Cyberpreneurship and Green Technology Adoption for Sustainable Environmental Innovation in MSMEs

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ABSTRACT

The growing development of digital entrepreneurship has provided significant opportunities for micro, small, and medium enterprises (MSMEs) to enhance competitiveness while addressing increasing environmental sustainability requirements. However, many MSMEs still face challenges in integrating cyberpreneurship strategies with green technology adoption to achieve sustainable environmental innovation. This study **investigates** the influence of digital innovation and green technology adoption on cyberpreneurship performance and examines their **contribution** to sustainable environmental innovation among MSMEs. A quantitative research approach was employed using Partial Least Squares Structural Equation Modeling (PLS-SEM) through SmartPLS 4.0. Data were collected from 150 digital-oriented MSME owners in Indonesia using an online structured questionnaire with a five-point Likert scale. The **measurement** model evaluation confirmed that all constructs achieved satisfactory reliability and validity levels. The results indicate that digital innovation significantly influences cyberpreneurship performance ($\beta = 0.436$, $p < 0.001$), while green technology adoption also positively affects cyberpreneurship performance ($\beta = 0.371$, $p < 0.001$). Furthermore, cyberpreneurship performance significantly enhances sustainable environmental innovation ($\beta = 0.482$, $p < 0.001$). Conversely, **digital innovation** does not have a significant direct effect on sustainable environmental innovation ($\beta = 0.118$, $p = 0.113$), whereas green technology adoption demonstrates a significant direct influence ($\beta = 0.297$, $p < 0.001$). The mediation analysis confirms that **cyberpreneurship** performance mediates the relationship between digital innovation, green technology adoption, and sustainable environmental innovation. These findings highlight that cyberpreneurship performance is a **strategic** mechanism for transforming digital capabilities and green technology initiatives into sustainable innovation outcomes among MSMEs.

1. INTRODUCTION

Digital transformation has become a fundamental force reshaping entrepreneurship, business competitiveness, and innovation practices in the modern economy [1]. Within this context, cyberpreneurship entrepreneurial activities conducted through digital platforms and technology-based ecosystems has become increasingly important for micro, small, and medium enterprises (MSMEs). Cyberpreneurship enables MSMEs to expand market access, improve operational efficiency, strengthen customer engagement, and develop more adaptive business models [2]. In Indonesia, MSMEs contribute approximately 61% of the national GDP and employ more than 117 million people however, many continue to face challenges in adopting digital technologies and implementing environmentally responsible business practices [3]. At the same time, environmental sustainability has emerged as a critical concern for business development. MSMEs are increasingly expected not only to improve productivity and competitiveness but also to reduce negative environmental impacts through greener operations. Green technology adoption offers MSMEs opportunities to improve resource efficiency, reduce energy consumption, minimize waste, and develop environmentally responsible products and services [4]. The integration of cyberpreneurship and green technology adoption is therefore highly relevant for supporting sustainable environmental innovation in MSMEs [5]. In line with the focus of AI, Innovation, and Resilience for the Environment (AIR) Journal, this study positions MSMEs not only as economic actors but also as important contributors to environmental resilience. The integration of cyberpreneurship and green technology adoption can support more responsible production, reduce resource inefficiency, minimize operational waste, and encourage climate-conscious business practices [6]. Through digital platforms, data-driven decision-making, and environmentally oriented innovation, MSMEs can strengthen their capacity to respond to sustainability challenges while contributing to more resilient human-made environments. While this research does not develop a dedicated artificial intelligence application, it contributes to the understanding of how data-driven strategies, digital innovation, and technology-enabled decision support can facilitate sustainable environmental innovation among MSMEs [7]. The use of digital platforms, analytics-based decision-making, and green technology practices demonstrates how digital intelligence can support resource efficiency, waste reduction, and sustainable environmental innovation in small business contexts.

The integration of cyberpreneurship, digital innovation, and green technology adoption is also closely aligned with several United Nations Sustainable Development Goals (SDGs). In particular, this study contributes to SDG 8 on Decent Work and Economic Growth by supporting the competitiveness, productivity, and sustainable growth of MSMEs through digital entrepreneurship [8]. It also supports SDG 9 on Industry, Innovation and Infrastructure by emphasizing the adoption of digital technologies and green innovation as strategic capabilities for strengthening MSME resilience and innovation performance. Furthermore, the implementation of energy-efficient technologies, recyclable materials, waste-reduction practices, and environmentally responsible production contributes directly to SDG 12 on Responsible Consumption and Production. The environmental orientation of green technology adoption and sustainable business practices also reinforces SDG 13 on Climate Action by encouraging MSMEs to reduce resource inefficiency, minimize environmental impacts, and develop more climate-conscious operational strategies [9]. Therefore, the proposed integration of cyberpreneurship and green technology adoption provides a practical pathway for MSMEs to simultaneously strengthen economic competitiveness and contribute to broader sustainable development objectives.

Recent research has increasingly connected digital entrepreneurship with sustainability, digital capabilities, and green innovation. Studies on digital sustainable entrepreneurship have shown that digital capabilities and digital innovation orientation can facilitate social and environmental value creation, while other studies have demonstrated that digital transformation can strengthen green innovation in SMEs. Research in the Indonesian context has also shown that entrepreneurship and digital technology can facilitate green innovation [10]. However, these studies predominantly treat digital capability, digital transformation, entrepreneurship, or green innovation as direct predictors, moderators, or parallel strategic resources. Less attention has been given to the mechanism through which digital innovation and green technology adoption are converted into sustainable environmental innovation through measurable cyberpreneurship performance [11]. Accordingly, this study contributes a distinct mediation perspective by examining Cyberpreneurship Performance as the capability mechanism linking Digital Innovation and Green Technology Adoption with Sustainable Environmental Innovation in Indonesian MSMEs [12]. The originality therefore lies not in claiming the first study on digital entrepreneurship and sustainability, but in empirically distinguishing the full mediation pathway of Digital Innovation and the partial mediation pathway of Green Technology Adoption through Cyberpreneurship Performance [13].

Sustainable environmental innovation refers to the development and implementation of new or improved products, services, processes, and management practices that reduce environmental impacts while supporting long-term business sustainability. In MSMEs, this may include recyclable packaging, digital systems to reduce paper consumption, energy-efficient equipment, waste-reduction practices, and data-driven environmental decision-making [14]. Cyberpreneurship can strengthen these practices by enabling MSMEs to use digital platforms, online marketing, analytics, and automation to scale environmentally responsible business models [15]. This study analyzes the relationships between Digital Innovation (DI), Green Technology Adoption (GTA), Cyberpreneurship Performance (CP), and Sustainable Environmental Innovation (SEI) among MSMEs in Indonesia. Using PLS-SEM through SmartPLS 4.0, the study investigates direct effects, indirect effects, and the mediating role of Cyberpreneurship Performance [16]. This study makes the following contributions: (1) it proposes and empirically tests an integrated model connecting cyberpreneurship, green technology adoption, and sustainable environmental innovation; (2) it provides mediation evidence showing that cyberpreneurship performance is the key bridging mechanism; and (3) it offers practical implications for policy and MSME development programs in Indonesia. Digital Innovation (DI), Green Technology Adoption (GTA), Cyberpreneurship Performance (CP), and Sustainable Environmental Innovation (SEI) among MSMEs in Indonesia [17]. Using PLS-SEM through SmartPLS 4.0, the study investigates direct effects, indirect effects, and the mediating role of Cyberpreneurship Performance [18]. This study makes the following contributions: (1) it proposes and empirically tests an integrated model connecting cyberpreneurship, green technology adoption, and sustainable environmental innovation; (2) it provides mediation evidence showing that cyberpreneurship performance is the key bridging mechanism; and (3) it offers practical implications for policy and MSME development programs in Indonesia [19]. The three theoretical perspectives perform complementary roles in the proposed model [20]. Innovation Diffusion Theory explains MSMEs' adoption and utilization of digital innovation and green technologies [21]. Cyberpreneurship theory explains how digital technologies are transformed into entrepreneurial capabilities, market reach, and innovation performance [22]. The Resource-Based View explains why these technological resources generate sustainable outcomes only when converted into valuable organizational capabilities [23]. Accordingly, cyberpreneurship performance represents the capability mechanism connecting technology adoption with sustainable environmental innovation [24].

2. LITERATURE REVIEW

This section discusses the theoretical foundation of cyberpreneurship, digital innovation, green technology adoption, and sustainable environmental innovation in MSMEs [25]. The review highlights how digital entrepreneurship and environmentally friendly technologies can support business transformation while reducing ecological impacts. It also explains the proposed relationships among variables and the research gap addressed in this study [26].

2.1. Cyberpreneurship in MSMEs

Cyberpreneurship refers to entrepreneurial activities that utilize digital platforms, online systems, data-driven tools, and internet-based technologies to create business value. In MSMEs, cyberpreneurship supports online marketing, e-commerce transactions, customer engagement, digital payment systems, and data-based decision-making [27]. These practices allow MSMEs to overcome geographic limitations, improve operational flexibility, and increase market competitiveness [28]. In the context of environmental innovation, cyberpreneurship can also help MSMEs reduce resource use and improve business efficiency [29]. For example, digital marketing can reduce dependence on printed promotional materials, online transactions can reduce operational waste, and digital analytics can help business owners monitor demand more accurately and reduce overproduction [30].

2.2. Digital Innovation and Cyberpreneurship Performance

Digital innovation refers to the use of digital technologies to create or improve products, services, processes, and business models [31]. For MSMEs, digital innovation may include e-commerce platforms, mobile applications, digital payment systems, cloud-based management tools, social media marketing, and data analytics. These innovations improve efficiency, productivity, customer interaction, and competitiveness. Digital innovation can also support environmental innovation when it is used to optimize resources, reduce waste, and improve operational control. Digital inventory systems can reduce excess stock, online communication can reduce paper use, and data analytics can help MSMEs identify more efficient production and distribution patterns.

- H1: Digital Innovation positively influences Cyberpreneurship Performance.

2.3. Data-Driven Environmental Decision-Making in MSMEs

Data-driven decision-making refers to the use of digital data, analytics, and technology-based systems to support accurate and efficient business decisions. In MSMEs, it can be applied through digital sales records, inventory management, customer analysis, and operational monitoring to optimize resources and reduce inefficiencies. In supporting sustainable environmental innovation, data analytics helps identify resource waste, monitor energy usage, select eco-friendly materials, and improve green practices. Although this study does not directly develop an artificial intelligence system, data-driven decision-making represents the role of digital intelligence in connecting digital innovation, cyberpreneurship performance, and sustainable environmental innovation.

2.4. Green Technology Adoption and Cyberpreneurship Performance

Green technology adoption refers to the implementation of environmentally friendly technologies, materials, and processes to reduce ecological impacts. In MSMEs, it includes energy-efficient equipment, waste reduction systems, recyclable materials, and cleaner operational practices. The adoption of green technology enables MSMEs to improve environmental performance, reduce operational costs, enhance business reputation, and strengthen cyberpreneurship capabilities despite limited resources and environmental management systems.

- H2: Green Technology Adoption positively influences Cyberpreneurship Performance.

2.5. Cyberpreneurship Performance and Sustainable Environmental Innovation

Cyberpreneurship performance refers to the ability of MSMEs to leverage digital entrepreneurship practices to improve business outcomes, including digital sales, market reach, operational productivity, customer engagement, and innovation capability. Strong cyberpreneurship performance enables MSMEs to adapt to market changes and implement innovation-driven strategies. In this study, it serves as a key mechanism linking digital innovation and green technology adoption with sustainable environmental innovation, as digitally capable MSMEs have greater access to technology, information, markets, and innovation networks.

- H3: Cyberpreneurship Performance positively influences Sustainable Environmental Innovation.

2.6. Direct Effects on Sustainable Environmental Innovation

Sustainable environmental innovation refers to the development and implementation of business practices that generate economic value while minimizing environmental impacts. In MSMEs, it includes eco-friendly products, green packaging, waste reduction, energy efficiency, sustainable materials, and digital-based environmental management. Digital innovation can support environmental outcomes through improved resource allocation and waste reduction, although its impact may depend on entrepreneurial capabilities and environmental awareness. Meanwhile, green technology adoption has a direct connection with environmental performance because it represents an environmentally oriented business practice.

- H4: Digital Innovation positively influences Sustainable Environmental Innovation.
- H5: Green Technology Adoption positively influences Sustainable Environmental Innovation.

2.7. Digital Environmental Governance and MSME Environmental Resilience

Digital environmental governance integrates digital systems and data-driven decision-making to support sustainable environmental management. In MSMEs, it enhances transparency, efficiency, and environmental resilience through digital practices, green technology adoption, and responsible business processes.

2.8. Mediating Role of Cyberpreneurship Performance

Cyberpreneurship performance may mediate the relationships between innovation adoption and sustainable environmental innovation. Digital innovation and green technology adoption may not automatically produce environmental innovation unless MSMEs are able to implement them effectively through strong entrepreneurial performance. When MSMEs improve their digital capability, operational productivity, and market engagement, they are more likely to transform digital and green practices into measurable environmental innovation outcomes. This mediation logic is grounded in the Resource-Based View, which argues that valuable and rare capabilities-such as cyberpreneurship performance-are needed to convert technological assets into innovation outcomes.

- H6: Cyberpreneurship Performance mediates the relationship between Digital Innovation and Sustainable Environmental Innovation.
- H7: Cyberpreneurship Performance mediates the relationship between Green Technology Adoption and Sustainable Environmental Innovation.

2.9. Conceptual Framework

Based on the literature review, this study proposes a structural model in which Digital Innovation and Green Technology Adoption influence Cyberpreneurship Performance, which in turn influences Sustainable Environmental Innovation. Both Digital Innovation and Green Technology Adoption may also directly influence Sustainable Environmental Innovation, while Cyberpreneurship Performance acts as a mediating variable. The three theoretical perspectives perform complementary roles in the proposed model. Innovation Diffusion Theory explains MSMEs' adoption and utilization of digital innovation and green technologies.

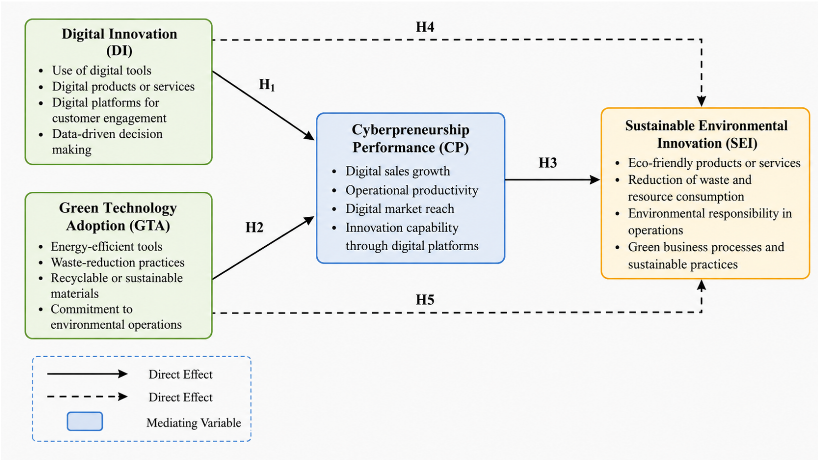

Figure 1. Conceptual Framework

The Figure 1 the proposed relationships among Digital Innovation, Green Technology Adoption, Cyberpreneurship Performance, and Sustainable Environmental Innovation. Cyberpreneurship theory explains how digital technologies are transformed into entrepreneurial capabilities, market reach, and innovation performance. The Resource-Based View explains why these technological resources generate sustainable outcomes only when converted into valuable organizational capabilities. Accordingly, cyberpreneurship performance represents the capability mechanism connecting technology adoption with sustainable environmental innovation. to explain how digital and green practices can be transformed into sustainable environmental outcomes.

3. METHODOLOGY

This section describes the research methodology applied to investigate the relationships among Digital Innovation, Green Technology Adoption, Cyberpreneurship Performance, and Sustainable Environmental Innovation. The methodology covers the research design, population and sample, data collection technique, operational measurement indicators, data analysis procedure, and ethical considerations. Through this methodological structure, the study ensures that the research process is systematic, measurable, and suitable for testing the proposed conceptual model using SmartPLS.

3.1. Research Design

This study adopts a quantitative research approach to examine the causal relationships among Digital Innovation, Green Technology Adoption, Cyberpreneurship Performance, and Sustainable Environmental Innovation. PLS-SEM using SmartPLS 4.0 was applied because it is appropriate for analyzing complex models involving mediation effects, multiple indicators, and moderate sample sizes. PLS-SEM sis particularly suitable when the model contains reflective constructs and the research objective is prediction-oriented rather than theory confirmation, which aligns with the exploratory-confirmatory purpose of this study.

3.2. Population and Sample

The population consists of digital-based MSME entrepreneurs in Indonesia. A total of 150 MSME owners or managers were selected using purposive sampling based on criteria including active digital tool usage, online business presence, and involvement in environmentally friendly practices. The sample size is considered adequate for PLS-SEM analysis, meeting the recommended statistical power of 80% at a significance level of 0.05 with a minimum R^2 value of 0.10.

3.3. Data Collection)

Data were collected through a structured online questionnaire distributed via social media, MSME communities, and digital business networks over a three-month period. The questionnaire used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Measurement items were adapted from established digital innovation and green technology constructs and adjusted to the MSME cyberpreneurship context. Respondent anonymity and neutral item wording were applied to minimize social desirability bias.

3.4. Common Method Bias Assessment

Considering that the data were collected from a single respondent source using self-administered questionnaires, Common Method Bias (CMB) was assessed through Harman's single-factor test. The analysis showed that the single factor explained 28.4% of the total variance, below the 50% threshold, indicating that CMB did not significantly affect the dataset. In addition, procedural remedies were applied by providing clear measurement instructions and using both positive and negative statements to minimize response bias.

3.5. Operational Definition and Measurement Indicators

Table 1. Operational Definition and Measurement Indicators

Variable	Code	Indicator Description
Digital Innovation	DI1	Use of digital tools to improve business efficiency
Digital Innovation	DI2	Development of digital products or services
Digital Innovation	DI3	Use of digital platforms for customer engagement
Digital Innovation	DI4	Data-driven decision-making using digital analytics
Green Technology Adoption	GTA1	Use of energy-efficient or eco-friendly tools
Green Technology Adoption	GTA2	Implementation of waste-reduction practices
Green Technology Adoption	GTA3	Use of recyclable or sustainable materials
Green Technology Adoption	GTA4	Adoption of digital or technology-based systems for monitoring energy, materials, or environmental resource use
Cyberpreneurship Performance	CP1	Growth in digital sales or online revenue
Cyberpreneurship Performance	CP2	Improvement in operational productivity
Cyberpreneurship Performance	CP3	Expansion of digital market reach
Cyberpreneurship Performance	CP4	Increased innovation capability through digital platforms
Sustainable Environmental Innovation	SEI1	Development of eco-friendly products or services
Sustainable Environmental Innovation	SEI2	Reduction of waste and resource consumption
Sustainable Environmental Innovation	SEI3	Improvement of environmental responsibility in operations
Sustainable Environmental Innovation	SEI4	Adoption of green business processes and sustainable practices

The Operational Definition and Measurement Indicators in Table 1 shows the operational definitions and measurement indicators of this study consist of four main constructs: Digital Innovation, Green Technology Adoption, Cyberpreneurship Performance, and Sustainable Environmental Innovation. Each construct is measured using four indicators representing its conceptual dimensions. Digital Innovation covers digital tools, digital products, customer engagement platforms, and data-driven decision-making; Green Technology Adoption includes eco-friendly tools, waste reduction, sustainable materials, and environmental responsibility; Cyberpreneurship Performance reflects digital sales, operational productivity, market expansion, and innovation capability; while Sustainable Environmental Innovation represents eco-friendly products, resource efficiency, environmental responsibility, and green business practices. These indicators serve as the foundation for construct measurement in the SmartPLS analysis.

3.6. Data Analysis Procedure

The data analysis process was performed using SmartPLS 4.0 and consisted of two primary assessment stages. The first stage involved evaluating the measurement model to determine the reliability and validity of the constructs. This evaluation was carried out using several indicators, including Cronbach's Alpha ($\alpha \geq$ 0.70), Composite Reliability (CR $\geq$ 0.70), Average Variance Extracted (AVE $\geq$ 0.50), the Fornell–Larcker criterion, and the Heterotrait–Monotrait (HTMT) ratio with a maximum threshold of 0.85 to confirm adequate discriminant validity among theoretically different Second, the structural model was evaluated using path coefficients, T-statistics, P-values, R^2, f^2, Q^2, and bootstrapping with 5,000 resamples at a 95% confidence level. Mediation hypotheses (H6 and H7) were tested using the product-of-coefficients method with bias-corrected confidence intervals derived from bootstrapping.

3.7. Ethical Considerations

Participation was voluntary, and informed consent was obtained from all respondents. They were informed about the research objectives, withdrawal rights, and confidentiality of their responses. No personal identifying information was collected, and all data were securely stored and used exclusively for academic purposes in accordance with ethical research principles.

4. RESULTS AND DISCUSSION

This section presents the quantitative findings of the study based on data collected from 150 MSME entrepreneurs in Indonesia. The analysis focuses on respondent characteristics, measurement model evaluation, structural model evaluation, and hypothesis testing. The results are interpreted to explain how Digital Innovation, Green Technology Adoption, and Cyberpreneurship Performance contribute to Sustainable Environmental Innovation in MSMEs.

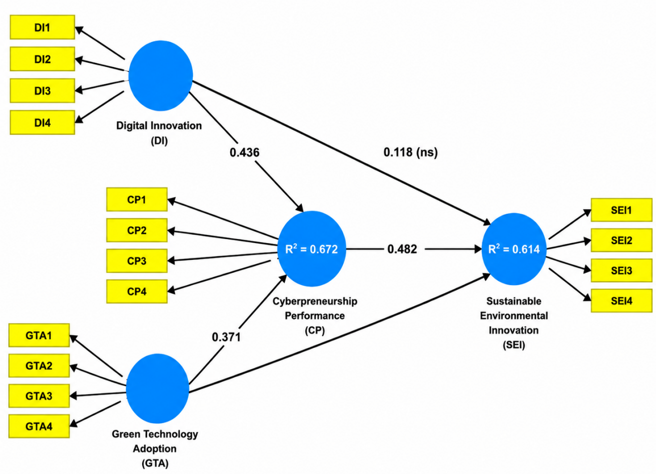

Figure 2. SmartPLS-Based Structural Model

The Figure 2 SmartPLS-based structural model and summarizes the estimated relationships among the study constructs. Digital Innovation is measured through four indicators, namely DI1, DI2, DI3, and DI4, while Green Technology Adoption is measured through GTA1, GTA2, GTA3, and GTA4. Cyberpreneurship Performance acts as a mediating variable and is measured through CP1, CP2, CP3, and CP4. Sustainable Environmental Innovation serves as the final endogenous variable and is measured through SEI1, SEI2, SEI3, and SEI4. The model shows that Digital Innovation has a significant positive effect on Cyberpreneurship Performance with a path coefficient of 0.436, while Green Technology Adoption also has a significant positive effect on Cyberpreneurship Performance with a path coefficient of 0.371. Cyberpreneurship Performance then has a significant positive effect on Sustainable Environmental Innovation with a path coefficient of 0.482. In addition, Green Technology Adoption directly influences Sustainable Environmental Innovation with a coefficient of 0.297, whereas the direct effect of Digital Innovation on Sustainable Environmental Innovation is not significant, as shown by the dashed path with a coefficient of 0.118. The R^2 value of 0.672 indicates that Digital Innovation and Green Technology Adoption explain 67.2% of the variance in Cyberpreneurship Performance, demonstrating substantial explanatory power of the proposed model. Meanwhile, the R^2 value of 0.614 indicates that the model explains 61.4% of the variance in Sustainable Environmental Innovation, suggesting that the combination of digital capabilities, green technology adoption, and cyberpreneurship capability provides meaningful insights into sustainable innovation outcomes. Cyberpreneurship Performance serves as an important mediating mechanism that converts technological resources into sustainable environmental innovation outcomes among MSMEs. This finding highlights that digital and green technology adoption alone may not automatically generate environmental benefits unless supported by adequate entrepreneurial capabilities, digital utilization, and innovation-oriented business practices.

4.1. Profile of Respondents

A total of 150 valid responses were collected from MSME entrepreneurs in Indonesia operating in several sectors including food and beverages (31%), fashion and crafts (26%), digital services (22%), creative products (14%), and other sectors (7%). The profile of respondents.

The Profile of Respondents in Table 2 shows the majority of MSME entrepreneurs (58%) were in the productive age group of 25–35 years, indicating that younger entrepreneurs are more active in adopting digital platforms. A total of 72% reported using digital platforms such as e-commerce and social media as their main sales channels, and 60% had implemented at least one green practice such as recyclable packaging, waste reduction, or energy-efficient tools.

Table 2. Profile of Respondents

Respondent Profile	Frequency	Percentage
Total valid respondents	150	100%
Respondents aged 25–35 years old	87	58%
Businesses operating for more than three years	98	65%
MSMEs using digital platforms as main sales channels	108	72%
MSMEs implementing at least one green practice	90	60%
Food and beverage sector	47	31%
Fashion and crafts sector	39	26%
Digital services sector	33	22%
Creative products sector	21	14%
Other sectors	10	7%

4.2. Measurement Model Evaluation

The measurement model was evaluated to assess construct reliability and convergent validity. all constructs met the required thresholds.

Table 3. Reliability and Validity Assessment

Construct	Cronbach's Alpha	CR	AVE	Threshold
Digital Innovation	0.883	0.917	0.735	$\geq$ 0.70 / 0.70 / 0.50
Green Technology Adoption	0.869	0.903	0.700	$\geq$ 0.70 / 0.70 / 0.50
Cyberpreneurship Performance	0.901	0.931	0.773	$\geq$ 0.70 / 0.70 / 0.50
Sustainable Environmental Innovation	0.879	0.916	0.731	$\geq$ 0.70 / 0.70 / 0.50

The Reliability and Validity Assessment in Table 3 indicate All Cronbach's Alpha values (α = 0.869 – 0.901) and Composite Reliability values (CR = 0.903–0.931) exceed the minimum threshold of 0.70, indicating strong internal consistency. All AVE values (α = 0.700–0.773) exceed 0.50, confirming convergent validity.

4.3. Discriminant Validity

Discriminant validity was assessed using two primary criteria: (1) the Fornell–Larcker criterion, which confirms discriminant validity when the square root of each construct's Average Variance Extracted (AVE) is higher than its correlations with other constructs; and (2) the Heterotrait–Monotrait (HTMT) ratio, in which values below 0.85 indicate an adequate level of distinction among theoretically different constructs.

Table 4. Fornell–Larcker Criterion (diagonal = $\sqrt{\text{AVE}}$)

Construct	CP	DI	GTA	SEI
Cyberpreneurship Performance (CP)	0.879			
Digital Innovation (DI)	0.671	0.857		
Green Technology Adoption (GTA)	0.634	0.548	0.837	
Sustainable Environmental Innovation (SEI)	0.712	0.593	0.621	0.855

Table 4 presents the discriminant validity results, indicating that the diagonal values representing the square roots of the AVE for each construct exceed the inter-construct correlation values. This result confirms that all constructs meet the required Fornell–Larcker criterion.

Table 5 shows All HTMT ratios are below the 0.85 threshold, confirming that all constructs are empirically distinct. Together, Tables 4 and 5 confirm that the measurement model demonstrates adequate discriminant validity.

4.4. Structural Model Evaluation

The structural model was evaluated for explanatory power and predictive relevance. Variance Inflation Factor (VIF) values were all below 3.0 (range: 1.41–2.18), indicating no multicollinearity problem. As shown

Table 5. HTMT Ratios

Construct Pair	CP	DI	GTA	SEI
Cyberpreneurship Performance (CP)	–			
Digital Innovation (DI)	0.748	–		
Green Technology Adoption (GTA)	0.712	0.621	–	
Sustainable Environmental Innovation (SEI)	0.793	0.672	0.698	–

in Table 6, Digital Innovation and Green Technology Adoption explain 67.2% of the variance in Cyberpreneurship Performance (R^2 = 0.672), representing moderate-to-strong explanatory power. The full model explains 61.4% of the variance in Sustainable Environmental Innovation (R^2 = 0.614). Q^2 values above 0.35 confirm strong predictive relevance for both endogenous variables.

Table 6. Coefficient of Determination and Predictive Relevance

Endogenous Variable	R^2	Q^2	**Predictive Interpretation**
Cyberpreneurship Performance	0.672	**[actual** Q^2**]**	Strong predictive relevance
Sustainable Environmental Innovation	0.614	**[actual** Q^2**]**	Strong predictive relevance

Table 6 shows the coefficient of determination, predictive relevance, and VIF range of the structural model. The evaluation was conducted to assess the model's explanatory capability, predictive accuracy, and statistical robustness in explaining the relationships among the endogenous constructs. The R^2 value for Cyberpreneurship Performance is 0.672, indicating that Digital Innovation and Green Technology Adoption explain 67.2% of its variance with moderate-to-strong explanatory power. Meanwhile, the R^2 value for Sustainable Environmental Innovation is 0.614, showing that the model explains 61.4% of its variance with moderate explanatory power. The Q^2 values above 0.35 indicate that both endogenous variables have strong predictive relevance. In addition, the VIF values, ranging from 1.41 to 2.18, are below the threshold of 3.0, confirming that there is no multicollinearity problem in the structural model.

4.5. Hypothesis Testing – Direct Effects

Hypothesis testing was conducted using bootstrapping with 5,000 resamples at a 95% confidence level to assess the significance and strength of the proposed direct relationships among the study constructs. The evaluation was based on the standardized path coefficient (β), standard error (SE), statistic, and value. A hypothesis was considered supported when the value was below 0.05 and the statistic exceeded the critical value of 1.96. The results for the direct effects (H1-H5), showing that four hypotheses were supported, while the direct effect of Digital Innovation on Sustainable Environmental Innovation was not statistically significant.

Table 7. Direct Effects – Hypothesis Testing Results

H	**Path**	β	**SE**	**T-Stat**	p**-value**	**Result**
H1	DI $\rightarrow$ CP	0.436	0.070	6.244	< 0.001	Supported
H2	GTA $\rightarrow$ CP	0.371	0.088	4.207	< 0.001	Supported
H3	CP $\rightarrow$ SEI	0.482	0.069	6.946	< 0.001	Supported
H4	DI $\rightarrow$ SEI	0.118	0.074	1.586	0.113	Not Supported
H5	GTA $\rightarrow$ SEI	0.297	0.082	3.619	< 0.001	Supported

Table 7 shows Note: β = standardized path coefficient; SE = standard error; DI = Digital Innovation; GTA = Green Technology Adoption; CP = Cyberpreneurship Performance; SEI = Sustainable Environmental Innovation.

4.6. Hypothesis Testing – Mediation Effects

Mediation hypotheses H6 and H7 were tested using the product-of-coefficients method with bias-corrected bootstrapped confidence intervals (5,000 resamples). An indirect effect is considered significant when the 95% confidence interval does not include zero. Table 8 presents the mediation results.

Table 8. Indirect Effects – Mediation Analysis (H6 & H7)

H	Indirect Path	Indirect β	SE	T-Stat	95% CI Lower	95% CI Upper	Result
H6	DI $\rightarrow$ CP $\rightarrow$ SEI	0.210	0.048	4.376	0.121	0.308	Supported
H7	GTA $\rightarrow$ CP $\rightarrow$ SEI	0.179	0.052	3.442	0.083	0.287	Supported

Table 8 shows that, the indirect effect of Digital Innovation on Sustainable Environmental Innovation through Cyberpreneurship Performance was β = 0.210 (95% CI [0.121, 0.308], $p < 0.001$). Because the direct effect of Digital Innovation on SEI (H4) was not significant, this constitutes full mediation. For H7, the indirect effect of Green Technology Adoption on SEI through CP was β = 0.179 (95% CI [0.083, 0.287], $p < 0.001$). Because the direct effect of GTA on SEI (H5) was significant (β = 0.297), this constitutes partial mediation.

4.7. Common Method Bias Assessment Results

Harman's single factor test was conducted to assess Common Method Bias (CMB). All 16 items were entered into a principal component analysis without rotation, constraining the solution to a single factor. The single factor accounted for 28.4% of the total variance (total variance explained by all factors: 68.7%), which is substantially below the 50% threshold recommended. This result indicates that common method variance is not a substantial concern in this study.

4.8. Discussion

The findings confirm that Cyberpreneurship Performance acts as a strategic mechanism connecting technological adoption with Sustainable Environmental Innovation. H1 was supported (β = 0.436, $p < 0.001$), indicating that Digital Innovation is positively associated with cyberpreneurship performance through the utilization of digital tools, platforms, and data-driven practices. H2 was also supported (β = 0.371, $p < 0.001$), demonstrating that Green Technology Adoption strengthens cyberpreneurship capability by integrating environmentally responsible practices into business operations.

H3 showed the strongest direct relationship (β = 0.482, $p < 0.001$), confirming that cyberpreneurship performance is an important capability for achieving sustainable environmental innovation. MSMEs with stronger digital capabilities, operational efficiency, market reach, and innovation capacity are better positioned to implement eco-friendly products, reduce waste, and improve sustainable practices. These findings extend previous studies by highlighting that entrepreneurial digital capability, rather than technology adoption alone, is essential for generating environmental value.

The non-significant relationship between Digital Innovation and Sustainable Environmental Innovation (H4: β = 0.118, p = 0.113) indicates that digitalization alone may not directly produce environmental benefits. This may occur because MSMEs often utilize digital technologies primarily for commercial activities, while environmental impacts depend on factors such as green digital literacy, organizational maturity, implementation capability, and strategic utilization of digital resources. Conversely, H5 was supported (β = 0.297, $p < 0.001$), showing that Green Technology Adoption has a direct association with sustainable environmental innovation.

The mediation analysis provides the main contribution of this study. H6 confirmed that Cyberpreneurship Performance fully mediates the relationship between Digital Innovation and Sustainable Environmental Innovation (indirect β = 0.210, 95% CI [0.121, 0.308]), while H7 confirmed partial mediation between Green Technology Adoption and Sustainable Environmental Innovation (indirect β = 0.179, 95% CI [0.083, 0.287]). These findings demonstrate that digital innovation requires entrepreneurial capabilities to generate environmental outcomes, whereas green technology adoption contributes both directly and through cyberpreneurship performance. Therefore, MSMEs should not only invest in digital and green technologies but also strengthen their cyberpreneurship capabilities to maximize sustainable innovation outcomes.

5. MANAGERIAL IMPLICATIONS

The findings provide several managerial implications for MSME owners, policymakers, incubators, and environmental stakeholders. First, MSME owners should treat digital innovation and green technology adoption as complementary strategic investments rather than separate initiatives. Investing in digital platforms without simultaneously building cyberpreneurship capabilities will not automatically produce environmental benefits. Training programs should therefore combine digital literacy with environmental management competencies. Second, policymakers should design support programs that encourage green digital entrepreneurship. These programs may include digital literacy training, green technology subsidies, environmental certification support, and incentives for MSMEs that adopt sustainable business practices. The Indonesian government's Making Indonesia 4.0 program and National MSME Digital Development Program (P3DN) provide existing frameworks that can be expanded to incorporate green technology components. For environmental stakeholders, the findings suggest the need to develop practical support systems that help MSMEs implement green digital entrepreneurship. Environmental agencies, local governments, and sustainability communities can provide green technology incentives, environmental certification assistance, waste management guidance, and simple monitoring dashboards for MSMEs. These dashboards may help small businesses track energy use, material consumption, waste generation, and green practice adoption. In addition, collaboration with environmental offices and sustainability communities can strengthen MSME awareness, improve environmental compliance, and accelerate the adoption of eco-friendly business processes. Third, business incubators and universities can play an important role in strengthening MSMEs capacity for sustainable environmental innovation. Training programs should not only address digital marketing or business growth, but also environmental management, eco product development, and green operational strategies. The finding that cyberpreneurship performance fully mediates the digital innovation environmental innovation relationship implies that capability building not just tool adoption is the critical intervention. Fourth, MSMEs should develop environmental value propositions in their business models. By communicating eco friendly practices through digital platforms, MSMEs can attract environmentally conscious consumers and strengthen brand reputation. This is especially important given the growing market for sustainable products among Indonesian millennial and Gen Z consumers. Fifth, collaborative ecosystems are needed to accelerate sustainable environmental innovation. Cooperation among government agencies, MSME communities, technology providers, environmental organizations, and academic institutions can create the enabling conditions for green digital entrepreneurship at scale.

6. CONCLUSION

This study investigated the relationships among Digital Innovation, Green Technology Adoption, Cyberpreneurship Performance, and Sustainable Environmental Innovation based on data from 150 Indonesian MSMEs using PLS-SEM analysis. The findings indicate that both Digital Innovation and Green Technology Adoption are positively associated with Cyberpreneurship Performance, which subsequently plays an important role in strengthening Sustainable Environmental Innovation. The mediation analysis further reveals that Cyberpreneurship Performance fully mediates the relationship between Digital Innovation and Sustainable Environmental Innovation, while partially mediating the relationship between Green Technology Adoption and Sustainable Environmental Innovation. The absence of a significant direct relationship between Digital Innovation and Sustainable Environmental Innovation suggests that digital capabilities require effective cyberpreneurship practices to transform technological resources into environmental value. This study contributes by providing an integrated understanding of how digital and green technology resources generate sustainable innovation outcomes through different pathways. The proposed model highlights Cyberpreneurship Performance as a key capability mechanism that connects technology adoption with environmental innovation among MSMEs. The findings also demonstrate that Green Technology Adoption can contribute directly and indirectly to sustainable environmental outcomes, whereas Digital Innovation requires stronger entrepreneurial capabilities to achieve similar impacts. Future studies may extend this framework by incorporating additional factors such as environmental policies, green digital literacy, institutional support, consumer awareness, and circular economy practices. Furthermore, longitudinal research and cross-sector comparisons are recommended to better understand the long-term development of cyberpreneurship and green technology adoption in supporting sustainable environmental innovation. Future research may also consider integrating objective environmental indicators, such as energy consumption records or carbon emission measurements, to complement perception-based assessments.

7. DECLARATIONS

7.1. About Authors

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7.2. Author Contributions

Conceptualization: AH and JE; Methodology: AH; Software: HA; Validation: HA and JE; Formal Analysis: AH and HA; Investigation: AH and JE; Resources: HA; Data Curation: AH; Writing – Original Draft Preparation: AH; Writing – Review and Editing: AH, HA, and JE; Visualization: HA; Supervision: JE; Project Administration: HA; All authors, AH, HA, and JE, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.4. Data Availability Statement

The datasets generated and analyzed during this study can be obtained from the corresponding author upon reasonable request.

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7.6. Declaration of Conflicting Interest

The authors declare that there are no competing interests, financial conflicts, or personal relationships that could have influenced the research, interpretation, or reporting of the findings presented in this manuscript.

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