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Digital Technology-Based Green Innovation Adoption Model in MSME Development to Promote Performance and Sustainable Business Competitiveness

Agusman [1*], Victor [2], Silvia Sofyan [3]
[1*,2,3] Business Administration Study Program, Sekolah Tinggi Manajemen Bisnis Multi Sarana Manajemen Administrasi dan Rekayasa Teknologi, Medan City, North Sumatra Province, Indonesia

Email: aguscmp@gmail.com [1*], victorawen10@gmail.com [2], silviasofyan898@gmail.com [3]

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Abstract

This study empirically examines the direct effects of green innovation adoption and digital technology utilization on MSME performance and sustainable business competitiveness, as well as the effect of MSME performance on sustainable business competitiveness, in the context of MSMEs in Medan, Indonesia. Method. A quantitative, cross-sectional survey design was employed. Primary data were collected from 100 MSMEs, selected by purposive sampling from a population of 18,000 active units using the Slovin formula, through a structured questionnaire. Data were analyzed using Structural Equation Modeling with Partial Least Squares (SEM-PLS) in SmartPLS 4, including outer model evaluation (loading factor, AVE, composite reliability, Cronbach's alpha, discriminant validity) and inner model evaluation (R^2, f^2). Main Findings. All measurement constructs met the required thresholds, confirming convergent validity, discriminant validity, and reliability. The structural model shows that Sustainable Business Competitiveness is explained by the exogenous variables with $R^2 = 0.385$, while MSME Performance is explained with $R^2 = 0.295$. Green Innovation and Digital Technology exert a moderate effect on Sustainable Business Competitiveness ($f^2 = 0.218$ and $f^2 = 0.192$, respectively), while their direct effect on MSME Performance is very small ($f^2 = 0.002$ and $f^2 = 0.006$). MSME Performance, in turn, shows a moderate effect on Sustainable Business Competitiveness ($f^2 = 0.194$). Practical Implications. The findings inform MSME owners, business incubators, MSME facilitators, and digital platform providers that green innovation initiatives yield stronger competitiveness gains when embedded within a broader digital transformation strategy. For policy makers, particularly the Ministry of Cooperatives and SMEs, the results support targeted programs on digital literacy, eco-innovation subsidies, and integrated capacity-building schemes for second-tier city MSMEs. Originality. This study contributes an integrated, empirically validated model that combines digital technology utilization and green innovation adoption as joint predictors of MSME performance and sustainable competitiveness, tested through SEM-PLS on Indonesian MSMEs a setting under-represented in the existing Q1/Q2 literature.

Keywords:
Green Innovation; Digital Technology; MSMEs; Sustainable Competitiveness; SEM-PLS.

1. INTRODUCTION

The rapid maturation of the digital economy has transformed the operating environment of Micro, Small, and Medium Enterprises (MSMEs) in emerging markets. In Indonesia, MSMEs serve as the backbone of the national economy through their substantial contribution to employment absorption and gross domestic product

(Bank Indonesia, 2023; Agusman & Victor, 2024). Within this context, green innovation—understood as the integrated development of environmentally responsible products, processes, and management practices—has emerged as a strategic pathway for improving business performance and long-term competitiveness (Google et al., 2022). Empirical evidence indicates that green innovation lowers environmental externalities while simultaneously reducing operational costs, enhancing brand reputation, and strengthening consumer trust (Kementerian Koperasi dan UKM, 2023). Nevertheless, MSMEs remain constrained by limited resources, knowledge asymmetries, and uneven access to enabling digital infrastructure (INDEF, 2023).

Field observations and secondary data further indicate that the diffusion of digital technology-based green innovation among Indonesian MSMEs is still uneven and comparatively low (Kementerian Koordinator Bidang Perekonomian, 2023; McKinsey & Company, 2023). Several factors act as inhibitors, including limited digital capabilities, low awareness of the tangible benefits of green innovation, and heightened perceptions of financial and operational risk associated with adoption (Statista, 2023; World Bank, 2022). Consequently, the joint value potential of digital transformation and green innovation remains under-realized in this segment.

Despite growing scholarly attention to digital transformation and green innovation as separate strands of inquiry, there is still limited empirical work that jointly models how digital technology utilization and green innovation adoption shape both MSME performance and sustainable competitiveness in Indonesian second-tier cities such as Medan (Dinas Koperasi dan UMKM Kota Medan, 2023; Sugiyono, 2021; Zaini, 2024; Evangeulista et al., 2023; Victor et al., 2025). Existing studies tend to emphasize either large firms, single-country technology adoption, or isolated environmental initiatives, leaving unresolved how these constructs operate as an integrated system in the MSME context. This gap defines both the research problem and the urgency of the present study, which develops and empirically tests such an integrated model using SEM-PLS.

The novelty of the study lies in three elements: first, the joint modeling of digital technology utilization and green innovation adoption as complementary drivers of MSME outcomes; second, the empirical grounding in a second-tier Indonesian city (Medan), which remains under-represented in Q1/Q2 international literature dominated by evidence from China, Vietnam, and Malaysia; and third, the use of a rigorous SEM-PLS framework to test both direct and structural relationships in a relatively small-sample MSME context.

This study contributes theoretically by extending the integration of the Technology Acceptance Model (TAM), the Resource-Based View (RBV), Dynamic Capability theory, and Green Innovation Theory to the MSME setting. It empirically demonstrates that digital technology utilization and green innovation adoption function as strategic capabilities that jointly explain variation in MSME performance and sustainable competitiveness, thereby enriching the sustainable competitive advantage literature with evidence from an under-studied emerging-market context.

This study contributes practically by providing an evidence-based reference for MSME owners, MSME facilitators, business incubators, and digital platform providers on how to sequence and combine digital adoption with green innovation initiatives. The results also inform policy design for the Ministry of Cooperatives and SMEs and local governments in Indonesia regarding capacity-building schemes.

1.1. Digital Technology Utilization and MSME Outcomes

Digital technology utilization reflects the ability of MSMEs to adopt, integrate, and productively deploy digital tools and information systems to support operational and strategic decision-making (Setiawan & Arief, 2022; INDEF, 2024; Sari & Nugroho, 2023). It encompasses mastery of digital infrastructure, use of information systems, and integration of technology into managerial and operational routines (Lubis et al., 2023; Harianto et al., 2024; Bharadwaj et al., 2013; Nambisan et al., 2017). MSMEs with stronger digital capability tend to achieve higher process efficiency, faster product and service innovation, and more effective data-driven marketing (Nambisan, 2017a; Oliveira & Martins, 2010; Kohli & Grover, 2008). A growing body of PLS-SEM–based evidence from emerging markets confirms that digital transformation and digital capability significantly enhance sustainable innovation capability, operational performance, and competitive positioning of SMEs, particularly under conditions of environmental dynamism (Wu et al., 2024; Al-Shammari, 2024; Van Hoang et al., 2025; Zhang & Chen, 2025). Together, these findings position digital technology utilization as a foundational enabler of green innovation adoption and sustainable MSME development.

1.2. Green Innovation and Sustainable Competitiveness

Green innovation refers to the introduction of new or significantly improved products, processes, and organizational practices that reduce environmental impact while creating economic value (Google et al., 2022; Kementerian Koperasi dan UKM, 2023). In the SME context, green innovation has been shown to enhance sustainable performance through both efficiency gains and legitimacy effects (Khan et al., 2024; Xie et al., 2024; Akhtar et al., 2024). Recent SEM-PLS studies further demonstrate that green innovation, especially when supported by digital transformation and dynamic capabilities, drives sustainable competitive advantage in emerging-market SMEs (Schrank & Kijkasiwat, 2024; Rachman et al., 2025; Reniati & Faisal, 2024). Government regulation, stakeholder pressure, and technological orientation are consistently identified as important antecedents that shape the strength of these effects (Wu et al., 2024; Sudaryana et al., 2025; Molina-García et al., 2024).

1.3. Perceived Benefits, Perceived Risks, and Adoption Behaviour

From the perspective of the Technology Acceptance Model and its extensions, perceived benefits capture MSME actors' beliefs that digital and green innovation adoption will improve operational efficiency, market reach, decision quality, and customer experience (Davis, 1989; Venkatesh et al., 2012; Kohli & Grover, 2008). Positive perceptions of benefit have been consistently associated with a higher intention to adopt digital and sustainability-oriented innovations (Rennings, 2000; Chen, 2011; Triguero et al., 2013; Porter & Kramer, 2011). Conversely, perceived risks—covering investment uncertainty, technological complexity, data security, and implementation failure—act as adoption barriers, particularly for resource-constrained MSMEs (Pavlou, 2003; Featherman & Pavlou, 2003; Thong, 1999; Dwivedi et al., 2019; Scupola, 2009; Raut et al., 2017). Effective mitigation of these perceived risks is therefore a precondition for translating digital capability and green innovation into performance and competitiveness outcomes (Oliveira et al., 2014; OECD, 2021; Kurnianingrum et al., 2025).

1.4. Synthesis and Positioning

Prior work has advanced our understanding of each construct separately but has rarely integrated digital technology utilization, green innovation, MSME performance, and sustainable business competitiveness within a single empirically tested model in a second-tier Indonesian city. The present study addresses this gap by jointly modeling these constructs and testing the resulting structural relationships through SEM-PLS, thereby offering an integrative view aligned with RBV, Dynamic Capability theory, and Green Innovation theory.

2. RESEARCH METHOD

2.1. Research Design and Roadmap

This study adopts a quantitative, cross-sectional survey design. The research roadmap is aligned with the Indonesian National Research Master Plan (RIRN) 2017–2045, the National Research Priority (PRN) 2020–2024, and the Asta Cita agenda toward Golden Indonesia 2045, particularly its emphasis on entrepreneurship, cooperatives, MSMEs, and the green economy. The methodological approach is Structural Equation Modeling with Partial Least Squares (SEM-PLS), which is used to test the hypothesized direct effects of digital technology utilization and green innovation adoption on MSME performance and sustainable business competitiveness among MSMEs in Medan.

2.2. Population and Sample

The population comprises 18,000 active MSME units in Medan. Purposive sampling was employed, and the sample size was determined using the Slovin formula, resulting in 100 MSMEs as respondents. This approach was chosen to obtain representative data reflecting the characteristics of MSMEs relevant to digital technology utilization and green innovation adoption. The sample size of 100 is consistent with the minimum-sample requirements for PLS-SEM under the ten-times rule for the most complex construct in the model.

2.3. Data Collection

Primary data were obtained through a structured questionnaire distributed directly to respondents. Each construct was measured using multiple items, adapted from established scales in the literature and adjusted to the MSME context in Medan. Prior to full-scale distribution, the instrument was tested for validity and reliability on 35 respondents outside the main sample to ensure that the items were understandable, unambiguous, and capable of capturing the intended constructs.

2.4. Data Analysis Technique

Data analysis was conducted using Structural Equation Modeling with Partial Least Squares (SEM-PLS) with the aid of SmartPLS 4. SEM-PLS was selected because it is well suited for predictive research, complex models with multiple latent variables, moderate sample sizes, and data that do not necessarily satisfy multivariate normality — conditions typical of MSME survey research. The analysis followed the standard two-step procedure. First, the outer (measurement) model was assessed for convergent validity (loading factor, Average Variance Extracted), discriminant validity (cross-loadings), and reliability (Composite Reliability, Cronbach's Alpha). Second, the inner (structural) model was evaluated using the coefficient of determination (R^2), effect size (f^2), and the significance of path coefficients through the bootstrapping procedure to test the hypothesized relationships. No additional analytical techniques were employed; all inferential results reported in this study derive exclusively from the SEM-PLS procedure.

2.5. Research Framework and Hypotheses

The conceptual framework of the study is presented in Figure 1. The model links Green Innovation adoption and Digital Technology utilization to MSME Performance and Sustainable Business Competitiveness, with MSME Performance further linked to Sustainable Business Competitiveness.

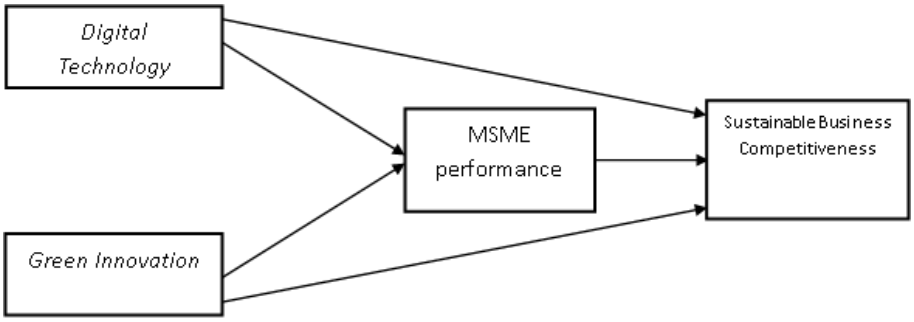

Figure 1. Conceptual Framework

The hypotheses tested in this study are as follows:
H1: Green innovation adoption has a positive and significant effect on MSME performance.
H2: Digital technology utilization has a positive and significant effect on MSME performance.
H3: Green innovation adoption has a positive and significant effect on sustainable business competitiveness.
H4: Digital technology utilization has a positive and significant effect on sustainable business competitiveness.
H5: MSME performance has a positive and significant effect on sustainable business competitiveness.

2.6. Validity and Reliability Criteria

Instrument validity was evaluated through the loading factor of each indicator; an item is considered valid if its loading exceeds 0.70. Discriminant validity was assessed through cross-loading values, whereby an indicator must correlate more strongly with its parent construct than with any other construct. Reliability was evaluated using Composite Reliability and Cronbach's Alpha, with values above 0.70 indicating adequate reliability. Convergent validity at the construct level was further confirmed through the Average Variance Extracted (AVE), with values above 0.50 indicating that the construct explains at least half of the variance of its indicators. Structural model quality was assessed through the R^2 of the endogenous constructs and the effect size (f^2), which measures the substantive contribution of each exogenous variable.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Outer Model Evaluation

3.1.1.1. Convergent Validity

Convergent validity results are assessed based on the magnitude of validity as indicated by loading factor values. The loading factor indicates the correlation between an item score and the composite indicator score.

Table 1. Convergent Validity Before Elimination

Variable	Item	Outer Loading
Green Innovation	GI.1	0.774
	GI.2	0.810
	GI.3	0.850
	GI.4	0.789
	GI.5	0.838
	GI.6	0.787
	GI.7	0.702
Digital Technology	TD.1	0.779
	TD.2	0.773
	TD.3	0.724
	TD.4	0.837
	TD.5	0.823
	TD.6	0.835
Sustainable Business Competitiveness	DSUK.1	0.608
	DSUK.2	0.675
	DSUK.3	0.733
	DSUK.4	0.730
	DSUK.5	0.764
	DSUK.6	0.654
MSME Performance	K.1	0.709
	K.2	0.804
	K.3	0.769

	K.4	0.816
	K.5	0.754
	K.6	0.862
	K.7	0.814

Source: SmartPLS Processing Results (2026)

Based on Table 1, there are 26 statement items with loading factor values greater than 0.7, which means they are valid, while the remaining items must be eliminated.

Table 2. Convergent Validity After Elimination

Variable	Item	Outer Loading
Green Innovation	GI.1	0.774
	GI.2	0.810
	GI.3	0.850
	GI.4	0.789
	GI.5	0.838
	GI.6	0.787
	GI.7	0.702
Digital Technology	TD.1	0.779
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	TD.3	0.724
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Sustainable Business Competitiveness	DSUK.3	0.733
	DSUK.4	0.730
	DSUK.5	0.764
MSME Performance	K.1	0.709
	K.2	0.804
	K.3	0.769
	K.4	0.816
	K.5	0.754
	K.6	0.862
	K.7	0.814

Source: SmartPLS Processing Results (2026)

Based on Table 2 above, after indicators with loading factor values below 0.70 were eliminated, all statement items show loading factor values greater than 0.70 and are therefore declared valid.

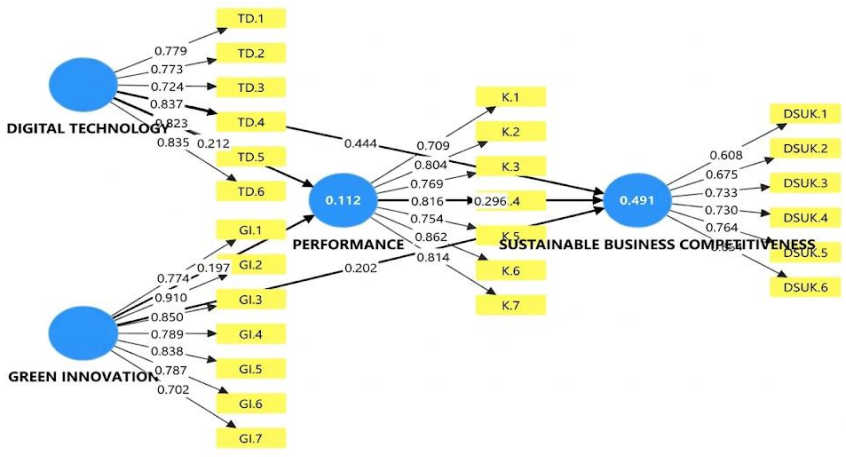

Figure 2. Outer Loading

3.1.1.2. Discriminant Validity

To evaluate the model, latent variables are measured by Composite Reliability and Cronbach's Alpha values. If the combined block of indicator reliability and Cronbach's Alpha values are both above 0.7, the structure is declared reliable.

Table 3. Cross Loading (Discriminant Validity)

Indicator	Sustainable Business Competitiveness	MSME Performance	Green Innovation	Digital Technology
DSUK.3	0.733	0.396	0.422	0.436
DSUK.4	0.730	0.230	0.213	0.419
DSUK.5	0.764	0.515	0.445	0.442
K.1	0.351	0.709	0.162	0.270
K.2	0.378	0.804	0.255	0.134
K.3	0.474	0.769	0.305	0.296
K.4	0.321	0.816	0.102	0.107
K.5	0.361	0.754	0.112	0.228
K.6	0.398	0.862	0.172	0.169
K.7	0.454	0.814	0.285	0.270
GI.1	0.284	0.087	0.774	0.165
GI.2	0.350	0.300	0.810	0.306
GI.3	0.467	0.326	0.850	0.334
GI.4	0.447	0.153	0.789	0.292
GI.5	0.345	0.198	0.838	0.277
GI.6	0.297	0.142	0.787	0.244
GI.7	0.277	0.144	0.702	0.194
TD.1	0.310	0.206	0.187	0.779
TD.2	0.310	0.009	0.242	0.774
TD.3	0.301	0.074	0.147	0.726
TD.4	0.425	0.112	0.208	0.832
TD.5	0.631	0.400	0.462	0.823
TD.6	0.397	0.266	0.203	0.835

Source: SmartPLS Processing Results (2026)

Based on Table 3, all constructs show good reliability because both Composite Reliability and Cronbach's Alpha values for all constructs are above 0.7. It can also be seen that each indicator's correlation with its own construct is higher than its correlation with other constructs, confirming adequate discriminant validity.

3.1.1.3. Average Variance Extracted (AVE)

If the Average Variance Extracted (AVE) value is above 0.50, the extract meets the requirements. The results of the average variance extracted test can be seen in the following table 4.

Table 4. Average Variance Extracted (AVE)

Variable	Average Variance Extracted (AVE)
Sustainable Business Competitiveness	0.633
MSME Performance	0.628
Green Innovation	0.630
Digital Technology	0.633

Source: SmartPLS Processing Results (2026)

The Average Variance Extracted values in Table 4 show AVE > 0.50 for all constructs, thus meeting the requirements. The next step is to compare the square root of AVE with the correlation between constructs in the model.

3.1.1.4. Composite Reliability

Reliability testing is conducted to assess the level of consistency and reliability of the measurement tools used in the research. In SmartPLS, a construct is considered reliable if composite reliability > 0.70.

Table 5. Composite Reliability

Variable	Composite Reliability
Green Innovation	0.922
Digital Technology	0.912
MSME Performance	0.922
Sustainable Business Competitiveness	0.838

Source: SmartPLS Processing Results (2026)

3.1.1.5 Cronbach's Alpha

Cronbach's Alpha testing is conducted to reinforce the results of the composite reliability test in assessing construct reliability. A variable is declared reliable if its Cronbach's Alpha value is greater than 0.70.

Table 6. Cronbach's Alpha

Variable	Cronbach's Alpha
Green Innovation	0.903
Digital Technology	0.888
MSME Performance	0.901
Sustainable Business Competitiveness	0.717

Source: SmartPLS Processing Results (2026)

Table 6 shows that all variables have Cronbach's Alpha values greater than 0.70, indicating that all variables are reliable or trustworthy.

3.1.2. Inner Model Evaluation

The inner model can be resolved by examining R-squared values for endogenous variable boundaries and T-statistics from the path coefficient test. The higher the R-squared value, the better the predictive model of the proposed research model. The path coefficient value indicates the significance level in hypothesis testing.

3.1.2.1. Coefficient of Determination (R^2)

The determination test is conducted to determine the influence of exogenous variables on endogenous variables.

Table 7. Coefficient of Determination (R^2)

Variable	R^2
Sustainable Business Competitiveness	0.385
MSME Performance	0.295

Source: SmartPLS Processing Results (2026)

Based on Table 7, the coefficient of determination (R^2) values shows that the R^2 value for Sustainable Business Competitiveness is 0.385, meaning that 38.5% of the variation in Sustainable Business Competitiveness can be explained by the exogenous variables in the research model, while the remaining 61.5% is influenced by other variables outside the model. Meanwhile, the R^2 value for MSME Performance is 0.295, meaning that 29.5% of the variation in performance can be explained by the exogenous variables, while the remainder is influenced by other variables outside the model. Therefore, the R^2 value for Sustainable Business Competitiveness is classified as moderate, while that for MSME Performance is classified as weak.

3.1.2.2. Effect Size (f^2)

In addition to examining R^2 values, effect size (f^2) testing is conducted to measure how large the impact of each exogenous variable is on the endogenous variable in the research model.

Table 8. Effect Size (F-Square)

Variable	MSME Performance	Sustainable Business Competitiveness
Green Innovation	0.002	0.218
Digital Technology	0.006	0.192
Sustainable Business Competitiveness	0.194	-

Source: SmartPLS Processing Results (2026)

Table 8 shows that Green Innovation and Digital Technology have a very small effect on MSME Performance, with f^2 values of 0.002 and 0.006, respectively. Conversely, Sustainable Business Competitiveness shows a moderate effect on MSME Performance with an f^2 value of 0.194. In terms of effect on Sustainable Business Competitiveness, Green Innovation shows a moderate effect with $f^2 = 0.218$, while Digital Technology also shows a moderate effect with $f^2 = 0.192$.

3.2. Discussion

Taken together, the empirical results indicate that digital technology-based green innovation is an important antecedent of both MSME performance and sustainable business competitiveness, with a comparatively stronger effect on sustainable competitiveness than on short-term performance. This pattern warrants theoretical, practical, and cross-country reflection.

3.2.1. Theoretical Implications

From the perspective of the Technology Acceptance Model (TAM) and its extensions, the moderate structural contribution of digital technology to sustainable competitiveness supports the argument that when MSME actors perceive digital tools as useful and easy to use, they are more likely to embed them into strategic activities that yield long-term competitive advantage rather than only short-term efficiency gains (Davis, 1989; Venkatesh et al., 2012).

From the Resource-Based View (RBV), green innovation and digital technology function as valuable, rare, and difficult-to-imitate strategic resources. Their moderate effect on sustainable competitiveness (f^2 = 0.218 and 0.192) is consistent with the RBV proposition that heterogeneous resources of this kind explain differences in the long-run competitive positioning of firms (Wade & Hulland, 2004; Barney, 1991).

From the Dynamic Capability perspective, the ability of MSMEs to sense environmental change, seize opportunities through green innovation, and reconfigure their digital resources translates into a stronger competitive posture. This is aligned with recent SEM-PLS evidence from emerging markets showing that dynamic digital capabilities mediate the impact of digital transformation on sustainable competitive advantage (Wu et al., 2024; Van Hoang et al., 2025; Zhang & Chen, 2025).

From the Green Innovation Theory and the broader Sustainable Competitive Advantage literature, the results reinforce the view that environmental responsibility and business performance are complementary rather than competing objectives. The moderate f^2 of Green Innovation on Sustainable Business Competitiveness confirms recent empirical findings that green innovation is a systematic driver of sustainable performance in SMEs (Khan et al., 2024; Akhtar et al., 2024; Rachman et al., 2025).

The Technology Adoption Theory further explains the very small direct effects of Green Innovation and Digital Technology on MSME Performance in the short run. Adoption processes typically require time, learning, and organizational adjustment before their effects materialize in operational performance indicators; longer-term outcomes such as sustainable competitiveness are more sensitive to these adoption processes than short-window performance metrics.

3.2.2. Practical Implications

For MSME actors, the findings suggest that the highest strategic payoff arises not from adopting digital tools or green practices in isolation, but from embedding both within a coherent business model that connects everyday operations, marketing channels, and product design. Investment in eco-friendly raw materials, waste reduction, energy efficiency, and greener product portfolios should be planned jointly with the adoption of e-commerce platforms, digital payment systems, and business management applications.

For the Ministry of Cooperatives and SMEs and other government agencies, the results support the design of targeted programs that combine digital literacy training, sustainability certification support, and access to green financing. Programs should be tailored to MSMEs in second-tier cities such as Medan, whose profile differs from Jakarta-centric MSMEs both in resource base and in exposure to competitive pressure.

For business incubators and MSME facilitators, the results provide an evidence base for integrated mentoring curricula in which digital skills modules and green innovation modules are delivered as complementary components. This integration is likely to produce higher gains in sustainable competitiveness than either module implemented in isolation.

For digital platform providers, the findings imply that services designed for MSMEs should not only optimize transactions but also expose sustainability-relevant functionalities—such as carbon-aware logistics, waste tracking dashboards, or ESG-aligned marketplace filters—that reinforce the link between digital adoption and green competitiveness.

3.2.3. Global Relevance and Comparison

Comparable studies in China indicate that digital transformation enhances SMEs' green competitive advantage through both green innovation and government regulation, with a strong role for institutional support (Wu et al., 2024). Studies from Vietnam show that digital capabilities significantly improve sustainable competitive advantage in manufacturing SMEs, mediated by digital absorptive capacity (Van Hoang et al., 2025). Evidence from Malaysia and Southeast Asia more broadly points to digital business model innovation and digital capability as central pathways to SME competitiveness (Schrank & Kijkasiwat, 2024; Reniati & Faisal, 2024). Comparable Thai and regional studies further identify sustainability readiness and firm size as boundary conditions of the green-innovation–performance relationship (Akhtar et al., 2024). Multilateral reports from the OECD and the World Bank likewise emphasize the joint role of digitalization and green innovation in improving SME resilience and competitiveness in emerging economies (OECD, 2022; World Bank, 2021; OECD, 2021; UNIDO, 2022).

Against this global backdrop, the Indonesian evidence obtained in this study is consistent with the international pattern in terms of the moderate contribution of green innovation and digital technology to sustainable competitiveness. However, the smaller short-term effect on MSME performance suggests that Indonesian MSMEs, particularly in second-tier cities, may still be in an earlier phase of the adoption curve, where operational returns are yet to be fully realized. This positions Indonesia as an informative case for understanding the transition dynamics of digital and green transformation in emerging markets.

3.2.4. Future Research Directions

Building on the present findings, several avenues for future research are recommended. First, moderating variables such as government support, environmental dynamism, firm age, and digital leadership could be introduced to explore boundary conditions of the observed relationships. Second, mediating mechanisms — for example, digital absorptive capacity, sustainability readiness, or innovation capability — could be modeled

to trace how digital technology and green innovation translate into sustainable competitiveness. Third, a longitudinal design would allow the observation of adoption dynamics over time and clarify why short-term performance effects appear small in this cross-sectional setting. Fourth, cross-country comparative studies (e.g., Indonesia–Vietnam–Thailand–Malaysia) could isolate the role of institutional and cultural factors. These extensions can be pursued without altering the core structural model developed in the present study.

4. CONCLUSION

This study empirically examined the effect of digital technology utilization and green innovation adoption on MSME performance and sustainable business competitiveness among 100 MSMEs in Medan, Indonesia, using SEM-PLS. The results confirm that both digital technology and green innovation function as important structural determinants of sustainable competitiveness, while their direct effect on short-term MSME performance is limited. MSME performance itself contributes moderately to sustainable competitiveness, indicating a partially indirect pathway.

The study extends the joint application of TAM, RBV, Dynamic Capability, Green Innovation Theory, and the Sustainable Competitive Advantage framework to the MSME context in an under-studied second-tier Indonesian city. It provides empirical support for treating digital technology utilization and green innovation adoption as complementary strategic capabilities rather than isolated initiatives.

MSME owners are encouraged to integrate green innovation practices — including the use of environmentally friendly raw materials, waste reduction, energy efficiency, and sustainable product development — with the systematic use of digital technology such as marketplaces, digital payment systems, business management applications, and data-driven marketing tools. The strongest competitive gains are expected when both domains are pursued jointly rather than in isolation.

For policy makers, particularly the Ministry of Cooperatives and SMEs and local governments, the findings support integrated programs that combine digital literacy training, green innovation incentives, sustainability certification support, and financing facilities. Programs should be spatially differentiated to reflect the specific conditions of MSMEs in second-tier cities.

Business incubators and MSME facilitators are recommended to develop mentoring curricula that treat digital adoption and green innovation as complementary modules. Digital platform providers are encouraged to embed sustainability-oriented functionalities in their MSME-facing services.

This study is subject to several limitations. It relies on a cross-sectional survey of 100 MSMEs in a single city, which limits generalizability and causal inference. Perceptual measures are drawn from a single respondent per firm, which may introduce common-method concerns. Contextual factors such as sector, firm age, and institutional support were not explicitly modeled.

Future research is encouraged to test the same structural model with larger, multi-city samples, incorporate moderators (e.g., government support, environmental dynamism) and mediators (e.g., digital absorptive capacity, innovation capability), adopt a longitudinal design to capture adoption dynamics, and conduct cross-country comparative studies across Indonesia, Vietnam, Thailand, and Malaysia.

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