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Supply Chain Digitalization and Product Innovation Effects on Circular Economy-Based Enterprise Performance Improvement

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Abstract

Purpose: This study examines the effects of supply chain digitalization and product innovation on the performance of circular economy-based Micro, Small, And Medium Enterprises (MSMEs). It aims to extend previous circular economy and MSME performance literature by integrating digital transformation and innovation capabilities as complementary mechanisms for improving sustainable business outcomes.

Research Methodology: This study employed a quantitative explanatory research design involving 100 circular economy-based MSMEs in South Bogor, Bandung, and Yogyakarta selected through purposive sampling. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 to evaluate the relationships among the proposed constructs.

Results: The findings reveal that supply chain digitalization and product innovation significantly enhance MSME performance. The model explains 65.2% of the variance in MSME performance, indicating that digital supply chain capabilities and innovation practices play important roles in strengthening circular economy-based business sustainability.

Conclusions: Supply chain digitalization and product innovation are critical drivers of MSME performance within the circular economy context. This study highlights that combining technological adoption with innovation-oriented strategies provides a broader perspective on achieving sustainable MSME development.

Limitations: This study is limited by its cross-sectional design and focus on MSMEs in three regions, which may affect the generalizability of the findings to other contexts.

Contribution: This study contributes to the advancement of circular economy and MSME performance research by demonstrating how supply chain digitalization and product innovation jointly enhance sustainable business performance, particularly in emerging economy contexts.

Keywords: *Circular Economy, MSME Performance, Product Innovation, Supply Chain Digitalization, PLS-SEM*

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1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) play a strategic role in supporting Indonesia economic development. According to the Ministry of Cooperatives and SMEs in 2024, Indonesia has more than 64 million MSMEs, contributing approximately 61.07% to national Gross Domestic Product (GDP) and absorbing more than 97% of the non-agricultural workforce. However, the increasing pressure of global competition and sustainable development requirements requires MSMEs to improve not only their economic performance but also their ability to adopt sustainable business practices (Amrina, 2026; Dey et al., 2022). In this context, circular economy-based MSMEs require strategic capabilities that enable them to optimize resources, reduce waste, and create sustainable value (Kirchherr et al., 2023). Supply chain digitalization has emerged as an important mechanism for improving MSME performance by enhancing coordination, efficiency, and responsiveness across business activities (Teng et al., 2022). Supply chain digitalization refers to the adoption of digital technologies to integrate information flows, transactions, and operational processes among supply chain actors (Sanders & Swink, 2020; Yang et al., 2021). Through digital platforms, inventory management systems, and electronic payment technologies, MSMEs can improve resource efficiency, strengthen market access, and optimize decision-making processes (Zainurrafiqi & Gazali, 2023; Rahardjo et al., 2026). In the context of circular economy, digital supply chains provide greater opportunities for MSMEs to manage material flows, monitor resource utilization, and support sustainable production processes (Chauhan et al., 2022; Liu et al., 2022). Therefore, digitalization is not merely a technological adoption strategy but also an organizational capability that enables MSMEs to achieve sustainable performance improvements (Troise et al., 2022).

Besides digital transformation, product innovation represents another critical mechanism for strengthening the competitiveness and sustainability of circular economy-based MSMEs. Product innovation enables firms to respond to changing customer preferences while creating economic value through improved product quality, diversification, and sustainable design (Novita, 2022; Ilhami & Damayanti, 2024). Within the circular economy framework, innovation extends beyond traditional product development by incorporating environmentally responsible practices, such as the utilization of recycled materials, waste reduction, and product life-cycle extension (Mahendra, 2025; Hutomo et al., 2026; Suchek et al., 2021). Thus, product innovation allows MSMEs to transform waste-based resources into marketable products while simultaneously supporting sustainability objectives (Nson & Adejoh, 2025).

Previous studies have provided valuable insights into the role of supply chain digitalization and product innovation in improving MSME competitiveness and operational performance (Amrina, 2026; Zainurrafiqi & Gazali, 2023; Novita et al., 2023; Ferina & Widyaningsih, 2025). However, several limitations remain in the existing literature. First, previous studies have predominantly investigated the impact of digitalization on MSME performance from a general technology adoption or operational efficiency perspective, while insufficient attention has been given to how digital supply chain capabilities support circular economy practices through resource optimization, waste reduction, and sustainable value creation (Neligan et al., 2023). Second, studies examining product innovation have largely focused on market competitiveness and business growth, with limited exploration of how innovation capabilities enable MSMEs to transform circular economy principles into sustainable products and processes (Hina et al., 2022). Third, existing research has rarely integrated supply chain digitalization and product innovation within a single analytical framework, resulting in limited understanding of how these two strategic capabilities complement each other in enhancing the performance of circular economy-based MSMEs.

Furthermore, most prior MSME studies have focused on conventional performance indicators, such as financial performance, productivity, or competitiveness, without adequately considering the unique characteristics and challenges of circular economy-based MSMEs. In Indonesia, where MSMEs face constraints related to technological readiness, resource efficiency, supply chain integration, and sustainable production capacity, an integrated perspective is required to explain how technological and innovation capabilities contribute to sustainable MSME development (Setiawati et al., 2025; Hutomo et al., 2026; Manan et al., 2024). Therefore, this study addresses the identified research gap by

developing an integrated framework that simultaneously examines the roles of supply chain digitalization and product innovation in improving the performance of circular economy-based MSMEs. This study contributes to the existing literature in three ways. First, it extends circular economy and MSME performance research by positioning supply chain digitalization as a strategic capability that facilitates sustainable resource management and operational improvement. Second, it highlights product innovation as an essential capability that enables MSMEs to create sustainable value through environmentally responsible product development. Third, by examining the simultaneous effects of supply chain digitalization and product innovation, this study provides a more comprehensive understanding of how technological and innovation capabilities interact to strengthen the performance of circular economy-based MSMEs in an emerging economy context such as Indonesia.

2. Literature Review and Hypotheses Development

2.1 Circular Economy

Circular economy represents a sustainable economic paradigm that challenges the traditional linear production model of "take-make-dispose" by promoting resource efficiency, waste reduction, and value recovery through the principles of reduce, reuse, recycle, and redesign (Mahendra, 2025; Kirchherr et al., 2023). From the perspective of Circular Economy Theory, business sustainability is achieved when organizations are able to maintain the value of products, materials, and resources within the economic system for as long as possible (Nson & Adejoh, 2025). Therefore, circular economy implementation requires not only environmental awareness but also organizational capabilities that enable firms to redesign production processes, manage resources efficiently, and create sustainable value.

For MSMEs, the circular economy approach provides opportunities to overcome resource limitations while developing environmentally responsible business models. Unlike large enterprises, MSMEs often face constraints related to access to raw materials, technology, financial resources, and market networks. The adoption of circular economy principles allows MSMEs to transform waste into valuable inputs, reduce production costs, and develop differentiated products with higher market value (Mahendra, 2025; Dey et al., 2022). However, previous studies have mainly emphasized the environmental benefits of circular economy practices, while the mechanisms through which circular economy-based MSMEs improve their business performance remain insufficiently explored (Centobelli et al., 2021; Hina et al., 2022).

In the Indonesian context, circular economy implementation is increasingly relevant due to the growing waste management challenges and the need for sustainable economic development (Pravitasari et al., 2025; Susanti et al., 2025). Previous empirical studies indicate that recycling-based business activities can generate economic value and increase MSME income (Hutomo et al., 2026; Mahendra, 2025). Nevertheless, these studies primarily focus on descriptive cases of circular economy adoption and provide limited explanation regarding the strategic capabilities required to translate circular practices into improved MSME performance. Therefore, further investigation is needed to understand how technological and innovation capabilities support circular economy-based MSME performance.

2.2 Supply Chain Digitalization

Supply chain digitalization refers to the integration of digital technologies into supply chain activities to improve information exchange, coordination, transaction efficiency, and decision-making processes (Sanders & Swink, 2020; Kraus et al., 2021). Based on the Resource-Based View (RBV), digital capabilities can be considered strategic resources that enable firms to achieve competitive advantages by improving operational efficiency and responsiveness (Bag et al., 2021). For MSMEs, digital supply chain capabilities provide opportunities to overcome traditional limitations related to market access, resource coordination, and operational control (Ghobakhloo & Iranmanesh, 2021).

In circular economy-based MSMEs, supply chain digitalization has a particularly important role because circular business models require effective management of material flows, information

transparency, and collaboration among supply chain actors (Khan et al., 2022). Digital technologies such as e-commerce platforms, inventory management systems, digital payment systems, and digital marketing tools enable MSMEs to optimize resource utilization and strengthen connections with suppliers and customers (Ranta et al., 2021).

Previous empirical studies have shown that digitalization positively affects MSME competitiveness and operational performance (Zainurrafiqi & Gazali, 2023; Amrina, 2026; Teng et al., 2022). However, most previous studies examine digitalization in general MSME contexts and focus primarily on competitiveness or market expansion. Limited research has investigated how supply chain digitalization contributes specifically to the performance of circular economy-based MSMEs, where resource efficiency and sustainability are central objectives (Centobelli et al., 2021). This limitation suggests that the relationship between supply chain digitalization and MSME performance requires further empirical examination.

2.3 Product Innovation

Product innovation refers to a firm's capability to develop new products or improve existing products through enhanced quality, design, functionality, and adaptation to customer needs (Novita, 2022; Ilhami & Damayanti, 2024). According to the Dynamic Capability Theory, innovation represents an organization's ability to adapt and reconfigure its resources in response to environmental changes (Troise et al., 2022). In the context of circular economy-based MSMEs, product innovation becomes an essential capability because businesses must transform recycled materials and sustainable resources into products that possess economic and competitive value.

Circular economy-oriented product innovation differs from conventional innovation because it incorporates environmental considerations throughout the product life cycle. Sustainable product design, utilization of recycled materials, waste reduction, and product durability represent important mechanisms through which MSMEs can create both environmental and economic value (Mahendra, 2025; Suchek et al., 2021). Thus, product innovation enables MSMEs to respond to increasing consumer awareness of environmentally friendly products while strengthening market competitiveness.

Previous studies have demonstrated that product innovation positively influences MSME competitiveness and business growth (Novita, 2022; Novita et al., 2023; Ferina & Widyaningsih, 2025). However, existing studies generally focus on innovation as a driver of market performance without considering the specific characteristics of circular economy-based businesses. Furthermore, some studies emphasize innovation outcomes rather than explaining how innovation capabilities contribute to sustainable MSME performance. Therefore, examining product innovation within a circular economy framework provides a more comprehensive understanding of how innovation contributes to MSME development.

2.4 MSME Performance

MSME performance represents the extent to which businesses achieve their strategic objectives through financial and non-financial outcomes, including sales growth, profitability, market expansion, capital development, and employment growth (Minuzu, 2010; Kurniawan et al., 2025). From the perspective of the Resource-Based View and Dynamic Capability Theory, MSME performance is determined not only by available resources but also by the ability of firms to develop, integrate, and utilize strategic capabilities in response to changing environments.

In circular economy-based MSMEs, performance improvement depends on the ability to combine sustainability practices with operational and market capabilities. Supply chain digitalization may enhance performance by improving efficiency, information accessibility, and market connectivity, whereas product innovation may increase performance through differentiation, customer value creation, and market adaptation. Therefore, these two capabilities represent complementary mechanisms that enable MSMEs to achieve sustainable competitive advantages (Dey et al., 2022).

Previous empirical research has identified several determinants of MSME performance. Yuliana et al. (2025) found that product knowledge and financial literacy contribute positively to MSME performance, while Zainurrafiqi and Gazali (2023) demonstrated the importance of digital supply chain adoption in improving MSME competitiveness. However, these studies have generally examined individual determinants separately and have not integrated technological capabilities and innovation capabilities into a single framework, particularly within circular economy-based MSMEs.

Accordingly, this study addresses this research gap by developing an integrated model that examines the effects of supply chain digitalization and product innovation on MSME performance. This approach extends previous literature by explaining how digital capabilities and innovation capabilities jointly contribute to sustainable performance improvement in circular economy-based MSMEs.

Based on the literature review and the framework of thought that has been described, this study proposes three hypotheses as follows. This study proposes three hypotheses as follows in Figure 1.

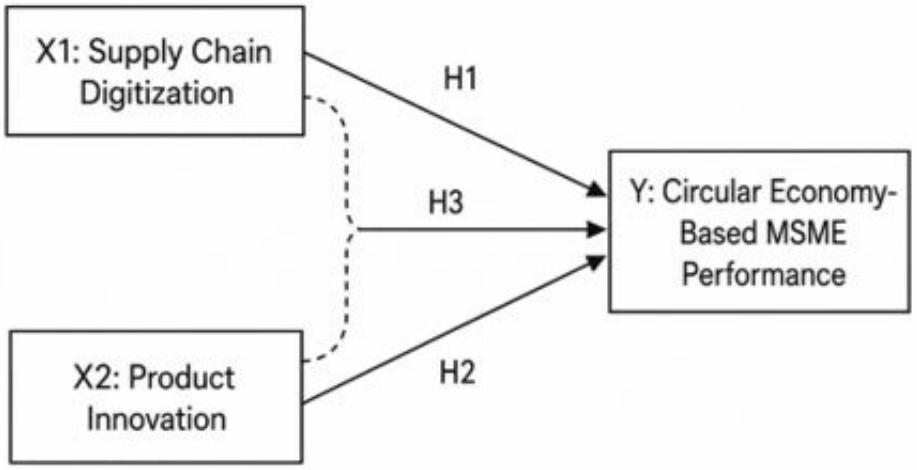


Figure 1. Thinking framework

2.5 Hypothesis Development

2.5.1 The Effect of Supply Chain Digitalization on MSME Performance

Based on the Resource-Based View (RBV), firms can achieve sustainable competitive advantages by possessing and effectively utilizing valuable, rare, inimitable, and non-substitutable resources (Bag et al., 2021). In this perspective, digital capabilities are considered strategic organizational resources that enhance firms' ability to acquire, process, and utilize information for improving operational effectiveness. For MSMEs, supply chain digitalization enables the integration of information systems, real-time data exchange, digital transactions, and coordination mechanisms among suppliers, producers, and customers. These capabilities allow MSMEs to improve inventory accuracy, reduce operational inefficiencies, optimize resource utilization, and respond more quickly to market changes (Rahardjo et al., 2026; Yang et al., 2021).

In the context of circular economy-based MSMEs, supply chain digitalization provides additional benefits by supporting sustainable resource management. Digital technologies enable firms to monitor material flows, track product life cycles, minimize waste generation, and improve collaboration among supply chain actors (Liu et al., 2022). Through greater visibility and transparency across supply chain activities, MSMEs can identify opportunities for resource efficiency and develop more sustainable business processes. Therefore, digitalization does not only improve operational performance but also strengthens MSMEs' ability to implement circular economy principles and create long-term value (Chauhan et al., 2022).

Previous studies have demonstrated that digital technology adoption enhances MSME competitiveness and operational performance by improving efficiency, market access, and

decision-making capabilities (Zainurrafiqi & Gazali, 2023; Amrina, 2026; Ghobakhloo & Iranmanesh, 2021). However, empirical evidence regarding how supply chain digitalization contributes to the performance of circular economy-based MSMEs remains limited. Based on the RBV perspective, this study argues that supply chain digitalization represents a strategic capability that can improve MSME performance through enhanced coordination, resource efficiency, and sustainable value creation. Therefore, the following hypothesis is proposed:

> *H_1:* Supply chain digitalization has a positive and significant effect on the performance of circular economy-based MSMEs

2.5.2 The Effect of Product Innovation on MSME Performance

According to Dynamic Capability Theory, firms must continuously develop, integrate, and reconfigure their resources and capabilities to adapt to changing environmental conditions. Product innovation represents an important dynamic capability that enables MSMEs to respond to evolving customer preferences, technological developments, and sustainability demands (Troise et al., 2022). Through product innovation, MSMEs can improve product quality, introduce differentiated products, expand market opportunities, and generate greater economic value.

Within the circular economy framework, product innovation involves more than conventional product improvement; it reflects the ability of firms to redesign products and processes based on sustainability principles. Circular economy-based MSMEs can utilize recycled materials, reduce production waste, extend product life cycles, and develop environmentally responsible products through innovation activities (Ranta et al., 2021; Suchek et al., 2021). These practices enable MSMEs to transform environmental challenges into business opportunities by creating products with higher market value and stronger consumer acceptance.

From the perspective of Dynamic Capability Theory, product innovation strengthens MSME performance because it allows firms to adapt their resources and capabilities according to market and environmental changes. Previous studies have shown that product innovation contributes to MSME competitiveness, growth, and market adaptation (Novita, 2022; Novita et al., 2023; Ilhami & Damayanti, 2024). Nevertheless, research examining the role of circular economy-oriented product innovation in improving MSME performance remains limited. Therefore, this study proposes:

> *H_2:* Product innovation has a positive and significant effect on the performance of circular economy-based MSMEs

2.5.3 The Effect of Supply Chain Digitalization and Product Innovation on MSME Performance

The integration of technological and innovation capabilities provides MSMEs with stronger mechanisms to achieve sustainable performance improvements. From the RBV perspective, supply chain digitalization and product innovation can be viewed as strategic resources that enhance firms' ability to manage operations, utilize resources efficiently, and create competitive advantages. Meanwhile, Dynamic Capability Theory explains that firms must continuously combine and transform these resources to respond effectively to environmental changes and emerging market opportunities.

Supply chain digitalization strengthens MSME performance by improving information visibility, supply chain coordination, and operational flexibility. Meanwhile, product innovation enhances performance by enabling MSMEs to develop differentiated products, satisfy changing consumer needs, and create sustainable value. When these two capabilities are combined, MSMEs can achieve greater synergy because digital technologies support more efficient innovation processes, while innovative products increase the economic value generated from improved supply chain practices (Kraus et al., 2021; Neligan et al., 2023).

For circular economy-based MSMEs, the combination of supply chain digitalization and product innovation is particularly important because sustainable business models require both efficient resource management and continuous innovation. Digital supply chains enable MSMEs to identify available resources, monitor material utilization, and support sustainable production decisions, while product innovation transforms these capabilities into market-oriented products (Khan et al., 2022).

However, previous studies have generally examined digitalization and innovation as independent factors, providing limited understanding of their combined contribution to MSME performance within a circular economy context. Therefore, this study proposes:

H_3: Supply chain digitalization and product innovation simultaneously have a significant effect on the performance of circular economy-based MSMEs

3. Research Methodology

3.1 Types of Research

This study employed a quantitative approach using an explanatory research design to examine the relationships between supply chain digitalization (X_1), product innovation (X_2), and the performance of circular economy-based MSMEs (Y). A quantitative approach was selected because this study aims to empirically test the proposed hypotheses through measurable constructs and statistical analysis. The research model was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. PLS-SEM was selected because it is appropriate for analyzing complex models involving latent variables, assessing predictive relationships, and examining the contribution of multiple constructs within exploratory and theory-development research contexts (Ghozali, 2021).

The measurement indicators for each construct were adapted from previous validated studies. Supply chain digitalization indicators were developed based on the conceptual framework of Sanders and Swink (2020), covering digital planning, digital transactions, and digital communication within supply chain activities. Product innovation indicators were adapted from Novita (2022), consisting of product quality, product variants, and product style and design. MSME performance indicators were adopted from the performance measurement framework of Minuzu (2010) as cited in Kurniawan et al. (2025), including sales growth, capital growth, workforce growth, market growth, and profit growth. Before data collection, the questionnaire was reviewed through content validation to ensure that the indicators were relevant to the context of circular economy-based MSMEs. The measurement items were adjusted to the characteristics of MSMEs involved in recycling activities and sustainable production practices. Furthermore, the instrument was tested through validity and reliability assessments using PLS-SEM, including convergent validity, discriminant validity, and composite reliability evaluations.

3.2 Place and Time of Research

This research was conducted in three regions of Indonesia with active circular economy-based MSME activities: South Bogor, Bandung, and Yogyakarta. These locations were selected because they represent diverse circular economy practices, including waste recycling, sustainable product development, and creative industry-based MSME activities. The study population consisted of MSMEs implementing circular economy principles, particularly those involved in utilizing recycled materials, reducing production waste, or developing environmentally sustainable products. The sample was selected using purposive sampling, as the research required respondents with specific characteristics relevant to the research objectives. The purposive sampling criteria included MSMEs actively operating in circular economy-related activities, businesses that have implemented digital technology in supply chain or business processes, MSMEs that have developed or modified products through innovation practices, and business owners or managers who understand their operational and performance conditions.

This sampling technique was considered appropriate because not all MSMEs meet the specific requirements of circular economy implementation. Therefore, selecting respondents based on predetermined criteria ensured that the collected data represented MSMEs with relevant experience regarding digitalization, innovation, and sustainable business practices. The research was conducted from January to March 2025. To minimize potential response bias, several procedures were implemented. First, respondents were provided with clear explanations regarding the purpose of the study and were assured that their responses would remain confidential. Second, questionnaires were distributed to MSME owners or managers who had sufficient knowledge of business operations and decision-making processes. Third, the questionnaire was designed using clear and neutral statements

to reduce ambiguity and encourage accurate responses. These procedures were implemented to improve data quality and reduce the possibility of inaccurate or socially desirable responses.

Table 1. Circular economy practices and green innovation among business actors in South Bogor, Bandung, and Yogyakarta

Business Name	Location	Business Description	Problems
Abhinaya Waste Bank / Rancamaya Recycling MSME	Rancamaya Village, South Bogor District, Bogor City	Managing and utilizing scrap fabric, paper, cardboard, cans, plastic packaging, plastic bottles, and used cooking oil into materials or products with economic value.	Production and marketing constraints require strengthening technology, production capacity, financial record-keeping, digital transactions, and market access.
Newhun Recycle	Bandung City, West Java	Sorting and processing plastic waste into products of economic value by applying circular economy principles.	Plastic waste management in the Bandung area still faces limitations in terms of policies, waste bank institutions, and sorting processes.
Micro and small garment industry processes Majun fabric waste	Bandung City, West Java	Utilizing waste fabric from convection activities as raw material for alternative textile products through fiber identification, shredding, and reprocessing.	Businesses have limited technical knowledge and processing facilities; majun cloth waste is difficult to decompose and has the potential to pollute the environment.
Rajoet Binong Village	Bandung City, West Java	Developing the use of plastic bottles to make yarn as a material for knitting and textile products.	Requires strengthening of processing technology, consistent supply of recycled raw materials, design development, and market expansion.
Jogja Patchwork Community	Yogyakarta, Special Region of Yogyakarta	Processing scrap fabric into environmentally friendly craft and fashion products with the support of community empowerment and digital marketing.	Facing design standardization constraints, understanding export market tastes, and product photography limitations for international digital marketing.
Natural dye batik SMEs	Special Region of Yogyakarta	Producing batik products using natural dyes, such as mahogany bark, jalawe fruit peel, and other local plants, as a form of green innovation.	Limited distribution and logistics systems, dependence on word-of-mouth marketing, and suboptimal use of consumer data and market research.

Table 1 presents an overview of circular economy practices and green innovation characteristics among MSME actors in South Bogor, Bandung, and Yogyakarta. The table highlights the diversity of sustainable business activities implemented by MSMEs, including waste utilization, recycled product development, and environmentally oriented innovation practices. These characteristics provide an empirical background for understanding the research context and demonstrate the relevance of examining the role of supply chain digitalization and product innovation in improving the performance of circular economy-based MSMEs.

3.3 Research Population and Sample

The population of this study consisted of MSMEs operating in South Bogor, Bandung, and Yogyakarta that have implemented circular economy principles in their business activities. The population criteria included MSMEs that utilize recycled materials or implement

reduce–reuse–recycle practices, have operated for at least one year, and have experience in developing sustainable products or managing circular business processes.

The sampling technique used in this study was purposive sampling because the research required respondents with specific characteristics related to circular economy practices, digital technology adoption, and product innovation activities. The purposive sampling criteria were MSMEs that utilize digital technology in supply chain, production, or marketing activities; MSMEs that implement product innovation practices; and owners or managers who understand business operations and are willing to participate in the study. This approach was considered appropriate because the characteristics of circular economy-based MSMEs are relatively specific and cannot be represented by general MSME populations.

A total of 100 MSMEs were selected as research samples, consisting of 34 respondents from South Bogor, 33 respondents from Bandung, and 33 respondents from Yogyakarta. The sample size was considered adequate for PLS-SEM analysis because this method is suitable for predictive research models with latent constructs and relatively moderate sample sizes (Ghozali, 2021). Furthermore, the sample size exceeded the minimum requirement based on the ratio between sample size and measurement indicators, where the minimum sample should be five to ten times the number of indicators in the most complex construct. To minimize potential response bias, data collection was conducted by involving MSME owners or managers who had direct knowledge of business activities and decision-making processes. Respondents were also provided with clear information regarding the research objectives and confidentiality of responses to encourage accurate and objective answers.

3.4 Operational Variables

This study consists of two independent variables, namely supply chain digitalization (X_1) and product innovation (X_2), and one dependent variable, namely MSME performance (Y). The measurement indicators were adapted from previous theoretical and empirical studies to ensure construct relevance and validity in the context of circular economy-based MSMEs. Supply chain digitalization (X_1) was measured using indicators adapted from Sanders and Swink (2020), which reflect the implementation of digital technologies in supply chain activities, including digital planning, digital transactions, and digital communication. Product innovation (X_2) was measured based on Novita (2022), covering product quality, product variants, and product style and design. MSME performance (Y) was measured using indicators developed by Minuzu (2010) as cited in Kurniawan et al. (2025), including sales growth, capital growth, workforce growth, market growth, and profit growth.

All measurement items were assessed using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Before hypothesis testing, the measurement model was evaluated using PLS-SEM to assess indicator reliability, convergent validity, and discriminant validity. The operational definitions and measurement indicators of each construct are presented in Table 2.

Table 2. Operational research variables

Variables	Indicator	Code	Number of Items
Supply Chain Digitalization (X_1) (Sanders & Swink, 2020)	Digital Planning	$X_1.1$ - $X_1.3$	3
	Digital Transactions	$X_1.4$ - $X_1.6$	3
	Digital Communication	$X_1.7$ - $X_1.9$	3
Product Innovation (X_2) (Novita, A., Suhendra, R., & Wulan, 2023)	Product Quality	$X_2.1$ - $X_2.3$	3
	Product Variants	$X_2.4$ - $X_2.6$	3
	Product Style and Design	$X_2.7$ - $X_2.9$	3
MSME Performance (Y) (Kurniawan et al., 2025)	Sales Growth	$Y_1.1$ - $Y_1.3$	3
	Capital Growth	$Y_2.1$ - $Y_2.3$	3
	Increased Manpower	$Y_3.1$ - $Y_3.2$	2

Variables	Indicator	Code	Number of Items
MSME Performance (*Y*) (Kurniawan et al., 2025)	Market Growth	$Y_4.1$ - $Y_4.3$	3
	Profit Growth	$Y_5.1$ - $Y_5.3$	3

3.5 Data Collection Methods

Primary data were collected through a structured questionnaire distributed to circular economy-based MSME actors in South Bogor, Bandung, and Yogyakarta. The questionnaire was developed based on measurement indicators derived from previous studies related to supply chain digitalization, product innovation, and MSME performance. Each measurement item was adapted to the context of circular economy-based MSMEs to ensure relevance to the research objectives. The questionnaire consisted of two main sections. The first section collected demographic information, including business location, business duration, and type of circular economy activities. The second section contained statements measuring the research constructs using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Data collection was conducted online using Google Forms and supported by direct assistance from research assistants in each research location. The questionnaires were distributed through MSME community networks, local cooperative institutions, and direct communication with eligible MSME owners or managers. The respondents were selected based on predetermined sampling criteria to ensure that they had relevant experience with digital technology adoption, product innovation practices, and circular economy activities. To improve data quality and minimize potential response bias, respondents were informed about the purpose of the study, the confidentiality of their responses, and the voluntary nature of participation. In addition, questionnaires were completed by business owners or managers who had sufficient knowledge of operational activities and business performance, reducing the possibility of inaccurate responses due to limited information.

3.6 Data Analysis Techniques

The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 software. PLS-SEM was selected because it is suitable for predictive research models involving latent variables, complex relationships among constructs, and relatively moderate sample sizes. In addition, PLS-SEM does not require strict assumptions regarding multivariate normality, making it appropriate for analyzing MSME-related research models (Ghozali, 2021). The analysis consisted of two main stages: evaluation of the measurement model (outer model) and evaluation of the structural model (inner model). The outer model evaluation was conducted to assess the reliability and validity of the research constructs. Convergent validity was examined through outer loading values and Average Variance Extracted (AVE), while discriminant validity was assessed using the Fornell–Larcker criterion and cross-loading values. Construct reliability was evaluated using Cronbach Alpha and Composite Reliability to ensure internal consistency among measurement indicators.

The inner model evaluation was conducted to examine the explanatory and predictive capability of the proposed research model. The assessment included the coefficient of determination (R^2) to evaluate the variance explained by the independent variables, effect size (f^2) to determine the contribution of each exogenous construct, and predictive relevance (Q^2) to assess model prediction capability. Hypothesis testing was performed using bootstrapping procedures with 5,000 subsamples to determine path coefficients, t-statistics, and p-values for evaluating the significance of relationships among constructs. Furthermore, descriptive statistical analysis was conducted to describe respondent characteristics and provide an overview of MSME perceptions regarding supply chain digitalization, product innovation, and business performance.

4. Results and Discussions

4.1 Descriptive Analysis Results

The characteristics of the respondents in this study are presented to provide an overview of the profiles of the respondents who served as the research data sources. These characteristics include

region, age, gender, education, and length of business experience. The purpose of presenting these characteristics is to provide a general overview of the background of the respondents who participated in the study. The characteristics of the respondents in this study can be seen in Table 3 below.

Table 3. Respondent characteristics

No	Characteristics	Category	Number (n)	Percentage (%)
1	Region	South Bogor	34	34
		Bandung	33	33
		Yogyakarta	33	33
2	Age	21-30 years old	27	27
		31-40 years	38	38
		41-50 years	25	25
		>50 years	10	10
3	Gender	Man	38	38
		Woman	62	62
4	Education	High school/equivalent	55	55
		Diploma	22	22
		Bachelor	23	23
5	Length of Business	1-3 years	28	28
		3-5 years	25	25
		>5 years	47	47
		Total	100	100

Based on Table 3, it can be seen that the research respondents numbered 100 people spread across South Bogor, Bandung, and Yogyakarta with a relatively balanced proportion. Based on age, the majority of respondents were aged 31–40 years, namely 38 people (38%). Based on gender, respondents were predominantly female, namely 62 people (62%). In terms of education, the majority of respondents had a high school education or equivalent, namely 55 people (55%). Meanwhile, based on the length of business, the majority of respondents had run their business for more than 5 years, namely 47 people (47%). This condition indicates that the majority of respondents were MSME actors who had considerable business experience.

4.2 Descriptive Analysis Results

Descriptive analysis was conducted to provide an overview of respondents' responses to the variables used in the study. This analysis included Supply Chain Digitalization (X_1), Product Innovation (X_2), and MSME Performance (Y), which were measured based on each research indicator using the mean, median, minimum, maximum, and standard deviation values. As can be seen in Table 4.

Table 4. Results of descriptive analysis of research variables

Variables	Indicator	Mean	Median	Observed min	Observed max	Standard deviation
Supply Chain Digitalization (X_1)	Digital Planning	3,467	3,333	1,000	5,000	0.708
	Digital Transactions	3,473	3,000	1,333	5,000	0.675
	Digital Communication	3,467	3,333	1,333	5,000	0.694
	Average (X_1)	3,469	3,222	1,222	5,000	0.692
Product Innovation (X_2)	Product Quality	3,453	3,000	2,000	5,000	0.726
	Product Variants	3,450	3,000	2,000	5,000	0.778
	Product Style and Design	3,453	3,000	2,000	5,000	0.758
	Average (X_2)	3,452	3,000	2,000	5,000	0.754
MSME Performance (Y)	Sales Growth	3,447	3,000	1,000	5,000	0.678
	Capital Growth	3,447	3,167	1,000	5,000	0.663
	Increased Manpower	3,466	3,222	1,000	5,000	0.682

Variables	Indicator	Mean	Median	Observed min	Observed max	Standard deviation
MSME Performance (*Y*)	Market Growth	5,190	4,750	1,500	7,500	1,060
	Profit Growth	3,473	3,000	1,333	5,000	0.633
	Average (*Y*)	3,804	3,428	1,167	5,500	0.743

The results of the descriptive analysis in Table 4 show that the three research variables have average values categorized as high, with Supply Chain Digitalization (X_1) obtaining a mean of 3.469, Product Innovation (X_2) of 3.452, and MSME Performance (Y) of 3.804 out of a maximum scale of 5.00. Of the three variables, MSME Performance has the highest average value, which indicates that in general, circular economy-based MSME respondents in the three research areas (South Bogor, Bandung, and Yogyakarta) have shown good performance in terms of sales growth, capital, labor, market, and profit. Meanwhile, Supply Chain Digitalization and Product Innovation have relatively balanced average values, indicating that the application of digital technology in the supply chain and the development of product innovation have been running at a moderate to high level among MSMEs that apply circular economy principles. The standard deviation value which ranges from 0.633 to 0.754 also indicates that the respondent data has a relatively homogeneous level of distribution, so that the average picture can represent the general condition of respondents consistently in the three research areas.

4.3 Testing the Measurement Model (Outer Model)

The outer model test aims to ensure that the indicators used accurately measure the intended latent variables. This test includes convergent validity, discriminant validity, and reliability. The convergent validity test results show that all outer indicator loadings are above 0.70, indicating that all indicators meet the convergent validity requirement. The Average Variance Extracted (AVE) values for the three variables also exceeded the 0.50 threshold. As can be seen in Table 5.

Table 5. Outer loading test results

	Supply Chain Digitalization (X_1)	Product Innovation (X_2)	MSME Performance (Y)
$X_1.1$	0.922		
$X_1.2$	0.902		
$X_1.3$	0.911		
$X_1.4$	0.906		
$X_1.5$	0.942		
$X_1.6$	0.878		
$X_1.7$	0.904		
$X_1.8$	0.953		
$X_1.9$	0.929		
$X_2.1$		0.926	
$X_2.2$		0.940	
$X_2.3$		0.942	
$X_2.4$		0.953	
$X_2.5$		0.938	
$X_2.6$		0.949	
$X_2.7$		0.943	
$X_2.8$		0.933	
$X_2.9$		0.954	
Y_1			0.919
Y_2			0.895
Y_3			0.927

	Supply Chain Digitalization (X_1)	Product Innovation (X_2)	MSME Performance (Y)
Y_4			0.904
Y_5			0.913
Y_6			0.910
Y_7			0.938
Y_8			0.888
Y_9			0.943
Y_{10}			0.811
Y_{11}			0.907
Y_{12}			0.931
Y_{13}			0.820
Y_{14}			0.830

The results of the outer loading test in Table 5 show that all outer loading values of the indicators for the three variables are above 0.70, with a range of values between 0.811 and 0.954 **.** The lowest values are found in indicators Y.10 (0.811) and Y.13 (0.820) in the MSME Performance variable, but are still far above the required minimum limit of 0.70. Thus, all indicators are declared valid and meet the requirements of convergent validity, so that statistically these indicators are feasible and able to reflect their respective latent constructs consistently.

Table 6. Reliability test results

Variables	Cronbach alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
Supply Chain Digitalization (X_1)	0.976	0.977	0.979	0.840
Product Innovation (X_2)	0.984	0.985	0.986	0.887
MSME Performance (Y)	0.981	0.982	0.983	0.804

The reliability test results in Table 6 show that all three variables have a very high level of reliability and meet all measurement criteria. The Cronbach's alpha and Composite Reliability (rho_c) values for Supply Chain Digitalization (0.976 and 0.979), Product Innovation (0.984 and 0.986), and MSME Performance (0.981 and 0.983) are all well above the 0.70 threshold, indicating excellent internal consistency. Furthermore, the Average Variance Extracted (AVE) values for all variables also exceeded the 0.50 threshold, reaching 0.840, 0.887, and 0.804, respectively. This confirms that the research instrument is not only reliable but also possesses strong convergent validity, explaining more than 80% of the variance in its indicators. As can be seen in Table 7.

Table 7. Results of the Fornell-Larcker criterion test

Variables	Supply Chain Digitalization (X_1)	Product Innovation (X_2)	MSME Performance (Y)
Supply Chain Digitalization (X_1)	0.916		
Product Innovation (X_2)	0.166	0.942	
MSME Performance (Y)	0.617	0.617	0.896

Based on Table 7, the diagonal values, which are the square roots of the AVE for each construct, show a value of 0.916 for Supply Chain Digitalization, 0.942 for Product Innovation, and 0.896 for MSME

Performance. These values are greater than the correlation values of each construct with other constructs. Thus, it can be concluded that all constructs in this study have met discriminant validity based on the Fornell-Larcker Criterion, so that each construct is able to differentiate itself from other constructs in the research model.

4.4 Structural Model Testing (Inner Model)

Structural model or inner model testing is conducted to determine the relationships between latent variables in the research model and to test the formulated hypotheses. Inner model testing in this study includes path coefficients, R-square, and f-square. Path coefficients are used to determine the direction and magnitude of the influence between variables, while R-square is used to determine the ability of the independent variables to explain the dependent variable. Meanwhile, f-square is used to determine the magnitude of the effect of each independent variable on the dependent variable in Ghozali (2021). Structural model testing was conducted to evaluate the relationships between the latent variables and to examine the proposed hypotheses. The structural model assessment includes the analysis of path coefficients, coefficient of determination (*R*-square), and effect size (f-square). Path coefficients were used to determine the direction and strength of the relationships between constructs, while R-square was used to assess the explanatory power of the independent variables on the dependent variable. The f-square value was analyzed to determine the effect size of each exogenous variable on the endogenous variable. The results of the structural model analysis are presented in Figure 2.

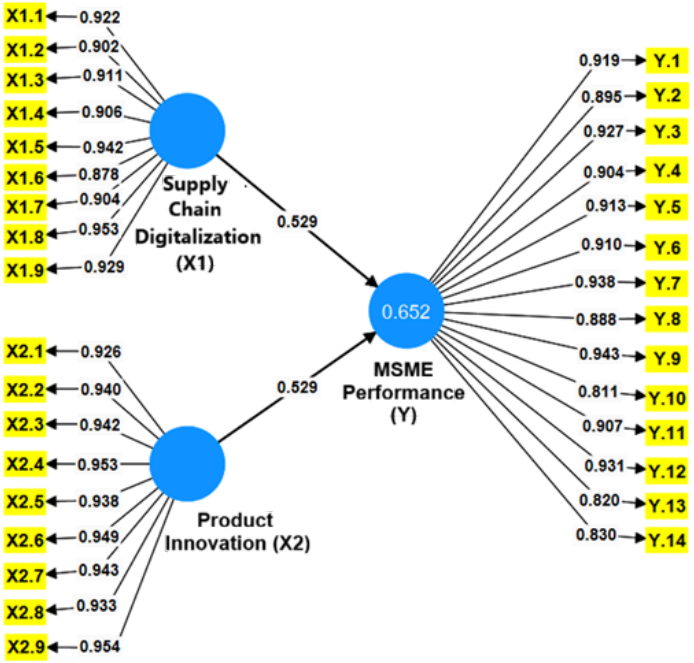


Figure 2. Hypothesis test results

Based on Figure 2, the structural model illustrates the relationships between supply chain digitalization, product innovation, and MSME performance. The model shows that supply chain digitalization and product innovation have a direct relationship with MSME performance. The path coefficient values indicate the magnitude and direction of the influence of each independent variable on the dependent variable. Furthermore, the hypothesis testing results based on path coefficients, t-statistics, and p-values are presented in Table 8.

Table 8. Hypotheses test results (path coefficients)

Hypotheses	Track	Original sample (O)	Sample mean (M)	STDEV	T statistics (|O/STDEV|)	P values
H_1	Supply Chain Digitalization (X_1) → MSME Performance (Y)	0.529	0.525	0.081	6.559	0.000
H_2	Product Innovation (X_2) → MSME Performance (Y)	0.529	0.533	0.070	7.582	0.000

Based on Table 8, Supply Chain Digitalization (X_1) has a positive and significant effect on MSME Performance (Y). This is indicated by the original sample value of 0.529, the t-statistics value of 6.559 > 1.96, and p-values of 0.000 < 0.05. Thus, H_1 is accepted, which means that the better the implementation of supply chain digitalization, the better the performance of MSMEs. This finding is in line with research by Zainurrafiqi and Gazali (2023) who found that supply chain digitalization has a positive and significant effect on the competitiveness of MSMEs in Pamekasan Regency, and Amrina (2026) who emphasized that digital economic transformation can increase operational efficiency and competitiveness of MSMEs (Rahardjo et al., 2026; Teng et al., 2022). These findings are consistent with the results of (Suryawan et al., 2025), which demonstrate that service quality and trust have a significant influence on customer loyalty and company value in Umrah travel agencies.

The study revealed that trust, reflected through the role of the *muthawif*, and customer relationships strengthened by the role of *ustaz* and pilgrims' experiences, significantly enhance customer satisfaction, which in turn drives customer loyalty and company value. This indicates that performance improvement mechanisms do not solely depend on operational and technological aspects but also on the development of trust and strong personal relationships. (Suryawan et al., 2022) further emphasized that customer loyalty serves as a mediating variable linking brand image, service quality, customer relationship, trust, and customer satisfaction to company value. These findings are relevant to the context of circular economy-based MSMEs, where customers' trust in environmentally friendly products and personal relationships with MSME owners are important factors in encouraging repeat purchases and customer loyalty, ultimately contributing to sustainable business performance.

Product Innovation (X_2) has a positive and significant effect on MSME Performance (Y). The test results show an original sample value of 0.529, a t-statistic of 7.582 > 1.96, and p-values of 0.000 < 0.05. Thus, H_2 is accepted, so it can be concluded that the better the product innovation carried out by MSMEs, the better the performance of MSMEs. This finding is consistent with Mahendra (2025) who showed that the creation of recycled-based products can significantly increase MSME income, and Novita (2022) who proved that product innovation has a positive influence on business competitiveness (Ilhami & Damayanti, 2024; Suchek et al., 2021).

Table 9. R-square test results

Variables	*R*-square	*R*-square adjusted
MSME Performance (Y)	0.652	0.645

Based on Table 9, the R-square value of MSME Performance (Y) is 0.652. This indicates that the variables Supply Chain Digitalization (X_1) and Product Innovation (X_2) together are able to explain the variation in MSME Performance by 65.2%, while the remaining 34.8% is explained by other variables not included in the research model. Meanwhile, the adjusted R-square value of 0.645 indicates that after adjusting for the number of predictors in the model, the ability of the independent variables to explain MSME Performance is 64.5%.

Table 10. F-square test results

Variables	f-square
Supply Chain Digitalization (X_1) → MSME Performance (Y)	0.782
Product Innovation (X_2) → MSME Performance (Y)	0.782

Based on Table 10, the f-square value of Supply Chain Digitalization (X_1) on MSME Performance (Y) is 0.782, while the f-square value of Product Innovation (X_2) on MSME Performance (Y) is also 0.782. Based on the f-square effect size criteria, these values indicate a large effect. Thus, Supply Chain Digitalization and Product Innovation each have a strong contribution to MSME Performance in the research model.

5. Conclusions

5.1 Conclusion

This study concludes that supply chain digitalization and product innovation represent important strategic capabilities for improving the performance of circular economy-based MSMEs. Beyond confirming the positive relationship between these constructs, this study contributes theoretically by extending circular economy and MSME performance literature through an integrated framework that combines digital supply chain capability and innovation capability. The findings demonstrate that sustainable MSME performance is not only influenced by the adoption of circular economy principles but also by the ability of firms to utilize digital technologies and develop innovative products as complementary mechanisms for creating economic and environmental value.

From a practical perspective, this study highlights that MSME actors should strengthen digital capabilities in supply chain activities, including information management, digital transactions, and market connectivity, while continuously developing innovative products aligned with sustainability principles. For policymakers and MSME development institutions, the findings emphasize the importance of supporting digital transformation programs, innovation training, and sustainable business ecosystems to enhance the competitiveness of circular economy-based MSMEs. The study also provides evidence that integrating technological capability and innovation capability offers a broader approach to achieving sustainable MSME development. Therefore, circular economy-based MSMEs should not only focus on waste reduction and resource efficiency but also develop strategic capabilities that enable long-term business growth and resilience.

5.2 Research Limitations

This study has several limitations. First, the research was conducted in only three regions, namely South Bogor, Bandung, and Yogyakarta, which may limit the generalizability of the findings to other circular economy-based MSMEs with different characteristics. Second, the cross-sectional research design limits the ability to capture changes in MSME performance over time following the adoption of digitalization and innovation practices. Third, this study examined only supply chain digitalization and product innovation as explanatory variables, while other factors such as financial capability, entrepreneurial orientation, government support, and market orientation may also influence MSME performance.

5.3 Suggestions and Directions for Future Research

Future research is recommended to expand the geographical scope and employ longitudinal approaches to provide deeper insights into the long-term effects of digitalization and innovation adoption on MSME performance. Further studies may also incorporate additional organizational and environmental factors, such as green innovation capability, financial literacy, entrepreneurial orientation, and institutional support, to develop a more comprehensive model of circular economy-based MSME performance. Comparative studies across different MSME sectors may also provide further understanding of how digital and innovation capabilities contribute to sustainable business development.

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Author Contributions

RFS contributed to the conceptualization, research design, methodology development, data analysis, manuscript preparation, and final revision. MR contributed to literature review, data collection, interpretation of results, and manuscript review. IW contributed to data collection, research administration, and manuscript improvement. NPP contributed to data analysis, validation,

visualization, and final manuscript review. All authors have read and approved the final version of the manuscript.

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