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Corresponding author:
Filzah Wafiyah
Email: filzahwafiyah@gmail.com

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THE IMPACT OF ARTIFICIAL INTELLIGENCE, BIG DATA ANALYTICS, AND THE INTERNET OF THINGS ON SUSTAINABLE BUSINESS PRACTICES AMONG MARKETPLACE-USING MSMEs IN INDONESIA

Filzah Wafiyah[1]

[1]*Universitas Airlangga, Indonesia*

ABSTRACT

Objective: This study aims to analyze the impact of the use of Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) on sustainable business practices among MSMEs using marketplaces in Indonesia.

Research Design & Methods: This study employs a quantitative approach using a cross-sectional survey design. Data were collected from 285 MSMEs owners or managers who actively use marketplaces such as Shopee, Tokopedia, Lazada, and Blibli. Data analysis was conducted using the Partial Least Squares Structural Equation Modeling (PLS-SEM) method with the assistance of SmartPLS 4.0 software.

Findings: The results indicate that all hypotheses were accepted. Artificial Intelligence has a positive and significant effect on sustainable business practices ($\beta = 0.341$; $p < 0.001$), followed by Big Data Analytics ($\beta = 0.298$; $p < 0.001$) and the Internet of Things ($\beta = 0.219$; $p < 0.001$). The coefficient of determination value of $R^2 = 0.674$ indicates that these three digital technologies account for 67.4% of the variation in sustainable business practices among Indonesian MSMEs using marketplaces. Among the three variables, Artificial Intelligence is the factor with the most dominant influence.

Contributions: This study makes an empirical contribution to the literature on digital transformation and MSMEs sustainability by demonstrating that the simultaneous use of AI, BDA, and IoT can enhance sustainable business practices from economic, social, and environmental perspectives. The study's findings also offer practical implications for MSMEs operators, marketplace providers, and policymakers in promoting the adoption of digital technologies to support business sustainability.

Novelty: This study integrates Artificial Intelligence, Big Data Analytics, and the Internet of Things into a single conceptual model to explain sustainable business practices among marketplace-using MSMEs in Indonesia. Unlike previous studies, which generally examined each technology separately or focused on large corporations, this study provides empirical evidence within the context of SMEs in a developing country operating within a digital marketplace ecosystem.

Keywords: Digital Transformation; Sustainable Business Practices; MSMEs

JEL codes: L26, M15, O33
Article type: research paper

INTRODUCTION

Digital transformation has become one of the key drivers reshaping the global business landscape over the past decade. Rapid advancements in information and communication technology have created new opportunities for organizations to boost productivity, expand market access, and develop more innovative business models. In developing countries like Indonesia, digital transformation not only plays a role in improving operational efficiency but also serves as a strategic tool to strengthen the national economy's competitiveness in the era of the knowledge-based economy. The acceleration of digitalization has become increasingly evident in the wake of the COVID-19 pandemic, as economic and trade activities have shifted significantly toward digital platforms. Indonesia has even emerged as one of the largest digital markets in Southeast Asia, with the digital economy projected to exceed USD 130 billion by 2025. An internet penetration rate of 79.5%, with over 221 million internet users, indicates the public's increasingly high level of connectivity to the rapidly expanding digital ecosystem (International Trade Administration, 2025). These conditions create a conducive environment for businesses to leverage digital technology in conducting and expanding their business activities.

Micro, Small, and Medium Enterprises (MSMEs) play a strategic role in Indonesia's economy. MSMEs serve as the backbone of the national economy, contributing more than 60% of the Gross Domestic Product (GDP) and employing more than 97% of the national workforce. This significant contribution makes MSMEs key players in

driving inclusive and sustainable economic growth. The increasing digitalization of the economy is driving more MSMEs to utilize marketplace platforms as their primary means of marketing products and reaching a wider consumer base. Digital marketplaces such as Shopee, Tokopedia, Lazada, and Blibli have evolved into business ecosystems connecting millions of business owners with consumers across Indonesia. Throughout 2024, Shopee recorded over 10.9 billion orders with a Gross Merchandise Value (GMV) reaching USD 100.5 billion, a significant increase compared to the previous year's figure of USD 78.5 billion. The number of active sellers on Tokopedia has also increased by more than two million over the past two years, indicating a rising adoption rate of digital platforms among Indonesian MSMEs (Arif, 2025). This phenomenon demonstrates that marketplaces no longer function merely as sales channels but have become an integral part of MSMEs' business development strategies.

The level of digital transformation among MSMEs in Indonesia still faces various challenges that could potentially hinder the full realization of the benefits of digital technology. Various studies indicate that the majority of MSMEs are still in the early stages of digitalization and have not yet been able to fully leverage technology. Only about 19% of MSMEs have been sufficiently digitized, while the majority still face various obstacles such as low digital literacy, limited access to financing, a lack of technological competence, and the digital infrastructure gap between urban and rural areas (Bahtiar et al., 2025). This situation has resulted in many MSMEs failing to derive optimal benefits from the use of digital technology to improve their business performance. Demands for the implementation of sustainable business practices are also increasing as consumer awareness of social and environmental issues grows. The government and various international stakeholders are also promoting the application of sustainability principles as part of the long-term economic development agenda. Therefore, MSMEs are not only required to undergo digital transformation but must also ensure that this transformation supports business sustainability from economic, social, and environmental perspectives.

Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) are next-generation digital technologies with significant potential to support sustainable business practices. Artificial Intelligence (AI) enables companies to automate business processes, improve decision-making accuracy, and provide more responsive customer service through intelligent systems and digital chatbots (Soomro et al., 2025). Big Data Analytics (BDA) enables businesses to analyze large volumes of transaction data, consumer behavior, and market trends, leading to more accurate and data-driven business decisions (Alyahya et al., 2023). The Internet of Things (IoT) supports real-time connectivity between devices, enabling more efficient and measurable management of inventory, logistics, and the supply chain (Khan et al., 2022). Various studies indicate that the utilization of these three technologies can enhance resource efficiency, reduce operational waste, improve customer satisfaction, and strengthen business competitiveness in a sustainable manner (Bahtiar et al., 2025). The role of digital technology is no longer limited to boosting productivity but has also become a key enabler in achieving an organization's sustainability goals.

The research gap regarding the relationship between digital technologies and sustainable business practices still warrants further attention. Most previous studies have tended to examine the impact of AI, BDA, or IoT separately on organizational performance and have primarily been conducted on large companies in developed countries. Research that integrates these three technologies into a single conceptual model to explain sustainable business practices among Indonesian MSMEs using marketplaces remains relatively limited. The characteristics of MSMEs in developing countries also differ significantly from those of companies in developed nations, particularly regarding financial resources, human capital quality, technological readiness levels, and available institutional support. These differences mean that the results of previous studies cannot necessarily be directly generalized to the context of Indonesian MSMEs. Bahtiar et al., (2025) emphasize that the digital transformation of Indonesian SMEs faces multidimensional challenges that require a more holistic and contextual research approach. Given these circumstances, this study aims to analyze the impact of Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) on sustainable business practices among MSMEs using online marketplaces in Indonesia. A survey-based quantitative approach using the Partial Least Squares Structural Equation Modeling (PLS-SEM) method was employed to provide empirical evidence that can enrich the literature on digital transformation and the sustainability of MSMEs in Indonesia.

LITERATURE REVIEW

Resource-Based View (RBV)

The Resource-Based View (RBV), introduced by Barney (1991) is the most widely used theoretical framework for explaining how a company's unique resources and capabilities create sustainable competitive advantage. This theory posits that resources that are valuable, rare, inimitable, and non-substitutable—known as the VRIN criteria—form the foundation of long-term competitive advantage.

The digital era has transformed digital technology into a crucial strategic resource that meets the VRIN criteria. As noted by Kamardi et al., (2025), digital resources combined with strong organizational capabilities can generate superior growth and sustainable competitive advantage. Studies on competitive advantage from an RBV

perspective in the IT sector indicate that the economic, social, and environmental dimensions of the Triple Bottom Line (TBL) can be achieved through strategic management of digital resources (Kamardi et al., 2025).

The implementation of RBV for MSMEs underscores the importance of digital capabilities as a resource that enables small businesses to compete on equal footing with large corporations. Marketplace platforms such as Shopee and Tokopedia provide democratic access to digital resources—including AI-powered product recommendations, consumer transaction big data analytics, and IoT-based logistics integration—which were previously only accessible to large corporations (Bahtiar et al., 2025). Thus, MSMEs that actively leverage digital technology within the marketplace ecosystem have the potential to build resources and capabilities that support long-term business sustainability.

Sustainable Business Practices

Sustainable business practices are an organizational management approach that integrates economic, social, and environmental objectives in a balanced manner across all business activities. This concept, known as the Triple Bottom Line (TBL), was introduced by Elkington (1998) through three main dimensions: profit (economic), people (social), and planet (environmental). From a TBL perspective, a company's success is measured not only by financial profit but also by its contribution to societal well-being and its ability to preserve the environment for future generations. This approach is becoming increasingly important for MSMEs because business sustainability is viewed as a key factor determining competitiveness and business resilience in the face of dynamic market changes.

Sustainable business practices reflect the ability of MSMEs to create long-term economic value through improved operational efficiency, product and service innovation, enhanced competitiveness, and stable profitability growth. The social dimension relates to corporate responsibility toward stakeholders, including providing a safe work environment, improving employee well-being, consumer protection, empowering local communities, and implementing ethical business practices in the supply chain. Meanwhile, the environmental dimension emphasizes a company's efforts to reduce negative impacts on ecosystems through energy efficiency, waste management, carbon emission reduction, and the use of more environmentally friendly resources. These three dimensions complement one another and form the foundation for evaluating an organization's level of sustainability.

Various studies indicate that digital technology plays a crucial role in enhancing the sustainability performance of MSMEs. Digitalization enables companies to improve resource efficiency, strengthen supply chain transparency, accelerate data-driven decision-making, and foster innovation that supports sustainability goals. A study by Melo et al., (2023) indicates that digital transformation is strongly linked to achievements in economic, social, and environmental aspects within the TBL framework. Similar findings were reported by Haq and Huo (2023) who found that digital strategies and levels of digitalization positively contribute to the environmental performance of MSMEs. Furthermore, recent research on MSMEs confirms that digital transformation can improve resource efficiency, supply chain transparency, and green innovation, which ultimately strengthens overall business sustainability.

The Use of Artificial Intelligence (AI)

Artificial Intelligence (AI) is a branch of technology that enables computer systems to mimic human cognitive abilities, such as learning from data, recognizing patterns, understanding language, making predictions, and supporting automated decision-making. The rapid development of AI has driven its adoption across various business sectors, including Micro, Small, and Medium Enterprises (MSMEs). In the context of MSMEs, AI is used to support various operational and strategic activities, such as customer behavior analysis, product recommendation systems, customer service chatbots, inventory management, price optimization, market demand forecasting, and sentiment analysis of consumer reviews. The presence of AI enables MSMEs to improve business process efficiency, reduce operational costs, and generate faster and more accurate decisions compared to conventional methods (Dwivedi et al., 2023).

The business sustainability perspective views AI as a technology capable of generating economic value while supporting the achievement of social and environmental goals. Economically, AI helps companies improve productivity, resource efficiency, and profitability through process automation and more precise data analysis. On the social front, AI can enhance customer service quality, accelerate responses to consumer needs, and support more objective decision-making. Meanwhile, on the environmental dimension, AI contributes to reduced energy consumption, supply chain optimization, more effective waste management, and more efficient resource use. Research by Badghish and Soomro (2024) indicates that the adoption of AI has a significant positive impact on the sustainability performance of MSMEs, encompassing economic, social, and environmental aspects. These findings are reinforced by research by Gao et al., (2025) which confirms that AI can enhance an organization's dynamic capabilities, thereby fostering the creation of more sustainable and innovative business practices.

The digital business landscape, particularly for MSMEs utilizing marketplaces, has seen AI technology become an integral part of the digital platform ecosystem. Marketplaces like Shopee and Tokopedia leverage machine learning-based algorithms to provide more personalized product recommendations, optimize ad

placement, and enhance the relevance of product search results for consumers. These features help MSMEs reach a more precise target market, increase sales conversion rates, and strengthen customer relationships. Additionally, AI's ability to process large volumes of data enables MSMEs operators to gain real-time business insights, allowing them to respond to market changes more quickly. Thus, the use of AI by MSMEs on marketplaces not only contributes to improved economic performance but also supports more efficient resource utilization and more sustainable business practices.

The Use of Big Data Analytics (BDA)

Big Data Analytics (BDA) refers to an organization's ability to collect, manage, process, and analyze large volumes of data characterized by volume, velocity, and variety to generate valuable insights for business decision-making. As digital transformation advances, data has become a strategic asset capable of helping companies understand customer behavior, predict market trends, optimize operational processes, and improve the quality of managerial decisions. BDA encompasses various analytical approaches, ranging from descriptive analysis that explains past conditions, diagnostic analysis to identify the causes of a phenomenon, predictive analysis to forecast future conditions, to prescriptive analysis that provides recommendations for the best course of action for the organization (Wamba et al., 2017).

Big Data Analytics (BDA) capabilities in MSMEs serve as a strategic resource that can create a competitive advantage and sustainably improve business performance. Based on the Resource-Based View (RBV) and Dynamic Capabilities Theory, the ability to effectively utilize data enables companies to identify market opportunities more quickly, adaptively respond to changes in the business environment, and improve resource efficiency. Research by Akhtar et al., (2018) indicates that Big Data Analytics capabilities contribute to the creation of sustainable competitive advantage through enhanced supply chain resilience. Additionally, Alyahya et al., (2023) found that BDA positively influences corporate sustainability performance by improving strategic agility and organizational creativity. These findings indicate that the ability to manage and utilize data not only impacts economic aspects but also supports the achievement of a company's social and environmental goals.

Businesses operating through digital marketplaces can leverage BDA more easily, as various e-commerce platforms provide analytics features accessible to sellers. Through the analytics dashboards available on platforms like Shopee and Tokopedia, business owners can access information on sales trends, consumer behavior, promotional effectiveness, product performance, conversion rates, and customer search patterns. This information enables business owners to make more accurate decisions regarding inventory management, pricing, market segmentation, and digital marketing strategies. Thus, the use of BDA helps MSMEs improve operational efficiency, reduce resource waste, and strengthen business competitiveness and sustainability in the long term.

The Use of the Internet of Things (IoT)

The Internet of Things (IoT) is a technological concept that connects various physical devices via the internet, enabling them to automatically collect, transmit, and exchange data without requiring extensive human intervention. This technology utilizes sensors, software, network connectivity, and computing systems to generate real-time information that can be used in business decision-making. In the context of MSMEs, IoT has been applied to various operational activities such as RFID-based inventory management, monitoring product conditions during the distribution process, integrated business security systems, energy consumption monitoring, as well as digital payment and sales systems connected to e-commerce platforms. By providing real-time data, IoT helps businesses improve operational efficiency, reduce human error, and accelerate responses to changing market conditions (Borgia, 2014).

The IoT plays a crucial role in improving resource efficiency while supporting the achievement of a company's economic, social, and environmental goals. In the economic dimension, the IoT enables companies to optimize production, distribution, and inventory management processes, thereby reducing operational costs and increasing productivity. In the social dimension, the IoT supports improvements in customer service quality by providing more accurate information and faster responses to consumer needs. Meanwhile, on the environmental front, IoT enables monitoring of energy usage, waste reduction, and resource optimization, thereby mitigating the environmental impact of business activities. Research by Khan et al., (2022) indicates that the implementation of IoT in supply chain management can enhance operational visibility, strengthen business process efficiency, and support sustainable business practices. Additionally, a recent study on IoT adoption among MSMEs found that this technology positively contributes to improved energy efficiency, reduced carbon emissions, and enhanced overall organizational sustainability performance (Rupa et al., 2026).

The use of IoT is becoming increasingly relevant as it supports the integration of online sales activities with business operations management on digital marketplaces. IoT devices can be used to automatically monitor inventory, manage warehousing in real time, and optimize logistics and product delivery to customers. The integration of IoT with other technologies such as Artificial Intelligence (AI) and Big Data Analytics (BDA) enables MSMEs to obtain more comprehensive information regarding operational conditions and consumer behavior. Haryanti et al., (2025) explain that the convergence of IoT, AI, and BDA forms a digital ecosystem capable of enhancing an organization's ability to manage business complexity while strengthening the implementation of

sustainable practices. Therefore, for MSMEs using marketplaces in Indonesia, the utilization of IoT is not only a means of improving operational efficiency and customer service quality but also a strategic factor in achieving long-term business sustainability.

Conceptual Framework

This study is grounded in the Resource-Based View (RBV), which posits that organizational resources and capabilities serve as strategic assets that can create sustainable competitive advantages and improve long-term performance. In the context of digital transformation, Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) are considered strategic technological resources that enable MSMEs to enhance operational efficiency, improve decision-making quality, optimize resource utilization, and strengthen business competitiveness.

Artificial Intelligence (AI) assists MSMEs in automating business processes, analyzing customer behavior, forecasting market demand, and improving service quality through intelligent systems. Big Data Analytics (BDA) enables MSMEs to collect, process, and analyze large amounts of data to generate valuable insights for strategic decision-making. Meanwhile, the Internet of Things (IoT) facilitates real-time monitoring and connectivity among devices, supporting more effective inventory management, logistics operations, and resource control.

The integration of these digital technologies is expected to contribute positively to Sustainable Business Practices, which encompass economic, social, and environmental dimensions. Economically, digital technologies improve productivity, profitability, and competitiveness. Socially, they enhance customer satisfaction, transparency, and stakeholder engagement. Environmentally, they support resource efficiency, waste reduction, and environmentally responsible business operations.

Based on the theoretical foundation and previous empirical studies, this research proposes that Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) have direct positive effects on Sustainable Business Practices among marketplace-using MSMEs in Indonesia. The conceptual framework of this study is presented in Figure 1.

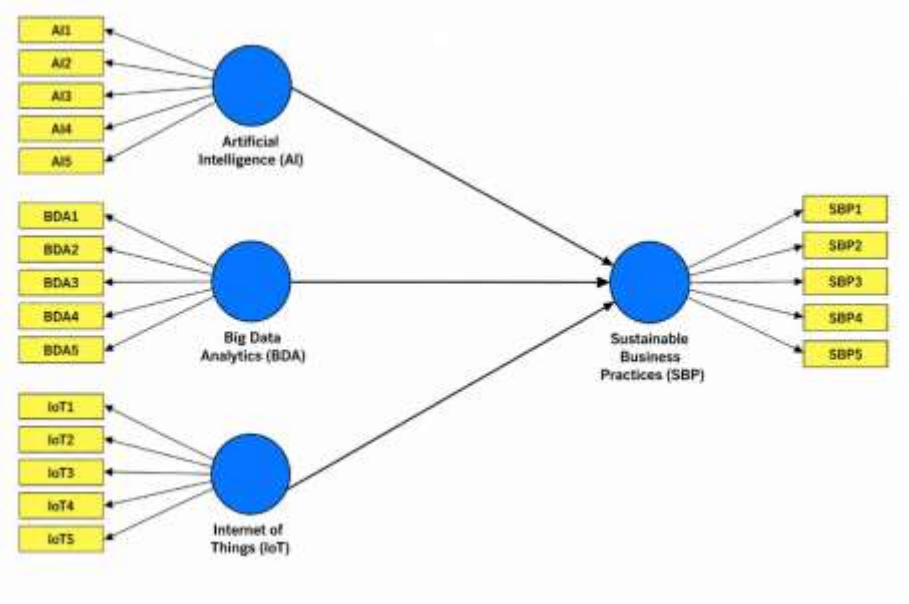

Figure 1. Conceptual Framework

Hypothesis Development

H1: The use of Artificial Intelligence (AI) has a positive and significant effect on the sustainable business practices of MSMEs using marketplaces.

H2: The use of Big Data Analytics (BDA) has a positive and significant effect on the sustainable business practices of MSMEs using marketplaces.

H3: The use of the Internet of Things (IoT) has a positive and significant effect on the sustainable business practices of MSMEs using marketplaces.

METHODS

This study employs a quantitative approach using a cross-sectional survey design aimed at testing the causal relationships among variables in the research model. The study is explanatory in nature as it seeks to explain the influence of the utilization of Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) on sustainable business practices among MSMEs using marketplaces in Indonesia. Data were collected through a structured questionnaire developed based on instruments validated in previous research and adapted to the context of digital MSMEs. This study adopts a positivist paradigm that views each construct as a variable that can be objectively measured and analyzed using statistical approaches to test the relationships formulated theoretically (Sekaran & Bougie, 2016).

The study population consists of MSME owners or managers who actively use marketplaces such as Tokopedia, Shopee, Lazada, or Bukalapak as their primary or secondary sales channels. The sampling technique employed a combination of purposive sampling and snowball sampling due to the lack of a comprehensive sampling frame covering all MSMEs that use marketplaces. Respondents were selected based on specific criteria, namely owning or managing an MSME in accordance with Law No. 20 of 2008, having operated on a marketplace for at least 12 months, and being directly involved in the digital operational management of the business. Referring to the recommended minimum sample size in PLS-SEM, the suggested sample size is ten times the maximum number of paths leading to a construct in the research model (Hair et al., 2019). Based on an expected response rate of 70%, the study aimed to distribute 300 questionnaires and successfully obtained 285 valid responses suitable for analysis.

The questionnaire was distributed online using Google Forms between January and March 2025. The survey link was disseminated through MSMEs communities, entrepreneur associations, marketplace seller groups, and social media platforms. To ensure respondent eligibility, screening questions were included at the beginning of the questionnaire regarding business ownership status, marketplace usage experience, and involvement in digital business operations. A total of 300 questionnaires were distributed, of which 291 responses were returned. After data screening for completeness and consistency, 285 responses were retained for final analysis.

This study measures four main variables using an instrument adapted from previous research with a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The Artificial Intelligence (AI) variable is measured through five indicators adapted from Badghish and Soomro (2024) and Soomro et al., (2025), namely: (1) the use of AI-based product recommendation features on marketplaces; (2) the use of AI-based chatbots or virtual assistants for customer service; (3) the use of AI-based predictive analytics systems for sales forecasting; (4) the use of AI in ad optimization and consumer targeting; and (5) the use of AI for fraud detection and transaction security. The Big Data Analytics (BDA) variable is measured using five indicators adapted from Alyahya et al., (2023) and Kumar et al., (2025), including: (1) the use of seller analytics dashboards on marketplaces; (2) the analysis of consumer behavior data for business decision-making; (3) the use of market data for competitive pricing; (4) analysis of product trend and market demand data; and (5) the utilization of data-driven business performance reports for strategy evaluation. The Internet of Things (IoT) variable is measured using five indicators adapted from Khan et al., (2022) and Rupa et al., (2026), namely: (1) the use of sensor-based or IoT-based automated inventory management systems; (2) the use of shipment tracking devices for logistics monitoring; (3) the integration of Point of Sale (POS) systems connected to marketplaces; (4) the use of internet-connected CCTV cameras for warehouse or store security; and (5) the use of sensors or IoT devices to monitor product conditions such as temperature and humidity. Meanwhile, the Sustainable Business Practices variable is measured through 15 indicators covering three dimensions—economic, social, and environmental—adapted from Udayana et al., (2024), Alyahya et al., (2023), and Bahtiar et al., (2025). The economic dimension consists of: (1) revenue growth; (2) profitability; (3) cost efficiency; (4) product or service innovation; and (5) market competitiveness. The social dimension includes: (1) customer satisfaction; (2) employee well-being; (3) impact on the community; (4) business ethics; and (5) operational transparency. The environmental dimension includes: (1) energy efficiency; (2) waste reduction; (3) carbon footprint reduction; (4) sustainable procurement practices; and (5) environmental reporting.

Data analysis was conducted in two stages using SmartPLS 4.0: The first stage involved testing the Measurement Model (Outer Model), which included: (1) Convergent Validity, measured by factor loadings (> 0.70) and Average Variance Extracted (AVE) (> 0.50); (2) Discriminant Validity, tested using the Heterotrait-Monotrait Ratio (HTMT < 0.90) and the comparison of the square root of AVE with the interconstruct correlation (Fornell-

Larcker Criterion); (3) Construct Reliability, measured through Composite Reliability (CR) (> 0.70) and Cronbach's Alpha (> 0.70). The second stage involves testing the Structural Model (Inner Model), which includes: (1) Coefficient of Determination (R^2) to assess the model's predictive ability; (2) Effect Size (f2) to assess the magnitude of the impact of each predictor construct; (3) Predictive Relevance (Q2) via the blindfolding procedure to assess the predictive relevance of the model; (4) Hypothesis Testing via the bootstrapping procedure (5,000 resamplings) to generate path coefficients, t-statistics, and p-values.

RESULT

Respondent Profile

The demographic profile of the 285 valid respondents reflects a representative cross-section of the Indonesian MSMEs ecosystem that uses online marketplaces. By business type, the majority of respondents operate in the fashion and apparel sector (28.1%), followed by food and beverages (22.5%), electronics and accessories (18.2%), beauty and personal care (15.4%), and other categories (15.8%). In terms of business age, MSMEs with 1–3 years of operation dominate (41.4%), followed by 3–5 years (31.2%), over 5 years (18.6%), and less than 1 year (8.8%)

Table 1. Respondent Profile

Characteristic	Category	Frequency	Percentage (%)
Business Type	Fashion & Apparel	80	28,1
	Food & Beverages	64	22,5
	Electronics & Accessories	52	18,2
	Beauty & Personal Care	44	15,4
	Other	45	15,8
Years in Business	< 1 year	25	8,8
	1–3 year	118	41,4
	3–5 year	89	31,2
	> 5 year	53	18,6
Primary Marketplace	Shopee	132	46,3
	Tokopedia	87	30,5
	Lazada	39	13,7
	Blibli	27	9,5
Total of Employees	1–5 people	158	55,4
	6–19 people	89	31,3
	20–99 people	38	13,3

Shopee is the dominant marketplace used by respondents (46.3%), followed by Tokopedia (30.5%), Lazada (13.7%), and Blibli (9.5%), which is consistent with platform traffic data for 2023–2024 (Databoks, 2024). In terms of business scale based on the number of employees, the majority are micro-enterprises with 1–5 employees (55.4%), followed by small businesses with 6–19 employees (31.3%), and medium-sized businesses with 20–99 employees (13.3%).

Results of the Measurement Model Analysis (Outer Model)

1. Convergent Validity

The results of the convergent validity test show that all indicators have outer loadings above 0.70, with Average Variance Extracted (AVE) values exceeding the threshold of 0.50 for all constructs. The AI construct has an AVE of 0.621, BDA has an AVE of 0.608, IoT has an AVE of 0.597, and Sustainable Business Practices have an AVE of 0.584. These results confirm that the convergent validity of all constructs is met.

Table 2. Convergent Validity Test Results

Construct	Indicator	Outer Loading	AVE
AI (Artificial Intelligence)	AI1	0,812	0,621
	AI2	0,798	
	AI3	0,779	
	AI4	0,803	
	AI5	0,754	
BDA (Big Data Analytics)	BDA1	0,806	0,608
	BDA2	0,791	
	BDA3	0,769	
	BDA4	0,784	
	BDA5	0,755	
IoT	IoT1	0,783	0,597
	IoT2	0,770	
	IoT3	0,762	
	IoT4	0,778	
	IoT5	0,751	
Sustainable Business Practices (SBB)	SBB_Eko1–5	0,731–0,811	0,584
	SBB_Sos1–5	0,722–0,803	
	SBB_Ling1–5	0,715–0,796	

2. Discriminant Validity

Discriminant validity was tested using the HTMT (Heterotrait-Monotrait Ratio) criterion. All HTMT values were below the threshold of 0.90, indicating that each construct is empirically distinct from the others. The highest HTMT value was between AI and BDA (0.742), which is still well below the critical threshold. These results confirm that the model's discriminant validity is met.

Table 3. Discriminant Validity Results

	AI	BDA	IoT	SBB
AI	—			
BDA	0,742	—		
IoT	0,698	0,721	—	
Sustainable Business Practices (SBB)	0,671	0,654	0,629	—

3. Construct Reliability

The results of the reliability tests show that all constructs have Composite Reliability (CR) and Cronbach's Alpha values exceeding the threshold of 0.70. CR ranged from 0.871 (IoT) to 0.903 (AI), while Cronbach's Alpha ranged from 0.842 (IoT) to 0.878 (AI). Thus, all constructs were found to be reliable and internally consistent.

Table 4. Results of Construct Reliability Testing

Costruct	Composite Reliability	Cronbach's Alpha	Conclusion
Artificial Intelligence (AI)	0,903	0,878	Reliable
Big Data Analytics (BDA)	0,888	0,861	Reliable
Internet of Things (IoT)	0,871	0,842	Reliable
Sustainable Business Practices (SBB)	0,895	0,876	Reliable

Structural Model Analysis (Inner Model)

1. R-Square Value

The coefficient of determination (R^2) for the Sustainable Business Practices variable is 0.674, meaning that 67.4% of the variance in MSME sustainable business practices can be explained by the three predictor variables (AI, BDA, and IoT) simultaneously. According to the guidelines by Hair et al. (2019), an R^2 value of 0.674 is categorized as moderate-to-substantial, with 0.50 considered moderate and 0.25 considered weak. In this study, this indicates adequate predictive capability of the model. The adjusted R^2 value of 0.669 confirms the model's robustness after accounting for the number of predictors.

Table 5. Results of the Coefficient of Determination (R^2) Test

Endogenous Variable	R-Square	Adjusted R Square	Categoriy
Sustainable Business Practices (SBB)	0,674	0,669	Moderate-to-Substantial

2. Effect Size (f^2)

The effect size (f2) measures the extent to which each predictor contributes to the change in R^2 when that predictor is removed from the model. AI showed the largest effect size (f2 = 0.241, medium category), followed by BDA (f2 = 0.189, medium category), and IoT (f2 = 0.134, small-medium category). These results indicate that AI contributes the most to the model's predictive ability.

Table 6. Effect Size Test Results

Construct	F-Square	Category
Artificial Intelligence (AI)	0,241	Medium
Big Data Analytics (BDA)	0,189	Medium
Internet of Things (IoT)	0,134	Small-Medium

According to Hair et al. (2019), effect sizes (f^2) are interpreted as follows: 0.02 = small, 0.15 = medium, and 0.35 = large. These findings indicate that AI is the predictor that contributes most significantly to explaining the variation in Sustainable Business Practices among MSMEs using marketplaces in Indonesia.

3. Predictive Relevance (Q^2)

Table 7. Results of the Predictive Relevance Test (Q^2)

Endogenous Variable	Q-Square	Criteria
Sustainable Business Practices	0,412	$Q^2 > 0$

According to Hair et al. (2019), a Q^2 value > 0 indicates that the model has predictive relevance. Furthermore, Q^2 values of 0.02, 0.15, and 0.35 indicate small, medium, and large predictive relevance, respectively. Based on the test results, the Sustainable Business Practices construct obtained a Q^2 value of 0.412, indicating that the model has strong predictive relevance. This finding indicates that the combination of Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) variables has a strong ability to predict sustainable business practices among Indonesian MSMEs using marketplaces.

4. Hypothesis Testing

Hypothesis testing was conducted to examine the direct effects of Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) on Sustainable Business Practices (SBP) among MSMEs using marketplaces in Indonesia. The testing was performed using the bootstrapping method in SmartPLS with a significance level of 5% (α = 0.05). A hypothesis is accepted if it has a t-statistic value > 1.96 and a p-value < 0.05.

Table 8. Hypothesis Testing Results

Hypothesis	Path	Path Coefficient (β)	t-Statistik	p-Value	Decision
H1	AI → SBB	0,341	5,812	0,000	Accepted
H2	BDA → SBB	0,298	4,934	0,000	Accepted
H3	IoT → SBB	0,219	3,501	0,00	Accepted

Based on the hypothesis testing above, all research hypotheses were accepted because each path had a t-statistic value > 1.96 and a p-value < 0.05, indicating a positive and significant effect on Sustainable Business Practices. The Artificial Intelligence (AI) variable had the greatest influence with a path coefficient of β = 0.341 (t = 5.812; p < 0.001), followed by Big Data Analytics (BDA) at β = 0.298 (t = 4.934; p < 0.001), and the Internet of Things (IoT) at β = 0.219 (t = 3.501; p < 0.001). These findings indicate that increased utilization of digital technology can drive the implementation of sustainable business practices among Indonesian MSMEs using marketplaces by improving operational efficiency, decision-making quality, resource management, and responsiveness to market needs. Among these three variables, AI is the most dominant factor in explaining the improvement in sustainable business practices, indicating that AI's capabilities in automation, intelligent analysis, and data processing contribute the most to the sustainability of MSMEs businesses.

DISCUSSION

The Impact of Artificial Intelligence on Sustainable Business Practices

The first hypothesis (H1) was accepted, indicating that Artificial Intelligence (AI) has a positive and significant impact on sustainable business practices among MSMEs using marketplaces in Indonesia (β = 0.341; p < 0.001). These results indicate that the higher the level of AI utilization by MSMEs, the better the implementation of sustainable business practices covering economic, social, and environmental aspects. This finding aligns with the research by Soomro et al., (2025) which found that AI adoption significantly improves the sustainability performance of MSMEs through increased operational efficiency, more accurate decision-making, and optimized resource utilization. Similar results were also reported by Badghish and Soomro (2024), who demonstrated that AI implementation in MSMEs can strengthen the achievement of sustainable business goals through increased productivity and business process effectiveness.

For MSMEs operating through marketplaces such as Shopee, Tokopedia, and other e-commerce platforms, AI technology plays a crucial role in helping business owners understand consumer behavior, predict market demand, and optimize digital marketing strategies. The use of AI through product recommendation features, customer service chatbots, consumer behavior analysis, and ad optimization enables MSMEs to increase sales conversion rates and improve marketing cost efficiency. From an economic sustainability perspective, these capabilities contribute to increased revenue and business competitiveness. Meanwhile, from an environmental perspective, AI helps reduce resource waste through more precise promotional targeting and more efficient inventory management. On the social front, AI supports improved service quality and customer satisfaction through faster, more responsive, and personalized interactions.

The significant influence of AI in this study is also reflected in the effect size (f^2 = 0.241), which is the highest value compared to the other independent variables. This finding indicates that AI is the most dominant factor in driving sustainable business practices among digital MSMEs. This can be explained by the fact that AI is relatively accessible through features already integrated into marketplaces, thus requiring neither significant infrastructure investment nor complex technical expertise. MSMEs operators can immediately leverage the various AI-based services available on the platform to enhance operational efficiency and decision-making. This finding aligns with the perspective of Cimino et al., (2025) who assert that AI is a strategic technology capable of driving organizational transformation toward more efficient, innovative, and sustainable business models through waste reduction, resource optimization, and the creation of greater value for various stakeholders.

The Impact of Big Data Analytics on Sustainable Business Practices

The second hypothesis (H2) was accepted, indicating that Big Data Analytics (BDA) has a positive and

significant impact on sustainable business practices among MSMEs using marketplaces in Indonesia ($\beta = 0.298$; $p < 0.001$). These results indicate that the higher the capacity of MSMEs to utilize and analyze business data, the better the implementation of sustainable business practices. This finding aligns with the research by Alyahya et al., (2023) which found that BDA can enhance corporate sustainability performance through increased strategic agility and organizational creativity based on the Resource-Based View (RBV) perspective. Additionally, Kumar et al., (2025) also confirmed that the adoption of BDA has a positive impact on the market and financial performance of MSMEs through improved decision-making quality and the ability to adapt to changes in the business environment.

The utilization of BDA is reflected in the use of various analytical features available on seller dashboards such as Shopee Seller Center, Tokopedia Seller Hub, and other digital platforms. Through data on customer behavior, sales trends, product performance, promotional effectiveness, and market demand patterns, MSMEs operators can make more accurate and evidence-based decisions. This capability enables more efficient inventory management, more competitive pricing, and more targeted marketing strategy planning. From an economic sustainability perspective, optimal data utilization helps improve business productivity and profitability. Meanwhile, on the environmental front, more accurate inventory management can reduce the risk of overstocking or unsold products that could potentially lead to resource waste.

Although the influence of BDA falls under the umbrella of Artificial Intelligence, the relatively high path coefficients indicate that data has become a strategic asset for digital MSMEs in building sustainable competitive advantage. Effective data analysis not only helps business owners understand current market conditions but also enables them to anticipate future changes in demand and business risks. These findings are supported by the research of Akhtar et al., (2018) which shows that BDA capabilities can enhance sustainable competitive advantage through improved supply chain resilience and decision-making quality. In a highly dynamic and competitive marketplace ecosystem, the ability to optimally utilize data is a critical factor in fostering more efficient, adaptive, and sustainable business practices in the long term.

The Impact of the Internet of Things on Sustainable Business Practices

The third hypothesis (H3) was accepted, indicating that the Internet of Things (IoT) has a positive and significant impact on sustainable business practices among MSMEs using marketplaces in Indonesia ($\beta = 0.219$; $p < 0.01$). These results indicate that increased utilization of IoT technology can drive the adoption of more sustainable business practices, although its impact is relatively smaller compared to Artificial Intelligence and Big Data Analytics. This finding aligns with the research by Khan et al., (2022) which found that the implementation of IoT in supply chain management can improve operational efficiency, process transparency, and support the achievement of corporate sustainability goals. Furthermore, Lanfranchi et al., (2025) also emphasize that IoT plays a crucial role in promoting environmental sustainability through enhanced monitoring capabilities, better control over resource usage, and the reduction of inefficient activities.

The implementation of IoT can be achieved through the use of sensor-based inventory management systems, real-time shipment tracking devices, point-of-sale (POS) systems connected to various digital platforms, and automated inventory monitoring technology. These technologies enable businesses to obtain more accurate and timely information regarding their operational status. From an economic perspective, IoT helps improve inventory management efficiency, reduce recording errors, and accelerate the process of distributing products to customers. From a social perspective, this technology supports improved service quality through accurate information and rapid responses to consumer needs. Meanwhile, from an environmental perspective, IoT contributes to reducing resource waste through more accurate inventory control and the optimization of logistics processes.

Although it has the smallest impact compared to the other two digital technologies, the significance of the relationship found indicates that IoT remains a key factor in supporting sustainable business practices among MSMEs. The substantial benefits generated are often offset by various implementation challenges, such as the need for relatively high initial investment, limitations in digital infrastructure, and the need for technical expertise in operating IoT devices. These conditions explain why the adoption rate of IoT among Indonesian MSMEs remains lower than that of AI and BDA. Nevertheless, for MSMEs that have successfully implemented IoT technology, the benefits are evident in the form of improved operational efficiency, strengthened supply chain management, increased customer satisfaction, and reduced resource waste. Therefore, IoT continues to hold strategic potential to serve as a key driver of MSMEs transformation toward more efficient, competitive, and sustainable business models in the digital economy era.

CONCLUSION

This study aims to examine the impact of Artificial Intelligence (AI), Big Data Analytics (BDA), and the Internet of Things (IoT) on sustainable business practices among marketplace-based MSMEs in Indonesia. Based on the PLS-SEM analysis of 285 respondents, all proposed hypotheses were supported. The findings reveal that AI, BDA, and IoT have positive and significant effects on sustainable business practices, with AI demonstrating the strongest influence, followed by BDA and IoT. These results indicate that the adoption of digital technologies can

enhance business sustainability by improving operational efficiency, decision-making quality, resource optimization, and customer service performance. Furthermore, the coefficient of determination ($R^2 = 0.674$) indicates that these technologies collectively explain a substantial proportion of the variance in sustainable business practices. Theoretically, the study strengthens the relevance of the Resource-Based View (RBV), which emphasizes digital capabilities as strategic resources that contribute to competitive advantage and long-term business sustainability. Practically, the findings suggest that MSMEs owners should intensify the adoption and utilization of AI, BDA, and IoT technologies to simultaneously achieve economic, social, and environmental objectives. In addition, governments, marketplace providers, and MSMEs support institutions should expand digital training programs, mentoring initiatives, and technology accessibility to accelerate digital transformation and sustainable business development.

Despite its contributions, this study has several limitations. First, the cross-sectional research design limits the ability to observe changes in technology adoption and sustainability practices over time. Second, the use of self-reported questionnaire data may be susceptible to common method bias. Third, the study focuses exclusively on marketplace-using MSMEs in Indonesia, which may limit the generalizability of the findings to different industries or geographical contexts. Although the model explains 67.4% of the variance in sustainable business practices, approximately 32.6% remains unexplained, suggesting that business sustainability is also influenced by other factors such as digital capability, innovation capability, technological readiness, organizational culture, government support, and environmental awareness. Therefore, future research is encouraged to employ longitudinal designs, incorporate additional explanatory, mediating, or moderating variables, and extend the research context across various sectors and regions to provide a more comprehensive understanding of the determinants of sustainable business practices among MSMEs.

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