

Original Article

Sustainable Tech Entrepreneurship and Green Innovation: Driving Resilience and Environmental Impact through Digital Transformation and Circular Business Models

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ABSTRACT

Growing issues of climate change and depletion of natural resources demand a business model change towards sustainable business models. This research examines Sustainable Technology Entrepreneurship (STE) and Green Innovation (GI), including a focus on digital transformation, circular business models, and green finance as evolution towards environmental resilience and sustainability. Regarding the potential issue of knowledge gaps when treating these components together, in this paper, the significant role these elements play in the implementation of the Sustainable Development Goals (SDGs) is also emphasized. In the study, a conceptual framework is developed, and a structural equation model (SEM) is used with data from over 200 participants. It is already demonstrated that digital technologies (DT) play the role of a considerable driving force behind sustainable entrepreneurship, a somewhat significant and supportive role of circular business models, and a moderate but significant one of green finance. STE is recognized as a significant mediating factor of the phenomenon, related to environmental resilience by way of innovative, sustainable concepts. This paper emphasizes the effectiveness of synergies between DT, circular economy principles and green finance to support sustainability, which can help key recommendations to policymakers and corporate managers for sustainable leverage of a growth path of economic development.

Keywords: *Circular economy, Digital transformation, Environmental resilience, Green finance, Green innovation, Sustainable tech entrepreneurship*

INTRODUCTION

Increased economic growth led to climate change and environmental degradation, which became global problems affecting economic and social aspects (Zhao & Qian, 2024), and according to the Chiu and Lee (2020), leading to climate problem, resource depletion, and environmental degradation demand transformation of business models focusing on sustainability and value creation (Hong et al., 2024). Hence, an entrepreneurial emergent paradigm of sustainable tech entrepreneurship combines green innovation with technological development. The framework, in this aspect, facilitates the creation of robust, eco-entities that aim to align themselves toward achieving the SDGs (Abbas, 2024) and take up wider social and environmental challenges (Gregori & Holzmann, 2020). This approach applies digital transition to the creation of circular business models in view of the principles of sustainable use of resources and waste reduction, hence contributing to a regenerative economic model (Payer et al., 2024). In this line, the study aims to develop an integrated conceptual framework of sustainable business models by securing interactions between sustainability, technological innovation, and entrepreneurship. This will ensure resiliency, economic growth, and finally provide a leading way to environmental responsibility.

Research Objectives & Hypotheses

This research objective to explore the structural relationships between all the above stakeholder as mentioned like (circular business models, green finance, digital transformation, and sustainable technology entrepreneurship) to fostering environmental

resilience. In this purpose, the analysis also considered the following hypothesis:

- H₁:The digital technologies revolution has brought a beneficial impact on sustainable technology companies.
- H₂:Circular business models have impact to enhance sustainable technology entrepreneurship.
- H₃:Green finance has an absolutely definite positive effect for technology entrepreneurship for sustainability.
- H₄:Sustainable technology entrepreneurship contributes to environmental resilience.
- H₅:Sustainable technology entrepreneurship mediated the effect of digital transformation on environmental resilience.
- H₆:Sustainable technology entrepreneurship moderates the impact of circular business models and environmental vulnerability.

Digital transformation is basis of sustainable entrepreneurship, which allows the green innovation with technologies of “blockchain”, “artificial intelligent” (AI) and “Internet of Things” (IoT). These tools enable optimization, access to information, and resource use, all of which are essential in reaching the targets for sustainability (Brenner & Drdla, 2023). Blockchain, which provides a view into the supply chain, fosters trust, trust in responsible activity. In the same way, IoT and AI also bring increased energy efficiency and minimized waste by applying a real-time data report on the resource quantity used (Ghobakhloo et al., 2023). Uniquely, these technologies, valuable, confer advantages that are advantageous (competitive) and, as a result, stimulate green work orders (Akhtar et al.,

2024).

Circular business models are in sync with digital transformation, and thus they focus on the reduction of waste, recycling, and the extension of the product life cycle, to promote regenerative economies. These kinds of models decrease reliance on resources and ecological footprint, and therefore businesses have the option to focus on sustainability. Digitizing increases efficiency in the tracking of resources and waste management (Kandpal et al., 2024; Ritter et al., 2024). Sustainable finance also contributes to sustainability through (e.g., green bonds and sustainability-linked loans) and through breaking up financial barriers of innovation (Gutterman, 2024). Policies that provide tax benefits and research and development government grants stimulate green behaviours, and lead consumers to choose environmentally friendly products (Pereira et al., 2022). Governmental oversight has been found to be an important factor to reduce financial barriers and foster green practices (Feng et al., 2023). Sustainable technology entrepreneurship integrates all these elements to create economic and environmental value (Eyo-Udo et al., 2024). By dint of digitalization, circularity and green finance companies can be made ever more solid against market pressures and environmental forces such that they are sustainable, green and become pioneers of the green economy (Nuryanto et al., 2024).

It also critically analyses how sustainable technology entrepreneurship could build resilience, environmental impact, and economic sustainability. This study analyses the interlinkages between digital transformation, the circular economic model, and green finance regarding their impact on developing an improved understanding of sustainable entrepreneurship by availing critical insights and frameworks that foster the sustainability of entrepreneurial ventures. This integration of innovation and sustainability in the process of value creation of a business interest is a radical paradigm shift; hence, sustainable technology entrepreneurship can be positioned as a significant catalysing factor for the potential regeneration and resilience of the economic system.

LITERATURE VIEW

In the area of technology entrepreneurship in sustainability and green innovation is advancing fast as businesses that recognize the need for sustainability in the pursuit of their corporate operations against adverse environmental degradation and resource depletion, as well as from public expectations of responsible corporate behaviour (Adewole, 2024).

In digital transformation the green innovation has importance role, which is enabled by the emerging technologies like AI, blockchain, and IoT (Trapp & Kanbach, 2021). These opportunities allow companies to improve their activities with better environmental impact, developing closed-loop systems, a critical need of the circular economy (Kara et al., 2022). This study synthesizes the latest literature to understand how digital transformation, circular business models, green finance, and legal frameworks enable sustainable entrepreneurship together. As Meena et al., (2024) stated that the existing organizations are adopting digital transformation to manage the environmental sustainability and operational effectiveness.

Well technologies such as blockchain, artificial intelligence (AI), and the Internet of Things (IoT) are proving importance in improving transparency, efficiency, and resource management across many other sectors, hence facilitating the advancement of the Sustainable Development Goals (SDGs) (Paul, 2025). Blockchain is a driving force in supply chain transparency, an agent of consumer trust and environmental regulation compliance (Feng et al., 2023). Technologies such as AI and IoT supply information in real-time to help optimize the use of resources, improve energy efficiency, minimize waste and offer companies an advantage in terms of sustainability markets (Grego et al., 2024). According to Brenner and Drdla (2023), IoT-based monitoring together with the applications of AI-driven analytics are of critical value to waste reduction, environmental performance reduction and stakeholder acceptance. Digital transformation should be incorporated when environmental objectives are adopted for corporate expansion (Adama et al., 2024; Challoumis, 2024; Dong, 2024; Ghobakhloo et al., 2023; Strazzullo et al., 2024).

Leder (2021) urged circular business models too are also evolutionary and can be considered as a logical extension to digitization which opens an opportunity for waste reduction and Madaan et al., (2024) said as well as adding value through eco-design, recycling and upcycling. As opposed to linear models, however, circularities, on the one hand, are limited to the sphere of the SDG, the most relevant for sustainable consumption and production (Bocken et al., 2014; Ritter et al., 2024). These types of digital tools also enable monitoring and management of resources in accordance with environmental rules (Jiang et al., 2019). AI algorithms have been employed to enhance material efficiency and thereby reduce costs as well as operation efficiency (Chen et al., 2022). Green finance is employed to support sustainability by green bonds

and impact investments, and to make renewable technologies financially viable (Khater et al., 2024; 하차루, 2024). Policies that stimulate R&D and grant tax credits reduce financial barriers and create consumer trust in sustainable products (Benkhodja et al., 2023; Gutterman, 2024; Shahzad et al., 2023). However, challenges emerge for sustainable technology entrepreneurship, especially for SMEs with limited resources (Agrawal et al., 2024; Bagale et al., 2021; Brenner & Drdla, 2023; Grego et al., 2024; Strazzullo et al., 2024). This necessitates the incorporation of financial, operation, and environmental aspects into business policy (Abbas, 2024; Feng et al., 2023).

The literature highlights the synergy between green innovation (GI) and Corporate Social Responsibility (CSR), as companies embed sustainability into all operational facets (Abbas, 2024). This integration satisfies business and societal interests, enhancing brand image and fostering customer loyalty, which motivates green behaviours (Fosu et al., 2024; Trevlopoulos et al., 2024). CSR promotes compliance, reduces financial risks, and strengthens corporate legitimacy, enabling durable sustainability programs (Khan et al., 2024). Guided by social and environmental objectives (Hong et al., 2024; Kandpal et al., 2024;

Sarfraz et al., 2023), CSR fuels socially responsible businesses, aligning economic and social benefits (Khan et al., 2024). Combined, CSR and GI enhance market performance, stakeholder satisfaction, and long-term adaptive capacity (DiBella et al., 2023). Digitalization along with circular and financial strategies can enable businesses to be inventive, adapt to market changes and be resilient (Xu et al., 2023). Chen et al., (2023) described companies that integrate green innovation and corporate social responsibility (CSR) enhance brand loyalty, stakeholder satisfaction and market performance, thus opening a route toward sustainable long-term business practices (Abbas, 2024; DiBella et al., 2023; Jorzik et al., 2024).

Conceptual Framework

This conceptual framework connects digital transformation, circular business models, and green finance to promote both sustainable technological entrepreneurship and its resilience. It stresses regenerative economies, green financing, and resilient business model development along Sustainable Development Goals (SDGs), providing practical recommendations for policymakers, entrepreneurs, and industry executives to accomplish economic sustainability and environmental resilience.

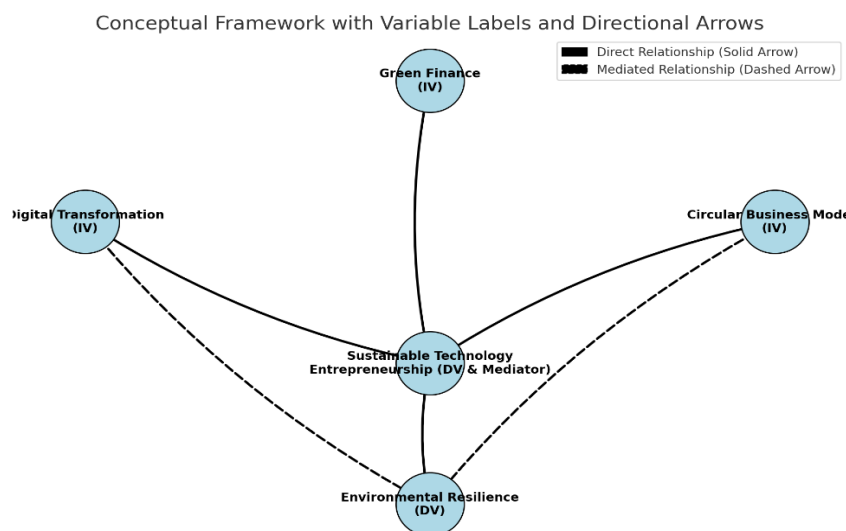


Fig. 1. The conceptual framework, solid arrows show direct relationships between variables and dashed arrows indicate mediated relationships

METHODOLOGY

Research Approach and Design

This study used Structural Equation Modelling (SEM) to analyse the relationships between digital transformation, circular business models, green finance, and technology entrepreneurship in sustainability. CSR-

GI integration enhances stakeholder satisfaction, brand loyalty, compliance, and long-term environmental, social, and economic sustainability.

Population and Sampling

The intended audience was executives, entrepreneurs, and policymakers implementing digital transformation, circular economy, and green finance

activities. Purposeful sampling ensured sustainability, green finance, or digital technology experience. We needed 10 respondents per estimated parameter for SEM. 200 samples with 20 estimated model parameters was a minimum. An oversample was chosen to adjust for non-responses and assure data robustness. SEM model estimate and validation statistical power were met by this sample size.

Data Collection Instrument

A structured questionnaire was the primary instrument for data collection. This questionnaire was divided into five sections:

- Background: industry, job, and green innovation.
- Digital Transformation: Used a 5-point Likert scale to evaluate blockchain, AI, and IoT sustainability.
- Circular Business Models: Assesses waste reduction, recycling, and product lifecycle management.
- Green Finance: Verified government grants and bonds.
- Environmental sustainability goals: environmental performance, and organizational resilience.
- The questionnaire, adapted from validated scales on digital transformation, green finance, and sustainability, was refined for green innovation focus. Experts reviewed it for clarity, relevance, and enhanced content validity in green technology.

Data Collection Procedure

Online surveys gave respondents broad access and eliminated regional limits. Potential participants received an invitation email with the survey link, study purpose, and confidentiality assurances. After two weeks, non-respondents received follow-up emails to boost response rates during six weeks of data collection. To encourage participation, respondents received a research summary.

Measurement Model and Constructs

The constructs in this study were operationalized as follows:

- Digital Transformation: As measured by indicators of levels of technology engagement with sustainability (i.e., AI, IoT, blockchain), plus the complexity of technological implementation in sustainable applications.
- Circular Business Models: Operationalized using proxy variables of resource recovery, waste minimization, and eco-friendly product design (activities) including recycled-data closed-loop

supply chains.

- Green Finance: Valuated according to the availability of green fund instruments (green bonds and sustainability-linked loans), which define the amount of funding dedicated to sustainable projects.
- Sustainable Technology Entrepreneurship: This mediating construct has been defined as the incorporation of digital change and circular business models into entrepreneurial work for sustainability.
- Environmental Resilience: As measured by the proxies of organizational absorptive capacity, environmental reduction and alignment with sustainability (ie, the respondent's perception of whether sustainability practices could foster resilience).

Each construct was measured using reflective indicators on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), with higher scores indicating stronger alignment with sustainable practices and green innovation principles.

Data Analysis Strategy

Data analysis was conducted in two stages: measurement model assessment and structural model evaluation.

Measurement Model Assessment

The measurement model's reliability and validity were assessed via CFA within SEM. Cronbach's alpha and Composite Reliability (>0.7) confirmed reliability, while AVE (>0.5) ensured convergent validity, and Fornell-Larcker criterion verified discriminant validity.

Structural Model Evaluation

The validated measurement model was tested using SEM with maximum likelihood estimation to estimate path coefficients and assess hypotheses. Model fit indices, including RMSEA (<0.08), CFI (>0.9), and TLI (>0.9), confirmed good structural model fit.

Mediation Analysis

The bootstrapping technique tested sustainable technology entrepreneurship's mediating role between digital transformation, circular business models, and environmental resilience, assessing significance of indirect effects.

Ethical Considerations

This study followed ethical procedures including informed consent, voluntary consent, confidentiality

and anonymity. Data was cryptically coded, restricted to the study group and which study was checked by an

institutional review board.

RESULTS & FINDINGS

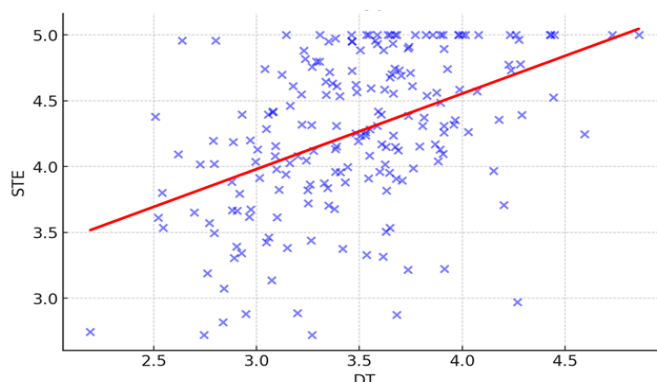
Table 1
SEM Testing Results

Hypothesis	Independent Variable	Dependent Variable	Path Coefficient	P-Value	Result
H1	DT	STE	0.572	1.658	Accepted
H2	CBM	STE	0.376	5.320	Accepted
H3	GF	STE	0.172	0.003	Accepted
H4	STE	ER	0.862	1.138	Accepted
H5 (Direct)	DT	ER	0.576	3.807	Accepted
H6 (Direct)	CBM	ER	0.297	0.000	Accepted

Hypothesis 1: Digital Transformation (DT) → Sustainable Technology Entrepreneurship (STE)

- Path Coefficient: $\beta=0.572$ \beta = 0.572
- P-Value: $p < 0.001$ $p < 0.001$
- Result: Accepted

DT has a significant positive effect on STE, as indicated by the path coefficient of 0.572. This suggests that a one-unit increase in Digital Transformation would increase STE approximately 0.572 units. The low p-value confirms the statistical significance of this relationship.



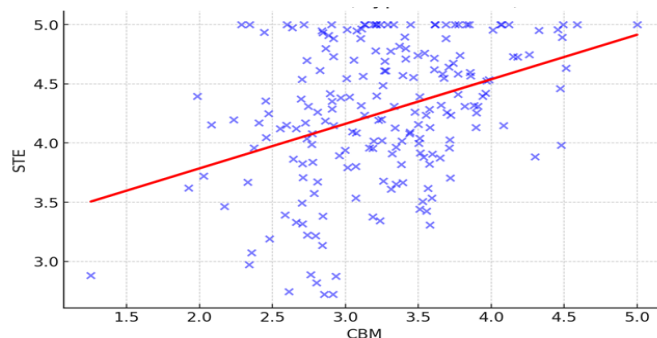
Graph. 1. DT vs. STE (Hypothesis H1)

Hypothesis 2: Circular Business Models (BM) → Sustainable Technology Entrepreneurship (STE)

- Path Coefficient: $\beta=0.376$ \beta = 0.376
- P-Value: $p < 0.001$ $p < 0.001$

- Result: Accepted

BM positively impacts STE with a path coefficient of 0.376. This means that an increase in BM is associated with a 0.376 unit increase in STE, showing a significant effect with a highly significant p-value.



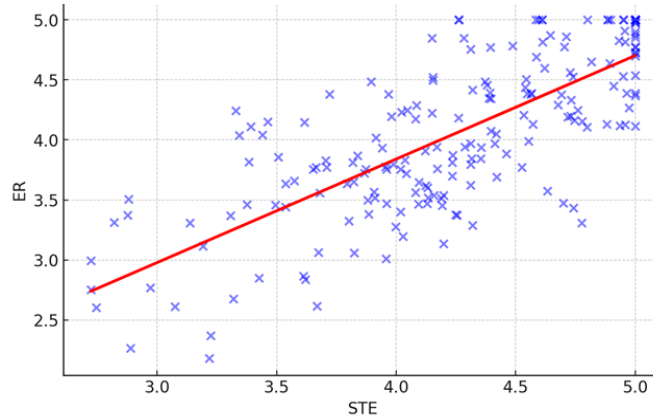
Graph. 2. CBM vs. STE (Hypothesis H2)

Hypothesis 3: Green Finance (GF) → Sustainable Technology Entrepreneurship (STE)

- Path Coefficient: $\beta=0.173$
- P-Value: $p=0.0038$

• Result: Accepted

GF has a smaller, yet statistically significant, positive impact on STE. With a path coefficient of 0.173, an increase in Green Finance corresponds to a 0.173 unit increase in STE. The p-value indicates that this effect is significant, though not as strong as H1 or H2.



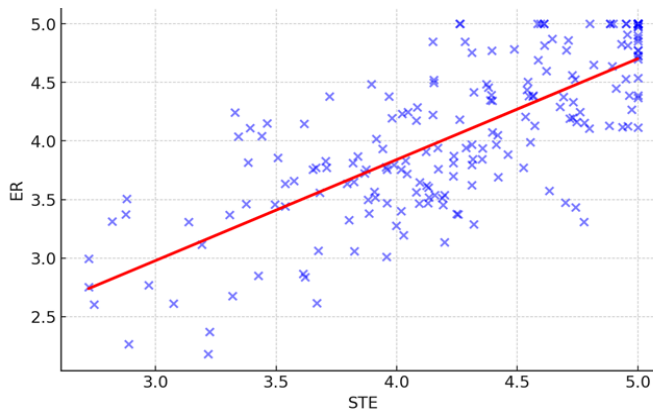
Graph. 3. GF vs. STE (Hypothesis H3)

Hypothesis 4: Sustainable Technology Entrepreneurship (STE) → Environmental Resilience (ER)

- Path Coefficient: $\beta=0.862$
- P-Value: $p<0.001$

• Result: Accepted

STE is shown to have a very strong positive influence on ER, with a path coefficient of 0.862. This substantial coefficient suggests that an increase in STE significantly boosts ER. The extremely low p-value strongly supports this relationship.

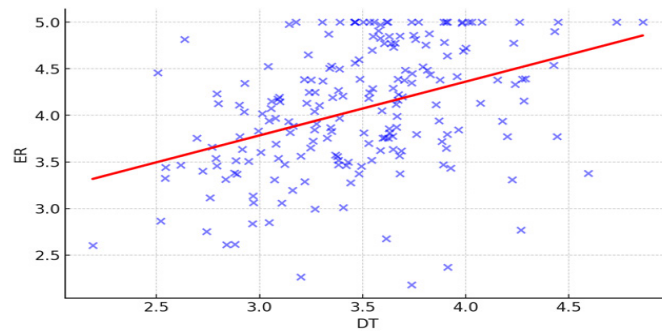


Graph. 4. STE vs. ER (Hypothesis H4)

Hypothesis 5: Digital Transformation (Direct) (DT) → Environmental Resilience (ER)

- Path Coefficient: $\beta=0.577$
- P-Value: $p<0.001$
- Result: Accepted

Interpretation: DT also has a significant direct positive effect on ER. The path coefficient of 0.577 suggests that as DT increases, ER also increases, though the effect is somewhat weaker than the indirect effect through STE. The p-value confirms the significance of this direct relationship.



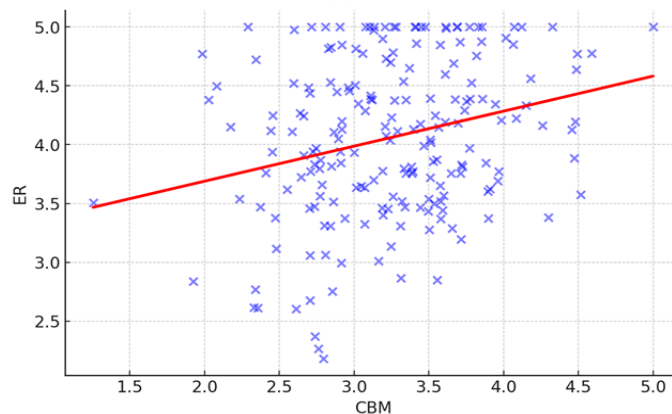
Graph. 5. DT vs. ER (Hypothesis H5 (Direct))

Hypothesis 6: Circular Business Models (Direct) (CBM) → Environmental Resilience (ER)

- Path Coefficient: $\beta=0.298$ \beta = 0.298 $\beta=0.298$
- P-Value: $p=0.0002$ $p = 0.0002$ $p=0.0002$

- Result: Accepted

Interpretation: BM has a direct positive effect on ER, with a path coefficient of 0.298. This effect is significant, though weaker compared to H5, suggesting that while BM contribute to ER, this effect is less pronounced than the effects of STE or DT.



Graph. 6. CBM vs. ER (Hypothesis H6 (Direct))

Discussion

This study explored the interrelationships between Digital Transformation, Circular Business Models, Green Finance, Sustainable Technology Entrepreneurship, and Environmental Resilience (Trapp & Kanbach, 2021). The findings discover the key pathways through which it may be extracted that, in turn, may be used to draw inferences about the relationships between such constructs and how these relationships may be exploited to generate insights about the nature of knowledge relating to the complexity of sustainable development itself and of resilience to environmental pressures. The following is an evaluative characterization of each of the hypotheses proposed and how it has been impacting the field. The results support Hypothesis 1, that confirmed the strength of Digital Transformation on Sustainable Technology Entrepreneurship (path coefficient 0.572). Innovations such as AI and machine

learning have been significantly optimizing processes, reducing waste and maximizing the consumption of resources, respectively. These results also emphasize the key importance of digital transformation on the way and in support of sustainable entrepreneurship, and call attention to the demand of public policy, namely on the promotion and carrying out of digitalization policies.

Hypothesis 2, also supported the positive effect of Circular Business Models on Sustainable Technology Entrepreneurship (path coefficient 0.376). The adoption of the principles of recycling and lifecycle extension has a sustainability impact and progresses from the linear to the regenerative model. Although strong bases exist, digital and financial backing is required to fully leverage the potential of circular models. The results also support Hypothesis 3, further supported the positive, although somewhat less positive, impact of Green

Finance on Sustainable Technology Entrepreneurship (path coefficient 0.173). Finance is known to reduce the risk for sustainable endeavours but on its own it does not guarantee it. Sharpening green finance by means of governmental subsidies, publicity (PR) activities, and information technology (IT) platforms, and of particular concern in the poorest areas, with limited access to finances, is very important (Xu et al., 2023). Hypothesis 4, validated the key mediator effect of Environmental Resilience as mediatized of Sustainable Technology Entrepreneurship (path coefficient 0.862). Companies practicing eco-friendly solutions not only address environmental concerns, but also address environmental factors of risk management and business development (so-called eco-economies), which are more resilient and stable (i.e. Governors and investors should support sustainable entrepreneurs as key players for building resilience to environmental perturbations).

Hypothesis 5 also validated that Digital Transformation has a positive direct effect on Environmental Resilience (path coefficient 0.577). Technologies (predictive modelling and environmental monitoring) that enable proactive use of resources and environmental management promote the need for public policy and funding to drive digital-enabled sustainability and resilience approaches. Finally, Hypothesis 6, validated that the circular business models can have a direct impact on Environmental Resilience, albeit in modest manner (path coefficient 0.298). Despite the robustness of circular motions, their scalability and their constrained resources make it of interest to combine them in digitization and investments, to have a high impact. Circularity is most potent as an element of a larger sustainability view.

This paper identifies the need for an integrated perspective integrating Digital Transformation, Circular Business Model, and Green Finance to promote sustainable entrepreneurship. Policymakers should prioritize digital infrastructure and circular schemes. Future studies therefore have a role to play in developing useful digital technologies, circularity practices and financial instruments across sectors to optimize sustainability and enhance resilience to environmental disruptions.

CONCLUSION

This study investigated the complex relationships between Digital Transformation (DT), Circular Business Models (CBM), Green Finance (GF), Sustainable Technology Entrepreneurship (STE), and Environmental Resilience (ER). So, the study has discovered the

underscore that each factor significantly contributes to fostering entrepreneurship in sustainability and environmental resilience. DT has emerged as a strong driver, directly enhancing both STE and ER. CBM also showed notable effects, emphasizing the potential of regenerative economic practices to support resilience, especially when coupled with digital and financial support. GF, while impactful, demonstrated a comparatively moderate effect, suggesting that financial incentives alone may be less influential than when combined with supportive policies and technologies. These results underscore the importance of an incorporated approach to achieving ER through entrepreneurship in sustainability, where DT, CBM, and GF work synergistically.

To recommend that sustainability, policymakers should leverage strong digital infrastructure to facilitate the use of IoT, AI and data analytics. Working incentives such as tax and subsidies should enable circular behaviour like reuse and lifecycle management. Combining green finance with technical support amplifies impact. Intersectoral collaboration drives innovation, and sector-specific research adapts policy to specific strengths to guarantee sustainable practices are properly applied. These approaches foster entrepreneurship and resilience in various sectors and locations. This study has limitations, including a focus on three drivers (Digital Transformation, Circular Business Models, Green Finance) and the omission of legislative, cultural, and market factors. Geographic and industry-specific differences were not addressed. Measurement complexities and cross-sectional data limit trend analysis, highlighting the need for longitudinal studies and refined metrics.

Competing Interest

The authors had no competing interests.

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