, establishing comprehensive digital literacy programs, providing tax incentives for businesses that implement certified circular practices, and creating regulatory sandboxes that allow micro, small, and medium-sized enterprises (MSMEs) to securely experiment with cutting-edge sustainable innovations (Arroyabe,2024). Collectively, these initiatives are designed to cultivate an enabling environment for the growth of circular and digital entrepreneurship.

### 6.3. Entrepreneurial Implications

Entrepreneurial implications emerge from the interplay of circular economy, digital transformation, and sustainable entrepreneurship. Entrepreneurs can identify innovation opportunities at the intersection of these trends, developing solutions that address both environmental concerns and digital needs. Market positioning becomes a key consideration for businesses with a strong focus on circularity and digital transformation, appealing to environmentally conscious consumers and investors. However, the study highlights the importance of understanding these interconnected trends for effective risk management in entrepreneurial ventures. In summary, the theoretical, practical, and entrepreneurial implications provide a comprehensive guide for academics, practitioners, and entrepreneurs navigating the evolving landscape of sustainable business practices.

## 7. Limitations and Future Research

While this study offers valuable insights, it has certain limitations that open avenues for future research:
Contextual Generalizability: The study is based on MSMEs in Cuttack, India, which may limit direct generalization. However, similar MSMEs in Bangladesh, Vietnam, and Kenya share characteristics such as limited resources, growing sustainability interest, and emerging digital adoption (Nath et al.,2024; Vo Thai et al.,2025; Tyson et al.,2020; Vu & Nguyen,2022; Mutegi et al., 2023). Future research could validate these findings through cross-country comparative studies.
Technology-Specific Insights: Digital transformation was treated as a unified construct, but technologies like IoT, AI, and blockchain may have different effects on CE and SE outcomes. Future studies could disaggregate DT to uncover technology-specific impacts.
Moderation Complexity: The negative moderating effect of DT (H5) suggests implementation challenges for resource-constrained MSMEs. Future research should use longitudinal and qualitative designs to better understand when and why DT weakens CE–SE relationships.
Methodological Considerations: This study used a cross-sectional survey, which limits causal inference. Future work could adopt longitudinal or mixed-method approaches to observe dynamic changes over time.

## 8. Conclusion Top of Form

This research explored the intricate relationship among Circular Economy (CE) practices, Digital Transformation (DT), and Sustainable Entrepreneurship (SE) among MSMEs in an emerging economy. The results indicate that CE practices directly bolster SE and encourage DT adoption, affirming circularity's role as a fundamental driver of sustainable entrepreneurship. Digital Transformation (DT) exhibits a dual function: it serves as a mediator in the CE–SE linkage, facilitating the conversion of circular practices into sustainable outcomes; however, it simultaneously acts as a negative moderator at advanced stages of digitalization due to complexities and resource limitations. The study contributes significantly to both academic theory and practical application by demonstrating that sustainable entrepreneurship in developing contexts flourishes with a phased, context-sensitive approach to digital adoption, particularly when aligned with circular strategies.
Limitations include the study's confinement to the Indian MSME landscape and its cross-sectional survey design, which restricts causal inference. Subsequent research ought to explore cross-country comparisons, conduct longitudinal studies, and perform technology-specific analyses to capture evolving dynamics more comprehensively. In essence, these findings provide a clear roadmap for entrepreneurs and policymakers to harness digital transformation in alignment with circular economy principles, thereby fostering resilient and sustainable business ecosystems

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## Conflicting Interest

There is no conflicting interest between the contributing authors for this paper.

## Author Contributions

All authors have equally contributed to accomplish the work within a specific time limit.

## Ethical Approval

The ethical committee of the university provided approval for primary data collection.

## References

[1] "EllenMacArthurFoundation - Intelligent Assets," pp. 19–39, 2016.
[2] Agal, S., Bhavsar, N., Shekokar, K., & Shrivastava, S. S. (2025). A unified framework for smart and secure digital transformation: Leveraging block chain, AI, and ICT across Healthcare, Education, E-Commerce, and Industrial Systems.
[3] Aguilar-Hernandez, G. A., Sigüenza-Sanchez, C. P., Donati, F., Rodrigues, J. F., & Tukker, A. (2018). Assessing circularity interventions: a review of EEIOA-based studies. *Journal of Economic Structures*, *7*(1), 1-24. https://doi.org/10.1186/s40008-018-0113-3.
[4] Ali, S. R., Abbas, M., Qasim, S., & Faraz, M. (2024). Sustainable Tech Entrepreneurship and Green Innovation: Driving Resilience and Environmental Impact through Digital Transformation and Circular Business Models. *Bulletin of Multidisciplinary Studies*, *1*(4), 156-167. https://doi.org/10.48112/bms.v1i4.938.
[5] Al-Khatib, A. W. (2024). Enabling the circular economy in the digital transformation era: evidence from an emerging country. *Kybernetes*, *53*(2), 779-802. https://doi.org/10.1108/K-02-2023-0297.
[6] Antikainen, M., Uusitalo, T., & Kivikytö-Reponen, P. (2018). Digitalisation as an enabler of circular economy. *Procedia Cirp*, *73*, 45-49. https://doi.org/10.1016/j.procir.2018.04.027.
[7] Arroyabe, M. F., Arranz, C. F., & de Arroyabe, J. C. F. (2024). The integration of circular economy and digital transformation as a catalyst for small and medium enterprise innovation. *Business Strategy and the Environment*, *33*(7), 7162-7181. https://doi.org/10.1002/bse.3858.
[8] Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*(23-28).
[9] Bansal, P., & DesJardine, M. R. (2014). Business sustainability: It is about time. *Strategic organization*, *12*(1), 70-78. https://doi.org/10.1177/1476127013520265.
[10] Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of management*, *17*(1), 99-120. https://doi.org/10.1177/014920639101700108.

[11] Bauldry, S. (2015). Structural Equation Modeling. International Encyclopedia of the Social & Behavioral Sciences, 615–620. https://doi.org/10.1016/B978-0-08-097086-8.44055-9.

[12] Berman, S. J. (2012). Digital transformation: opportunities to create new business models. *Strategy & leadership*, *40*(2), 16-24. https://doi.org/10.1108/10878571211209314.

[13] Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview. *Journal of cleaner production*, *45*, 1-8. https://doi.org/10.1016/j.jclepro.2012.08.013.

[14] Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. WW Norton & Company.

[15] Christensen, C. M. (2006). The ongoing process of building a theory of disruption. *Journal of Product innovation management*, *23*(1), 39-55. https://doi.org/10.1111/j.1540-5885.2005.00180.x.

[16] Colombi, C., & D'Itria, E. (2023). Fashion digital transformation: Innovating business models toward circular economy and sustainability. *Sustainability*, *15*(6), 4942. https://doi.org/10.3390/su15064942.

[17] Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of business ethics*, *95*, 471-486. https://doi.org/10.1007/s10551-010-0434-0.

[18] Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of business ethics*, *95*, 471-486. https://doi.org/10.1007/s10551-010-0434-0.

[19] Dean, T. J., & McMullen, J. S. (2007). Toward a theory of sustainable entrepreneurship: Reducing environmental degradation through entrepreneurial action. *Journal of business venturing*, *22*(1), 50-76. https://doi.org/10.1016/j.jbusvent.2005.09.003.

[20] Ellen MacArthur Foundation, Towards a circular economy: Business rationale for an accelerated transition (2015). https://www.ellenmacarthurfoundation.org/towards-a-circular-economy-business-rationale-for-an-accelerated-transition.

[21] Falk, R. F., & Miller, N. B. (1992). *A primer for soft modeling*. University of Akron Press.

[22] Fassott, G., Henseler, J., & Coelho, P. S. (2016). Testing moderating effects in PLS path models with composite variables. *Industrial management & data systems*, *116*(9), 1887-1900. https://doi.org/10.1108/IMDS-06-2016-0248.

[23] Fernandes, C. I., Veiga, P. M., & Ramadani, V. (2023). Entrepreneurship as a transition to the circular economy. *Environment, Development and Sustainability*, 1-13. https://doi.org/10.1007/s10668-023-03513-5.

[24] Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. https://doi.org/10.2307/3150980

[25] Gaskin, J., & Lim, J. (2016). Model fit measures. *Gaskination's StatWiki*, *37*(3), 814-822. https://doi.org/10.1108/IJM-12-2014-0268.

[26] Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. *Journal of cleaner production*, *143*, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048

[27] Geng, Y., Sarkis, J., & Bleischwitz, R. (2019). How to globalize the circular economy. *Nature*, *565*(7738), 153-155. https://doi.org/10.1038/d41586-019-00017-z.

[28] Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner production*, *114*, 11-32. https://doi.org/10.1016/j.jclepro.2015.09.007.

[29] Gimpel, H., & Röglinger, M. (2015). Digital transformation: changes and chances–insights based on an empirical study.

[30] Hair Jr, J. F., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European Business Review*, *26*(2), 106-121. https://doi.org/10.1108/EBR-10-2013-0128

[31] Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long range planning*, *46*(1-2), 1-12. https://doi.org/10.1016/j.lrp.2013.01.001.

[32] Henseler, J., Hubona, G., & Ray, P. A. (2016). Using PLS path modeling in new technology research: updated guidelines. *Industrial Management & Data Systems*, *116*(1), 2-20. https://doi.org/10.1108/IMDS-09-2015-0382.

[33] Hirschi, A. (2009). Career adaptability development in adolescence: Multiple predictors and effect on sense of power and life satisfaction. Journal of vocational behavior, 74(2), 145-155. https://doi.org/10.1016/j.jvb.2009.01.002.

[34] Hockerts, K., & Wüstenhagen, R. (2010). Greening Goliaths versus emerging Davids—Theorizing about the role of incumbents and new entrants in sustainable entrepreneurship. *Journal of business venturing*, *25*(5), 481-492. https://doi.org/10.1016/j.jbusvent.2009.07.005.

[35] Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic management journal*, *39*(8), 2255-2276. https://doi.org/10.1002/smj.2904.

[36] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005.

[37] Kline, R. B. (2015). The mediation myth. *Basic and Applied Social Psychology*, *37*(4), 202-213. https://doi.org/10.1080/01973533.2015.1049349.

[38] Li, R., Rao, J., & Wan, L. (2022). The digital economy, enterprise digital transformation, and enterprise innovation. *Managerial and Decision Economics*, *43*(7), 2875-2886. https://doi.org/10.1002/mde.3569.

[39] Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of cleaner production*, *115*, 36-51. https://doi.org/10.1016/j.jclepro.2015.12.042.

[40] Loorbach, D. (2007). Transition management. *New mode of governance for sustainable development. Utrecht: International Books*.

[41] M. Riesener, C. Dölle, C. Mattern and J. Kreß, "Circular Economy: Challenges and Potentials for the Manufacturing Industry by Digital Transformation," *2019 IEEE International Symposium on Innovation and Entrepreneurship (TEMS-ISIE)*, Hangzhou, China, 2019, pp. 1-7, https://doi.org/10.1109/TEMS-ISIE46312.2019.9074421.

[42] Morakanyane, R., Grace, A. A., & O'reilly, P. (2017). Conceptualizing digital transformation in business organizations: A systematic review of literature. https://doi.org/10.18690/978-961-286-043-1.30.

[43] Mutegi, L., Van Belle, J. P., & Sevilla, J. (2023, May). Assessing Kenya's Technology Innovation Ecosystem Towards Digital Entrepreneurship Success. In *2023 IST-Africa Conference (IST-Africa)* (pp. 1-14). IEEE. https://doi.org/10.23919/IST-Africa60249.2023.10187878.

[44] Nath, Avishek and Chowdhury, Sharmin Ara, Impact of Digital Marketing on Small and Medium Enterprises (SMEs) in Bangladesh(April 10, 2024). Available at SSRN: https://ssrn.com/abstract=5086502 or https://doi.org/10.2139/ssrn.5086502.

[45] Nunnally, J. C. (1978). An overview of psychological measurement. *Clinical diagnosis of mental disorders: A handbook*, 97-146. https://doi.org/10.1007/978-1-4684-2490-4_4.

[46] Okorie, O., Russell, J., Cherrington, R., Fisher, O., & Charnley, F. (2023). Digital transformation and the circular economy: Creating a competitive advantage from the transition towards Net Zero Manufacturing. *Resources, Conservation and Recycling*, *189*, 106756. https://doi.org/10.1016/j.resconrec.2022.106756.

[47] Pagell, M., & Wu, Z. (2009). Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. *Journal of supply chain management*, *45*(2), 37-56. https://doi.org/10.1111/j.1745-493X.2009.03162.x.

[48] Pagoropoulos, A., Pigosso, D. C., & McAloone, T. C. (2017). The emergent role of digital technologies in the Circular Economy: A review. *Procedia cirp*, *64*, 19-24. https://doi.org/10.1016/j.procir.2017.02.047.

[49] Pappas, I. O., Mikalef, P., Dwivedi, Y. K., Jaccheri, L., & Krogstie, J. (2023). Responsible Digital Transformation for a Sustainable Society. *Information Systems Frontiers*, 1-9. https://doi.org/10.1007/s10796-023-10406-5.

[50] Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., ... & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability*, *8*(11), 1212. https://doi.org/10.3390/su8111212

[51] Rogers, E. M. (1995). Lessons for guidelines from the diffusion of innovations. *The Joint Commission journal on quality improvement*, *21*(7), 324-328. https://doi.org/10.1016/S1070-3241(16)30155-9.

[52] Sarstedt, M., Ringle, C. M., Smith, D., Reams, R., & Hair Jr, J. F. (2014). Partial least squares structural equation modeling (PLS-SEM): A useful tool for family business researchers. *Journal of family business strategy*, *5*(1), 105-115. https://doi.org/10.1016/j.jfbs.2014.01.002.
[53] Schallmo, D., Williams, C. A., & Boardman, L. (2017). Digital transformation of business models—best practice, enablers, and roadmap. *International journal of innovation management*, *21*(08), 1740014. https://doi.org/10.1142/S136391961740014X.
[54] Schaltegger, S., & Wagner, M. (2011). Sustainable entrepreneurship and sustainability innovation: categories and interactions. *Business strategy and the environment*, *20*(4), 222-237. https://doi.org/10.1002/bse.682.
[55] Schaper, M. (2002). The challenge of environmental responsibility and sustainable development: Implications for SME and entrepreneurship academics. *Radical changes in the world: Will SMEs soar or crash*, 541-553.
[56] Shehadeh, M., Almohtaseb, A., Aldehayyat, J., & Abu-AlSondos, I. A. (2023). Digital Transformation and Competitive Advantage in the Service Sector: A Moderated-Mediation Model. *Sustainability*, *15*(3), 2077. https://doi.org/10.3390/su15032077.
[57] Shepherd, D. A., & Patzelt, H. (2011). The new field of sustainable entrepreneurship: Studying entrepreneurial action linking "what is to be sustained" with "what is to be developed". *Entrepreneurship theory and practice*, *35*(1), 137-163. https://doi.org/10.1111/j.1540-6520.2010.00426.x.
[58] Stahel, W. R. (2016). The circular economy. *Nature*, *531*(7595), 435-438. https://doi.org/10.1038/531435a.
[59] Sundarakani, B., Lai, Y. S., Goh, M., & de Souza, R. (2019). Studying the sustainability of third party logistics growth using system dynamics. *Journal of Modelling in Management*, *14*(4), 872-895. https://doi.org/10.1108/JM2-12-2018-0224.
[60] Trocin, C., Skogås, J. G., Langø, T., & Kiss, G. H. (2022). Operating room of the future (FOR) digital healthcare transformation in the age of artificial intelligence. *Digital Transformation in Norwegian Enterprises*, *151*. https://doi.org/10.1007/978-3-031-05276-7_9.
[61] Tyson, J., Diwakar, V., Adetutu, M. O., & Bishop, J. (2020). *Inclusive economic growth in Kenya: The spatial dynamics of poverty*. ODI Report.
[62] Vares, H., Shouraki, M. K., & Yazdi, N. (2024). Sustainable Entrepreneurship in the Age of Digital Transformation. *J. Mgmt. & Sustainability*, *14*, 155. https://doi.org/10.5539/jms.v14n2p155.
[63] Vo Thai, H. C., Hue, T. H. H., Tran, M. L., & Vo, X. V. (2025). A strategy tripod perspective on digitalization for sustainable development: a case of micro, small, and medium-sized enterprises in Vietnam. *Journal of Small Business & Entrepreneurship*, *37*(1), 32-61. https://doi.org/10.1080/08276331.2023.2253682.
[64] Vu, N. H., & Nguyen, N. M. (2022). Development of small-and medium-sized enterprises through information technology adoption persistence in Vietnam. *Information Technology for Development*, *28*(3), 585-616. https://doi.org/10.1080/02681102.2021.1935201.
[65] Wang, B., Farooque, M., Zhong, R. Y., Zhang, A., & Liu, Y. (2021). Internet of Things (IoT)-Enabled accountability in source separation of household waste for a circular economy in China. *Journal of Cleaner Production*, *300*, 126773. https://doi.org/10.1016/j.jclepro.2021.126773.
[66] Westerman, G., Bonnet, D., & McAfee, A. (2014). *Leading digital: Turning technology into business transformation*. Harvard Business Press.
[67] Wiengarten, F., Lo, C. K., & Lam, J. Y. (2017). How does sustainability leadership affect firm performance? The choices associated with appointing a chief officer of corporate social responsibility. *Journal of business ethics*, *140*, 477-493. https://doi.org/10.1007/s10551-015-2666-5.
[68] Zeng, G., & Lei, L. (2021). Digital transformation and corporate total factor productivity: empirical evidence based on listed enterprises. *Discrete Dynamics in Nature and Society*, *2021*, 1-6. https://doi.org/10.1155/2021/9155861.