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Role of Artificial Intelligence Adoption and Digital Transformation in Enhancing Sustainable Business Performance: The Mediating Effect of Green Product Innovation

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Abstract

In the context of Nepal's increasing vulnerability to environmental challenges, this study explores how emerging technologies – namely Digital transformation and artificial intelligence (AI) can help businesses operate sustainably practices. It specifically examines the role of green product innovation as a bridge between technological advancement and sustainable outcomes. Drawing on data from 384 firms, the research applies structural equation modeling (PLS-SEM) to evaluate key relationships. The results indicate that both the adoption of AI and the process of digital transformation contribute positively to environmental and operational performance, with green innovation acting as a critical mediator. While AI supports smarter decision-making and resource efficiency, digital tools improve operational transparency and customer engagement. When integrated, these technologies enable firms to align business goals with broader sustainability agendas. The study offers timely insights for policymakers, business leaders, and researchers focused on driving sustainable innovation in developing economies.

Keywords*: Sustainability, Artificial Intelligence, Digital Transformation, Green Innovation,* Nepal

Introduction

Sustainability has become an important concern for businesses around the world, including Nepal. Nepal is highly vulnerable to climate change and environmental disasters, which makes sustainable business practices more important than ever (Saxena et al., 2025). However, many businesses in Nepal, especially Small and medium-sized businesses (SMEs) are not yet fully ready to make this change due to a lack of awareness, funding, and long-term planning (Sujan et al., 2024). There is a growing demand for solutions that can help businesses perform well

financially while also protecting the environment (Dewi & Alif, 2024).

Artificial Intelligence (AI) is a powerful tool that is beginning to help businesses make better decisions, reduce waste, and improve efficiency (Islam, 2024). In Nepal, AI is being used in areas like agriculture, marketing, and finance, but its use is still limited and mostly in early stages (Karki et al., 2024). Many companies do not have access to AI experts or modern infrastructure, which makes it hard to adopt these new technologies widely (Tan, 2024). As a result, only a few businesses are truly benefiting from AI so far, and the full potential is not being realized (Dangol, 2024).

At the same time, digital transformation – using technology like cloud systems, smart sensors, and online platforms – is changing how businesses operate around the world. In Nepal, digital tools can help businesses save resources, go paperless, and work more efficiently (Attah et al., 2023). But many Nepalese SMEs struggle to use these tools because of poor internet access, lack of training, and fear of cyberattacks (Dangol, 2024). This means that the advantages of digital transformation are known, the actual use of these technologies remains low in many parts of the country (Islam, 2024).

Green product innovation – developing new products that are environmentally friendly – is another important strategy for sustainable business. It connects AI and digital tools to real-world environmental results (Sujan et al., 2024). However, in Nepal, green innovation is not yet common. Most businesses only focus on it when they are forced by government rules or donor programs, not because they see it as a competitive advantage (Islam, 2024). This indicates that a connection is lacking between using technology and achieving sustainability goals, which green innovation could help fill (Saxena et al., 2025).

Despite some progress, there is still a clear gap in research on how AI and digital transformation can work together with green innovation to improve business sustainability in Nepal. Most of the existing studies are general and do not focus on the unique challenges and opportunities in Nepal's private sector (Dewi & Alif, 2024; Karki et al., 2024). Thus, the purpose of this study is to investigate how these three factors – AI, digital transformation, and green innovation – can help businesses in Nepal become more sustainable.

Research Questions

- How does the adoption of Artificial Intelligence (AI) influence sustainable business performance in Nepalese firms?
- In what ways does digital transformation contribute to sustainable business outcomes in Nepal?
- How does green product innovation mediate the link between using AI, going digital, and running a business that is good for the environment?

Research Objectives

- To analyze the effects of AI implementation on the sustainable business performance of Nepalese firms.
- To assess the function of digital transformation in enhancing sustainable practices among businesses in Nepal.
- To investigate Innovation in green products' mediating effect in linking AI and digital transformation with sustainable business performance.

Literature Review

In today's world, businesses are expected not only to grow but also to protect the environment. In Nepal, this is becoming more important as the country faces serious environmental challenges. Technologies like Artificial Intelligence (AI) and digital tools can help companies reduce waste, use resources better, and make smarter decisions. However, research in Nepal has not fully explored how these tools affect sustainability in business, especially when combined with green product innovation (Saxena et al., 2025; Islam, 2024). This study aims to fill that gap.

AI Adoption and Sustainable Business Performance

AI is becoming more common in Nepalese business sectors like banking, marketing, and agriculture. It helps companies collect and analyze large amounts of data to make better decisions (Karki et al., 2024). For example, AI can predict equipment breakdowns, monitor energy use, and reduce waste, which supports both cost-saving and environmental goals (Islam, 2024).

Despite this potential, AI use in Nepal is still limited. Many small businesses struggle with low digital readiness and a lack of trained professionals to manage AI systems (Rajbhandari et al., 2022). Companies that do adopt AI often show better performance and higher sustainability standards, but most SMEs haven't reached this stage yet (Tamang, 2024). This highlights the importance of understanding how AI adoption influences sustainable outcomes.

H1: Adoption of artificial intelligence (AI) and sustainable business performance are strongly and favorably correlated.

Digital Transformation and Sustainable Business Performance

Digital transformation involves using modern tools like cloud platforms, smart sensors, and blockchain to make business processes more efficient. In Nepal, these tools have been slowly adopted, especially in urban firms that want to improve efficiency and reduce paperwork (Dangol, 2024). Tools like IoT can track energy use, blockchain improves supply chain transparency, and cloud systems help companies share sustainability reports more easily (Sheethal, 2024).

However, challenges still exist. Most SMEs in Nepal don't have the infrastructure or training to

use these tools effectively. Many lack awareness about how digital transformation can improve both business and environmental performance (Tan, n.d.). But firms that do invest in these tools report stronger financial, environmental, social, and performance (Oruganti et al., 2025).

H2: Digital transformation and sustainable business performance are strongly and favorably correlated.

Innovation in Green Products as a Mediating Factor (AI Pathway)

Green product innovation means creating products that use fewer natural resources and are less harmful to the environment. AI plays a key role in this by helping companies identify more eco-friendly materials and ways to reduce environmental harm during production (Islam, 2024). In Nepal, however, very few companies focus on green products unless required by government policies or external funding (Saxena et al., 2025).

Still, those that use AI for green innovation have seen better resource efficiency, stronger brand image, and reduced environmental impact (Tamang, 2024). Green innovation helps link AI tools directly to sustainable outcomes like cost savings and customer trust, making it a crucial mediator in the sustainability journey.

H3: The relationship between AI adoption and sustainable business performance is mediated by green product innovation.

Innovation in Green Products as a Mediating Factor (Digital Transformation Pathway)

Additionally, digital technologies are essential for promoting green innovation. For example, tools like 3D modeling or software-based design can help companies test new products virtually before making them, which saves energy and reduces waste (Sheethal, 2024). When paired with digital transformation, green innovation helps companies develop products that meet modern consumer expectations for eco-friendly goods (Islam, 2024).

Research has shown that digital systems help firms improve their environmental and economic performance by promoting product lifecycle tracking and greener resource choices (Oruganti et al., 2025). This makes green product innovation a key step in converting digital capabilities into real sustainability results (Tan, 2024).

H4: The connection between digital transformation and sustainable business performance is mediated by green product innovation.

Conceptual Framework

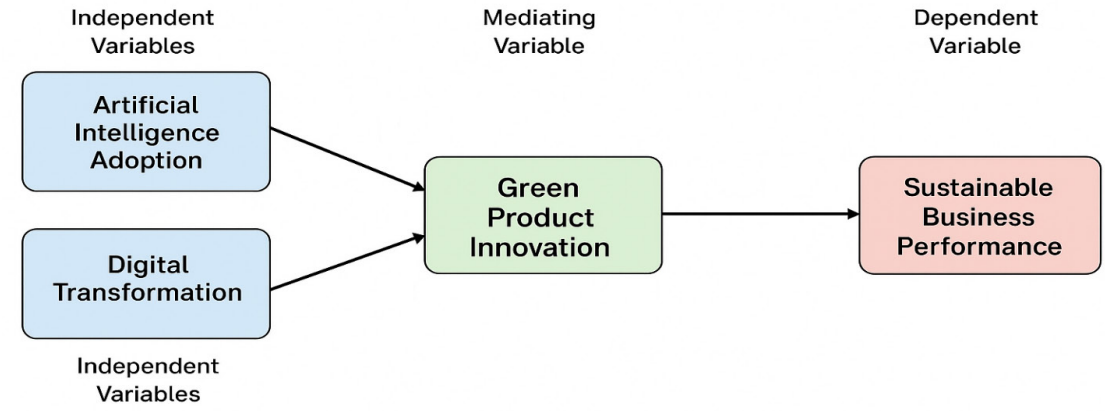

Figure: Conceptual Framework

Research Methodology

Research Design

In order to investigate how digital transformation, green product innovation, and the adoption of artificial intelligence (AI) affect sustainable business performance in Nepal, this study used a quantitative research methodology. Participants' data was gathered at one particular moment using a cross-sectional research design. This approach works well for analyzing correlations between variables without changing the study setting.

Population and Sample

The research targeted **Nepalese firms actively engaged in AI, digital transformation, and sustainability initiatives**. According to the Institute for Integrated Development Studies (IIDS), Nepal's Information Technology (IT) sector comprises **106 IT service export companies** and **14,728 IT freelancers**, indicating a growing ecosystem of tech-enabled businesses (IIDS, 2023). Based on recent national data, the estimated population for this study includes approximately **10,000–15,000 Nepalese firms** operating in the digital and sustainability domain (IIDS, 2023; OCR, 2023; World Bank, 2023).

To ensure the study's findings are statistically significant and generalizable, the sample size was 384 responders. This sample size is based on standard statistical formulas for populations with more than 10,000 people, with a 95% confidence level and a 5% margin of error. Purposeful sampling was used to choose participants who are actively involved in making decisions about AI adoption, digital transformation, and sustainability within their organizations.

Data Collection Procedure

Data were gathered through a **structured** an online questionnaire distributed over a period of three months. The purpose of the questionnaire was to gather information on:

- AI Adoption
- Digital Transformation
- Green Product Innovation
- Sustainable Business Performance

Each item was measured using a 5-point Likert scale with "Strongly Disagree" and "Strongly Agree" as the extremes. Before being fully implemented, the questionnaire was pre-tested with a small group of experts to guarantee its relevance and clarity.

Measurement of Constructs

This study used reliable and tested questions from recent research:

- **AI Adoption** was measured by how firms use AI for planning, decision-making, and operations, adapted from Farmanesh et al., 2025.
- **Digital Transformation** looked at the use of digital tools like blockchain, IoT, and analytics, based on Aftab et al., 2025.
- **Green Product Innovation** covered eco-friendly product design and green materials, using items from Chotia et al., 2024.
- **Sustainable Business Performance** included financial, environmental, and social aspects, following Yin et al., 2022.

All responses were rated on a **5-point scale**, from "strongly disagree" to "strongly agree.".

Data Analysis

Structural Equation Modeling (SEM) was employed to analyze the collected data and evaluate the hypothesized relationships among the variables. Confirmatory Factor Analysis (CFA) was employed to validate the measurement models for each construct prior to Structural Equation Modeling (SEM). The mediating effects of green product innovation on the relationships among AI adoption, digital transformation, and sustainable business performance were assessed using bootstrapping methods with 5,000 resamples.

Ethical Considerations

Ethical approval was obtained prior to data collection. Participants were informed about the purpose of the study, assured of the confidentiality of their responses, and provided informed consent. Participation was voluntary, and respondents had the right to withdraw at any time without any repercussions.

Results

Demographic Characteristics of Respondents (N = 384)

1. Current Age	**Frequency**	**Percentage (%)**
Below 20	94	24.5
21–30	96	25
31–40	65	16.9
41–50	56	14.6
51 and above	73	19
Total	**384**	**100**
2. Gender Identity		
Female	78	20.3
Male	285	74.2
Prefer not to say	21	5.5
Total	384	100
3. Highest Education Level		
High school	86	22.4
Bachelor's degree	93	24.2
Master's degree	56	14.6
Doctorate	13	3.4
Professional Certification	84	21.9
Other	52	13.5
Total	**384**	**100**
4. Role/Position in the Organization		
Consultant	63	16.4
Entry-level Employee	84	21.9
Middle Management	84	21.9
Senior Management	89	23.2
Other	64	16.7
Total	**384**	**100**
5. Current Employees Working in the Organization		
Less than 10	202	52.6
10–200	142	37
More than 200	40	10.4
Total	**384**	**100**
6. Type of the Organization		

Manufacturing	151	39.3
Services	84	21.9
Technology	78	20.3
Other	71	18.5
Total	**384**	**100**
7. Organization is Operating Since/From		
Less than 1 Year	80	20.8
1–3 Years	82	21.4
4–6 Years	76	19.8
7–10 Years	72	18.8
More than 10 Years	74	19.3
Total	**384**	**100**
8. Dedicated Budget for AI, Digital Transformation, or Sustainability		
Yes	122	31.8
No	143	37.2
Not Sure	119	31
Total	**384**	**100**

The survey included 384 participants. Most were aged between 21 and 30 (25%) or under 20 (24.5%). Males made up the majority (74.2%), with females at 20.3%, and 5.5% chose not to say. Educationally, most held a bachelor's degree (24.2%) or had a high school diploma (22.4%), with a notable shareholding professional certifications (21.9%).

Respondents held varied roles – senior and middle management (23.2% and 21.9%), entry-level (21.9%), consultants (16.4%), and others. Over half (52.6%) worked in small organizations with fewer than 10 employees. Industry types were mainly manufacturing (39.3%), followed by services (21.9%) and tech (20.3%).

About one in five organizations were under a year old, while 19.3% had operated for over 10 years. Only 31.8% reported having a dedicated budget for AI, digital transformation, or sustainability, while 37.2% did not, and 31% were unsure.

Factor Analysis

Items	Artificial Intelligence Adoption	Digital Transformation	Green Product Innovation	Sustainable Business Performance
AI01	0.721			
AI02	0.735			
AI03	0.804			

AI04	0.762			
DT1		0.812		
DT2		0.861		
DT3		0.838		
GIP1			0.745	
GIP2			0.701	
GIP3			0.769	
GIP4			0.822	
GIP5			0.738	
SFP1				0.763
SFP2				0.811
SFP3				0.799
SFP4				0.783
SFP5				0.772

The study employed exploratory factor analysis to examine the structural validity of constructs related to Artificial Intelligence (AI) Adoption, Digital Transformation, Green Product Innovation, and Sustainable Business Performance. The analysis revealed four distinct factors with strong item loadings, confirming the coherence of each construct. The AI Adoption construct was represented by four items (AI01 to AI04), all of which demonstrated high factor loadings ranging from 0.721 to 0.804, indicating consistent responses around AI implementation within organizations. Similarly, Digital Transformation was measured through three items (DT1 to DT3), which also exhibited robust loadings between 0.812 and 0.861, affirming its construct reliability. Green Product Innovation, assessed using five items (GIP1 to GIP5), showed substantial loadings between 0.701 and 0.822, confirming the dimension's relevance in capturing eco-innovation strategies. Finally, Sustainable Business Performance was measured with five indicators (SFP1 to SFP5), each reflecting strong loadings from 0.763 to 0.811, underscoring the internal consistency of the performance outcomes.

These findings are consistent with recent empirical applications of factor analysis in sustainability and Industry 4.0 domains. For instance, Oláh et al. (2022) employed factor analysis to validate constructs linking smart manufacturing technologies and business performance, demonstrating similar construct clarity and statistical robustness (Oláh et al., 2022).

In summary, the factor loadings provided strong empirical support for the dimensionality and reliability of the four constructs, laying a robust foundation for subsequent structural modeling and hypothesis testing.

Correlation

	Artificial Intelligence Adoption	Digital Transformation	Green Product Innovation	Sustainable Business Performance
Artificial Intelligence Adoption	1			
Digital Transformation	0.658	1		
Green Product Innovation	0.712	0.684	1	
Sustainable Business Performance	0.667	0.729	0.752	1

The analysis showed strong positive relationships among all four constructs. AI Adoption was closely linked to Digital Transformation (r = 0.658), Green Product Innovation (r = 0.712), and Sustainable Business Performance (r = 0.667). Digital Transformation was also highly correlated with Green Product Innovation (r = 0.684) and Sustainable Business Performance (r = 0.729). The strongest link was between Green Product Innovation and Sustainable Business Performance (r = 0.752), showing that eco-innovation drives better sustainability outcomes.

These findings echo recent studies that highlight how AI and digital strategies strengthen sustainable business results (Xi et al., 2025; Siswanti et al., 2024).

Quality Criteria

Construct	R-square	R-square Adjusted
Green Product Innovation	0.582	0.578
Sustainable Business Performance	0.663	0.659

The model explains 58.2% of the variance in Green Product Innovation ($R^2 = 0.582$) and 66.3% in Sustainable Business Performance ($R^2 = 0.663$), showing strong predictive power. These results suggest that factors like innovation and digital transformation significantly influence sustainability outcomes. Similar findings were reported by Hariadi et al. (2023) and Setyaningrum & Muafi (2023), who confirmed the importance of green innovation in driving sustainable business results.

Construct and Validity

Construct	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
Artificial Intelligence Adoption	0.751	0.763	0.842	0.567

Digital Transformation	0.826	0.829	0.891	0.731
Green Product Innovation	0.798	0.814	0.873	0.581
Sustainable Business Performance	0.857	0.861	0.894	0.628

Across the four constructs of Artificial Intelligence Adoption, Digital Transformation, Green Product Innovation, and Sustainable Business Performance, the measurement model's validity and reliability were validated. The range of Cronbach's Alpha values, which indicate acceptable to strong internal consistency, was 0.751 to 0.857. Composite reliability (rho_c) values were consistently above the recommended threshold, ranging from 0.842 to 0.894, further validating the reliability of each construct. Additionally, All Average Variance Extracted (AVE) scores, which ranged from 0.567 to 0.731, were above 0.50, confirming adequate Convergent validity is the ability of each construct to capture enough variation from the items it is associated with.

These results align with current best practices in sustainability and innovation research. For instance, Turkcan (2025) emphasized that green innovation and digital transformation constructs should meet rigorous reliability standards to predict performance outcomes. Similarly, Badwy (2024) applied AVE and composite reliability to validate constructs related to innovation capabilities in digital and sustainable business models.

Together, these indicators affirm that the measurement framework is statistically sound and well-suited for further structural equation modeling or regression analysis in the context of sustainability-focused research.

Heterotrait-monotrait ratio (HTMT) - Matrix

	Artificial Intelligence Adoption	Digital Transformation	Green Product Innovation	Sustainable Business Performance
Artificial Intelligence Adoption		0.798	0.865	0.792
Digital Transformation	0.798		0.779	0.832
Green Product Innovation	0.865	0.779		0.846
Sustainable Business Performance	0.792	0.832	0.846	

To evaluate discriminant validity among the constructs – Artificial Intelligence Adoption, Digital Transformation, Green Product Innovation, and Sustainable Business Performance

– the Heterotrait-Monotrait (HTMT) ratio was employed. All HTMT values fell well below the conservative threshold of 0.90, confirming strong discriminant validity across the model. Specifically, the HTMT ratios were 0.798 between AI Adoption and Digital Transformation, 0.865 between AI Adoption and Green Product Innovation, and 0.792 between AI Adoption and Sustainable Business Performance. The ratio between Digital Transformation and Green Product Innovation was 0.779, while its value with Sustainable Business Performance was 0.832. Lastly, Green Product Innovation and Sustainable Business Performance yielded an HTMT value of 0.846.

These results demonstrate that each construct is statistically distinct from the others, thereby validating the measurement model's discriminant power. This approach aligns with recent methodological standards in sustainability research. For example, Rashid et al. (2025) emphasized the necessity of HTMT ratios below 0.90 to ensure clear conceptual separation in models examining green supply chain practices and digital innovation. Similarly, Mukhtar et al. (2025) applied HTMT in their study of Malaysian manufacturing firms and confirmed its effectiveness in distinguishing constructs related to innovation and sustainability.

Overall, the results affirm that the constructs in this model are well-differentiated and suitable for further structural equation modeling or path analysis in the context of digital and green transformation research.

Fornell - Larcker Criterion

	Artificial Intelligence Adoption	Digital Transformation	Green Product Innovation	Sustainable Business Performance
Artificial Intelligence Adoption	0.759	0.638	0.699	0.661
Digital Transformation	0.638	0.869	0.676	0.721
Green Product Innovation	0.699	0.676	0.766	0.747
Sustainable Business Performance	0.661	0.721	0.747	0.791

The four constructs—Digital Transformation, Green Product Innovation, Artificial Intelligence Adoption, and Sustainable Business Performance—were evaluated for discriminant validity using the Fornell-Larcker criterion. Each construct's square root of the Average Variance Extracted (AVE) was greater than its correlations with every other construct, indicating that each variable is both statistically and conceptually unique. For example, Digital Transformation's AVE root was 0.869, which was higher than its correlations with Sustainable Performance (0.721), Green Product Innovation (0.676), and AI Adoption (0.638). Likewise, the AVE root of Green Product Innovation (0.766) was higher than its correlations with every associated construct.

This result validates the model's discriminant validity and aligns with recent empirical studies. Prakash et al. (2024) employed the Fornell–Larcker method in a structural equation model examining digital transformation's impact on environmental sustainability, reinforcing its applicability and relevance in current sustainability and innovation research.

Mean, STD, T - values, P- values

Path Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STD)	T Statistics	P Values
Artificial Intelligence Adoption ->Green Product Innovation	0.503	0.504	0.058	8.672	0
Artificial Intelligence Adoption -> Sustainable Business Performance	0.142	0.144	0.045	3.156	0.002
Digital Transformation -> Green Product Innovation	0.354	0.356	0.06	5.9	0
Digital Transformation-> Sustainable Business Performance	0.388	0.386	0.064	6.063	0
Green Product Innovation->Sustainable Business Performance	0.417	0.418	0.061	6.836	0

Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to evaluate the structural model. The strength of relationships between constructs was assessed using path coefficients and significance levels. Every one of the five proposed routes was found to be statistically significant ($p < 0.05$), and robust effects were confirmed by high T-values.

- **Artificial Intelligence Adoption → Green Product Innovation** showed a strong positive influence ($\beta = 0.503$, $t = 8.672$, $p = 0.000$), suggesting that increased AI use enhances eco-innovation initiatives.
- **AI Adoption → Sustainable Business Performance** had a weaker yet significant impact ($\beta = 0.142$, $t = 3.156$, $p = 0.002$), indicating that AI indirectly supports sustainable outcomes.
- **Digital Transformation → Green Product Innovation** also showed a solid positive relationship ($\beta = 0.354$, $t = 5.900$, $p = 0.000$), affirming the enabling role of digital technologies in driving innovation.
- **Digital Transformation → Sustainable Business Performance** revealed a strong path coefficient ($\beta = 0.388$, $t = 6.063$, $p = 0.000$), supporting the strategic value of digitalization in achieving sustainability goals.
- **Green Product Innovation → Sustainable Business Performance** presented the highest effect ($\beta = 0.417$, $t = 6.836$, $p = 0.000$), confirming that innovation in eco-friendly products substantially contributes to improved sustainability outcomes.

These results align with findings from recent studies. For example, Prakash et al. (2024) confirmed similar statistical significance using PLS-SEM to model digital transformation and sustainability linkages. Likewise, Khakwani & Zafar (2024) demonstrated that both AI and digital transformation positively influence firm performance through green innovation pathways.
Together, these path estimates provide strong empirical support for the proposed conceptual framework, reinforcing the critical role of digital and AI strategies in driving sustainable and innovative business practices.

Conclusion

This study explored the interrelationships among Adoption of artificial intelligence (AI), digital transformation, innovation in green products, and sustainable business performance in the context of Nepal. The results demonstrate that digital transformation and artificial intelligence both greatly improve sustainable results, especially when mediated by green product innovation. AI-enabled tools improve predictive analysis, decision-making, and operational efficiency, all of which align with broader sustainability goals (Farmanesh et al., 2025; Liang et al., 2024).

Similarly, digital transformation – especially through the adoption of IoT, cloud platforms, and analytics – provides a strong foundation for green innovation and supply chain transparency, which are essential for sustainable growth (Sheethal, 2024; Chotia et al., 2024). Green product innovation has emerged as a critical mediating factor that links technological capability to measurable environmental and financial outcomes (Lin et al., 2024).

The study contributes new empirical insights to the limited literature on the role of emerging technologies in the sustainability transformation of developing economies, particularly within South Asia. The results underscore the need for a multi-layered strategy that leverages AI and digitalization not as ends, but as tools to realize green and socially responsible business models.

Recommendations and Future Directions

- **Invest in Capacity Building and Skills Development**

  Policymakers and industry leaders in Nepal should invest in AI and digital literacy training to bridge the current knowledge gap among SMEs. Upskilling human capital will be essential for scaling AI and digital transformation across sectors (Xu et al., 2023).

- **Incentivize Green Innovation Initiatives**

  Government subsidies and tax incentives should be tailored to support firms engaging in green product innovation. Such policies would encourage firms to integrate sustainability into their R&D and operations (Chotia et al., 2024).

- **Integrate Digital and Environmental Policies**

  National digital strategies should align with environmental and climate policies to ensure a holistic transformation. This integration can help avoid fragmented efforts and maximize impact (Lin et al., 2024).

- **Support Cross-Sector Collaboration and Knowledge Sharing**
  Platforms that bring together stakeholders from academia, business, and government can facilitate innovation diffusion and help overcome the challenges of siloed knowledge systems (Khan et al., 2022).
- **Future Research Directions**
  Future studies could explore sector-specific effects of digital and green innovation, such as in manufacturing or agriculture. Longitudinal research may also reveal how digital maturity and green innovation co-evolve over time to support sustainable outcomes (Yin et al., 2022).

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