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The Role of Green Adaptability and Circular Economy in Encouraging Green Innovation in Batik SMEs in Pekalongan

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Abstract

This study examines the relationship between Green Supply Chain Management (GSCM), Green Adaptability, Circular Economy, and Green Innovation in the context of batik small and medium enterprises (SMEs) in Pekalongan, Indonesia, a traditional cultural industry facing significant environmental challenges. Although GSCM is often considered important in sustainable business transformation, this study empirically tests the integration of these three constructs through Structural Equation Modeling (SEM) and finds that Green Adaptability significantly influences Circular Economy ($\beta = 0.149$, $p < 0.001$) and Green Innovation ($\beta = 0.396$, $p < 0.001$), while Circular Economy also positively contributes to Green Innovation ($\beta = 0.119$, $p < 0.001$). In contrast, GSCM does not significantly influence these three variables ($p > 0.5$). These findings indicate that in the context of batik SMEs, the implementation of GSCM practices tends to be operational in nature and has not yet developed into a strategic capability capable of supporting sustainable innovation. Theoretically, this study extends the application of Dynamic Capability Theory and the Resource-Based View by emphasizing that organizational adaptive capabilities are the primary drivers of green innovation compared to fragmented green supply chain practices. Its empirical contribution is also significant because it fills a research gap in traditional cultural industries that has received little attention in the sustainability and innovation literature. These findings provide practical implications for policymakers and business actors to focus on developing adaptive capabilities and circular production systems to strengthen green innovation and the sustainable competitiveness of batik SMEs.

KEYWORDS

batik smes; circular economy; green adaptability; green innovation; green supply chain management.

Introduction

Batik production, as one of Indonesia's most valuable cultural heritages, particularly in Pekalongan, faces substantial environmental challenges, including intensive water consumption, the extensive use of hazardous synthetic dyes, and inadequate wastewater management practices (Musawwa et al., 2026; Mursidah et al., 2025). Increasing regulatory pressure concerning environmental management, together with growing market demand for sustainable products, has compelled batik MSMEs to adopt environmentally responsible business practices as a strategic response (Ministry of Industry of the Republic of Indonesia, 2021; IPCC, 2022). As one of Indonesia's largest batik production centers, Pekalongan provides a theoretically significant context because its traditional batik industry must simultaneously preserve cultural heritage, sustain economic growth, and respond to increasingly stringent environmental pressures.

Within this context, environmentally oriented business approaches, particularly Green Supply Chain Management (GSCM), Circular Economy (CE), and Green Adaptability has emerged as a critical research focus. GSCM integrates environmental considerations into supply chain activities by incorporating sustainable practices across activities ranging from sourcing and manufacturing to product delivery and the management of post-use flows (Putri et al., 2022; Lutfian, 2023). Evidence from the existing literature

does not yet provide a consistent picture of how GSCM contributes to green innovation, particularly among MSMEs (Aboelmaged & Hashem, 2019; Rupa & Saif, 2022). Likewise, circular economy principles reshape the way firms manage materials and resources by prioritizing regenerative processes and closed-loop practices. Such an approach seeks to retain resources in productive use for longer through reduction, reuse, and recycling, while simultaneously improving resource efficiency and reducing ecological pressure (Bernon et al., 2018; Gera et al., 2022). Although circular business practices are gaining greater attention, their application within batik MSMEs is still constrained by limitations in technology, financial resources, and organizational capacity (Ripanti & Tjahjono, 2019). Furthermore, Green Adaptability reflects an organization's dynamic capability to respond swiftly to changes in environmental conditions, regulations, technology, and market demands, thereby strengthening its capacity to pursue sustainable innovation (Vu & Dang, 2021; Jum'a et al., 2021). Nevertheless, its role within the context of batik MSMEs has received limited scholarly attention.

Existing research has largely focused on large-scale manufacturing companies, with considerable attention given to the role of GSCM in shaping environmental outcomes and fostering innovation. Evidence from MSMEs, however, is considerably less conclusive, particularly within traditional sectors such as the batik industry, where empirical results have varied across studies (Zhu et al., 2012; Aboelmaged & Hashem, 2019). Existing research has generally overlooked whether organizational capabilities, particularly Green Adaptability and Circular Economy practices, can serve as intermediary pathways through which GSCM contributes to Green Innovation. Moreover, empirical evidence remains scarce in culturally embedded industries such as batik MSMEs, where adaptive capabilities and circular business practices may constitute essential drivers of sustainable innovation.

Accordingly, an important theoretical gap concerns the extent to which the Resource-Based View (RBV) can account for adaptive capabilities in explaining the development of Green Innovation. While RBV primarily focuses on the strategic role of valuable organizational resources in generating competitive advantage, it provides limited explanation of how firms adapt those resources to respond to changing environmental conditions. Similarly, an empirical gap exists due to inconsistent evidence regarding the effectiveness of GSCM in MSMEs compared with large enterprises. From a contextual perspective, limited research has examined how the synergistic interaction among GSCM, Circular Economy, and Green Adaptability influences Green Innovation within batik MSMEs, particularly those operating in Pekalongan.

This study advances the theoretical perspective by combining the Resource-Based View (RBV) and Dynamic Capability Theory (DCT) to conceptualize Green Adaptability as an organizational capacity for responding to change. This integrated perspective further examines whether such adaptability enables Circular Economy practices to translate their potential into sustainable Green Innovation within traditional MSMEs. This integrated perspective not only provides a clearer explanation of the internal mechanisms distinguishing batik MSMEs from large manufacturing firms but also advances theoretical understanding of the critical role of adaptive capabilities in culturally embedded small enterprises pursuing environmental sustainability.

A systematic review of the literature indicates that GSCM generally contributes positively to Green Innovation and environmental performance across various industrial settings (Zhu et al., 2012; Aboelmaged & Hashem, 2019). However, empirical evidence within MSMEs remains inconclusive.

Several studies suggest that limited organizational resources, technological capabilities, and managerial competencies hinder the effectiveness of GSCM implementation in MSMEs (Rupa & Saif, 2022; Debnath et al., 2023). Conversely, other scholars argue that adaptive organizational capabilities and Circular Economy principles provide more effective strategic pathways toward sustainable innovation by facilitating resource optimization, waste minimization, and continuous organizational learning (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Vu & Dang, 2021).

Dynamic Capability Theory provides a basis for viewing Green Adaptability as the capacity of an organization to adjust its resources, competencies, and routines when confronted with changing environmental demands. This capacity can facilitate innovation while supporting sustained competitive performance (Teece et al., 1997; Jum'a et al., 2021). Simultaneously, circularity offers an integrated approach to managing materials and production activities by minimizing waste, enhancing the productive use of resources, and opening avenues for product and process innovation through regenerative practices (Bernon et al., 2018; Gera et al., 2022). Taken together, GSCM, Green Adaptability, and Circular Economy provide complementary perspectives for examining how traditional MSMEs can pursue more sustainable business practices and develop Green Innovation, particularly in Indonesia's batik industry.

The theoretical arguments developed above lead to six hypothesized relationships among Green Supply Chain Management (GSCM), Green Adaptability (GA), Circular Economy (CE), and Green Innovation (GI). The hypotheses are formulated in the same sequence as the structural paths specified in the conceptual model and reported in the subsequent hypothesis-testing results.

H1: Green Supply Chain Management (GSCM) has a positive effect on Green Adaptability (GA).

GSCM integrates environmental considerations into sourcing, production, distribution, and waste-management activities. Such integration can expose firms to changing environmental requirements and encourage the development of organizational routines for responding to these changes. In the context of batik SMEs, environmentally oriented supply-chain practices may therefore contribute to the development of adaptive capabilities that enable firms to respond to environmental regulations, technological changes, and market expectations. Accordingly, this study hypothesizes that GSCM positively affects Green Adaptability.

H2: Green Supply Chain Management (GSCM) has a positive effect on Circular Economy (CE).

GSCM emphasizes environmentally responsible resource management throughout supply-chain activities, including procurement, production, distribution, and waste management. These practices are conceptually consistent with Circular Economy principles that emphasize resource efficiency, waste reduction, reuse, recovery, and recycling. In batik SMEs, the integration of environmental considerations into supply-chain activities may facilitate more circular approaches to material and waste management. Therefore, GSCM is hypothesized to have a positive effect on Circular Economy implementation.

H3: Circular Economy (CE) has a positive effect on Green Innovation (GI).

Circular Economy practices encourage firms to reconsider how resources and materials are acquired, used, reused, recovered, and disposed of. Such practices can stimulate the development of new products, production processes, and resource-management approaches that reduce environmental impacts. For batik SMEs, waste reduction, material reuse, resource efficiency, and circular production practices may provide opportunities for environmentally oriented product and process innovation. Accordingly, Circular Economy is

hypothesized to positively affect Green Innovation.

H4: Green Adaptability (GA) has a positive effect on Green Innovation (GI).

Green Adaptability represents the organizational capacity to respond to changes in environmental regulations, technologies, stakeholder expectations, and market conditions. From a Dynamic Capability perspective, the ability to sense environmental changes, respond to emerging opportunities, and reconfigure organizational resources can facilitate innovation. Batik SMEs with stronger Green Adaptability may therefore be better able to modify production processes, adopt environmentally friendly technologies, and develop environmentally friendly products. Thus, Green Adaptability is hypothesized to have a positive effect on Green Innovation.

H5: Green Supply Chain Management (GSCM) has a positive effect on Green Innovation (GI).

GSCM can provide firms with environmental information, supplier collaboration, resource-efficiency practices, and pollution-prevention routines that create opportunities for green product and process innovation. By integrating environmental considerations throughout supply-chain activities, firms may identify opportunities to improve production processes and develop environmentally friendly products. Therefore, GSCM is hypothesized to positively affect Green Innovation.

H6: Green Adaptability (GA) has a positive effect on Circular Economy (CE).

The implementation of Circular Economy practices frequently requires firms to modify established production routines, resource-allocation practices, material use, waste-management systems, and relationships with suppliers and other stakeholders. Green Adaptability may facilitate these changes by enabling firms to respond to environmental and market developments and reconfigure their resources and routines accordingly. Hence, Green Adaptability is hypothesized to have a positive effect on Circular Economy implementation.

Methods

A quantitative explanatory design was employed to examine the hypothesized associations among Green Supply Chain Management (GSCM), Circular Economy (CE), Green Adaptability, and Green Innovation in the batik SME sector. The study utilized a cross-sectional survey, allowing the proposed relationships among latent constructs to be empirically assessed based on observations obtained during a single period of data collection. The quantitative approach

was selected to provide objective evidence and statistical generalization regarding the proposed conceptual framework through Structural Equation Modeling (SEM).

A purposive selection strategy was adopted to ensure that the participants possessed characteristics consistent with the predefined requirements of the research. Eligible enterprises were required to: (1) have been operating for at least five years; (2) employ a minimum of five workers; (3) market their products beyond the local region; and (4) have implemented environmentally friendly production practices. The total population of batik enterprises meeting these criteria in Pekalongan was estimated at approximately 1,824 businesses (Natalia, 2022; Ministry of Industry of the Republic of Indonesia, 2022). Questionnaire data were collected from eligible participants through established batik business associations and local industry networks, with 375 questionnaires circulated during the data-collection process. Following the data-collection process, 341 questionnaires met the requirements for inclusion in the analysis. This represented 91% of the questionnaires distributed. To minimize the potential for non-response bias, the characteristics of the participating enterprises including firm size, production type, and business location were compared with those of the target population. The comparison revealed no statistically significant differences that could compromise the representativeness of the sample. Furthermore, the final sample encompassed a diverse range of enterprise sizes and production types, thereby providing an adequate representation of the heterogeneity of batik SMEs operating in the Pekalongan region.

The research was conducted in Pekalongan City, Central Java, Indonesia, which is widely recognized as one of Indonesia's principal batik production clusters and is internationally acknowledged for preserving traditional batik craftsmanship. Pekalongan was selected because its batik industry significantly contributes to regional economic development while simultaneously facing substantial environmental challenges related to wastewater management, chemical dye utilization, and sustainable production practices. These characteristics make the city an appropriate empirical setting for examining sustainability-oriented business transformation among traditional manufacturing SMEs.

The study operationalized four core constructs: Green Supply Chain Management, Circular Economy, Green Adaptability, and Green Innovation. The indicators for each construct were derived from established measurement scales reported in prior research and subsequently contextualized to capture the specific characteristics of batik MSMEs. Table 1 summarizes the constructs, measurement sources, and adaptations made for the research context.

Table 1. Measuring Instruments

Construct	Item Codes	Sample Measurement Item	Reference Sources	Adaptation for the Batik MSME Context
Green Supply Chain Management (GSCM)	GSCM1, GSCM2, GSCM3, GSCM4, GSCM5, GSCM6.	"Our enterprise implements environmentally friendly procurement practices."	Putri et al., (2022); Lutfian (2023)	The wording of the measurement items was contextualized to the characteristics of batik production, particularly with respect to environmentally preferable raw materials, non-chemical production inputs, and materials obtained from local sources.
Circular Economy (CE)	CE1, CE2, CE3, CE4, CE5.	"Our enterprise reuses textile waste whenever possible."	Bernon et al., (2018); Gera et al., (2022)	Additional items were incorporated to capture batik-specific waste management practices, including fabric waste reuse and the utilization of natural dyes commonly adopted in local production processes.
Green Adaptability (GA)	GA1, GA2, GA3, GA4, GA5.	"Our enterprise responds quickly to new environmental regulations."	Vu and Dang (2021); Jum'a et al. (2021)	Items were reworded to reflect the operational characteristics of batik MSMEs, particularly their capacity to adapt to environmental regulations and adopt environmentally friendly technologies.

Construct	Item Codes	Sample Measurement Item	Reference Sources	Adaptation for the Batik MSME Context
Green Innovation (GI)	GI1, GI2, GI3, GI4, GI5.	"Our enterprise continuously develops environmentally friendly products."	Albort-Morant et al., (2018); Yuan et al., (2021)	The measurement emphasized product and process innovations specifically relevant to batik production and local environmental sustainability practices.

Several procedures were undertaken to establish the validity and contextual appropriateness of the research instrument.

1. Translation and Back-Translation: The questionnaire underwent a two-stage language adaptation process. First, a professional bilingual expert translated the original instrument into Indonesian. The resulting version was then back-translated into the original language to evaluate semantic equivalence and ensure that the intended meaning of each measurement item was retained.
2. Pilot Testing: Prior to the main survey, the questionnaire was pretested with 30 batik MSME owners who met the established eligibility requirements. The pretest was intended to assess whether the items were clear, easy to understand, and appropriate for the specific context of the batik industry.
3. Instrument Revision: Based on feedback obtained from the pilot study and expert evaluations, several questionnaire items were revised, rephrased, or simplified to improve respondent comprehension while maintaining the conceptual integrity of each construct. These refinements enhanced the instrument's relevance to the operational characteristics of batik MSMEs and strengthened its content validity.

Primary data were collected during a one-month period using two complementary survey administration modes: online and paper-based questionnaires. The online questionnaire was administered through Google Forms and distributed through established batik business associations and entrepreneur networks, whereas paper questionnaires were administered directly to eligible batik SMEs in production centers in Pekalongan City. A total of 375 questionnaires were distributed, of which 341 usable responses were retained for the final analysis. To minimize duplicate participation across the two survey modes, submitted questionnaires were screened for completeness, consistency, and potential duplication using the available enterprise-level information recorded during data collection. Potentially duplicate submissions were reviewed before the final dataset was established. Survey mode was recorded for each retained observation, and the composite scores of GSCM, CE, GA, and GI were compared between online and paper respondents to assess potential mode-related response differences before pooling the observations for SEM analysis. Supplementary field observations and informal interviews were also conducted with selected participating batik SMEs to provide contextual information concerning material use, production processes, waste management, resource efficiency, and the implementation of GSCM, Circular Economy, Green Adaptability, and Green Innovation. These observations and interviews served only as contextual and interpretive evidence and were not treated as an additional quantitative dataset or incorporated into the SEM model. Thus, the questionnaire responses constituted the sole quantitative basis for hypothesis testing, while the supplementary observations and interviews were used to contextualize the quantitative findings.

Structural Equation Modeling (SEM) was applied through AMOS to assess the proposed model. The approach provides an integrated means of evaluating relationships between observed indicators and their underlying constructs while simultaneously examining the hypothesized associations among the latent variables. Given the cross-sectional nature

of the research design, the analysis was intended to estimate and assess the relationships among the hypothesized constructs rather than establish definitive causal relationships. The analytical procedure consisted of four sequential stages.

Assessment of the measurement model began with Confirmatory Factor Analysis (CFA). Standardized factor loadings were examined to determine construct validity, whereas convergent validity was evaluated based on Average Variance Extracted (AVE). Values of 0.50 or greater were used as the minimum criterion for both factor loadings and AVE. Reliability was then assessed using Composite Reliability (CR), for which a threshold exceeding 0.70 was considered indicative of adequate internal consistency.

Prior to structural estimation, the data were assessed for multivariate normality, multivariate outliers, and measurement-model quality. The critical ratio for multivariate normality was 2.361, below the absolute criterion of 2.58, indicating an acceptable level of multivariate normality. Mahalanobis-distance assessment showed p^2 values greater than 0.001; therefore, no observation met the adopted exclusion criterion for multivariate outliers, and all 341 usable observations were retained. The retained indicators showed standardized factor loadings ranging from 0.600 to 0.903. CR values ranged from 0.813 to 0.842, while AVE values ranged from 0.522 to 0.643, supporting internal consistency and convergent validity.

Model fit was assessed using Chi-square, RMSEA, CMIN/DF, GFI, AGFI, TLI, CFI, and NFI. The resulting indices were CMIN/DF = 2.015, RMSEA = 0.055, GFI = 0.941, AGFI = 0.909, TLI = 0.953, CFI = 0.965, and NFI = 0.934, indicating acceptable overall model fit. The hypotheses were evaluated using standardized path estimates, Critical Ratios (C.R.), and p -values, with statistical significance assessed at $p < 0.05$. Coefficients were interpreted according to their magnitude and direction. Because the study employed a cross-sectional design, the structural estimates are interpreted as statistical associations rather than definitive causal effects.

The research procedures were designed in accordance with accepted ethical principles for studies involving human participants. Participants were provided with relevant information about the research purpose, their voluntary participation, and the confidentiality of the data before completing the survey. Informed consent was obtained prior to questionnaire completion. No identifying personal information was requested, while the responses were handled anonymously and reported in aggregated form to preserve participant confidentiality and privacy.

Result and Discussion

The structural model was first evaluated for overall fit before the hypothesized paths were examined. Several goodness-of-fit measures were considered within the SEM analysis, and the resulting statistics suggest that the model fits the observed data satisfactorily. The results indicate that the proposed model demonstrated an acceptable overall fit with the empirical data. The Chi-square statistic was statistically significant ($\chi^2 = 155.179$, $df = 77$, $p < 0.001$). However, the significant Chi-square result was not interpreted in isolation because the Chi-square test is sensitive to sample size and may become significant with relatively large samples. Therefore, the assessment of model fit was based on a combination of complementary goodness-of-fit indices.

Table 2. Goodness-of-Fit Indices

Goodness-of-Fit Index	Result	Recommended Value	Interpretation
Chi-square	155.179	Acceptable	Fit
Degrees of freedom (df)	77		
Probability (p)	<0.001		Significant
RMSEA	0.055	≤ 0.08	Fit
CMIN/DF	2.015	≤ 3.00	Acceptable Fit
GFI	0.941	≥ 0.90	Fit
AGFI	0.909	≥ 0.90	Fit
TLI	0.953	≥ 0.90	Fit
CFI	0.965	≥ 0.90	Fit
NFI	0.934	≥ 0.90	Fit
Sample Size	341	≥ 200	Adequate

Table 3. Measurement Model Assesment

Construct	Indicator	Standardized Factor Loading	Decision
Green Adaptability (GA)	GA1	0.841	Retained
	GA2	0.600	Retained
	GA4	0.624	Retained
	GA5	0.864	Retained
Green Supply Chain Management (GSCM)	GSCM1	0.746	Retained
	GSCM3	0.801	Retained
	GSCM4	0.680	Retained
	GSCM6	0.653	Retained
Circular Economy (CE)	CE1	0.675	Retained
	CE3	0.903	Retained
	CE5	0.811	Retained
Green Innovation (GI)	GI1	0.744	Retained
	GI3	0.708	Retained
	GI4	0.813	Retained
	GI5	0.636	Retained

Table 4. Validity and Reliability Results

Construct	CR	AVE	Assessment
Green Adaptability (GA)	0.827	0.551	Valid and Reliable
Green Supply Chain Management (GSCM)	0.813	0.522	Valid and Reliable
Circular Economy (CE)	0.842	0.643	Valid and Reliable
Green Innovation (GI)	0.817	0.530	Valid and Reliable

Table 5. Hypothesis Testing Results

Hypothesis	Relationship	Estimate	S.E.	C.R.	p-value	Result
H1	GSCM → GA	-0.009	0.035	-0.259	0.795	Not Supported
H2	GSCM → CE	-0.002	0.029	-0.053	0.958	Not Supported
H3	CE → GI	0.119	0.033	3.622	<0.001	Supported
H4	GA → GI	0.396	0.055	7.142	<0.001	Supported
H5	GSCM → GI	0.019	0.028	0.674	0.501	Not Supported
H6	GA → CE	0.149	0.042	3.535	<0.001	Supported

The CMIN/DF value of 2.015 was below the recommended threshold of 3.00, while the RMSEA value of 0.055 indicated an acceptable level of approximation between the proposed model and the observed data. Furthermore, the GFI (0.941), AGFI (0.909), TLI (0.953), CFI (0.965), and NFI (0.934) values were all above the recommended threshold of 0.90. Taken together, these indices provide sufficient evidence that the proposed model has an acceptable fit with the empirical data.

Regarding model specification, the final model was

evaluated based on the relationships theoretically proposed in the conceptual framework. No model modifications were made solely to improve the statistical goodness-of-fit. Modification indices were not used as an automatic basis for adding structural paths or correlating error terms. Any modification, if considered, would require a clear theoretical justification and consistency with the underlying conceptual framework. This approach was adopted to minimize the risk of data-driven model specification and to maintain the theoretical integrity of the proposed model.

The overall pattern of fit measures supports the adequacy of the model and permits further evaluation of the hypothesized relationships among the latent constructs. Nevertheless, because the data were collected cross-sectionally, the structural coefficients should be interpreted as indicating the direction and relative strength of associations, rather than establishing definitive causal relationships.

Assessment of the measurement model was performed through Confirmatory Factor Analysis (CFA), with particular attention to the extent to which the observed items represented the intended latent constructs. Standardized factor loadings were used to assess indicator validity. The results presented in Table 3 show that all retained items achieved loadings greater than 0.50, supporting their adequacy as measures of the associated constructs.

Confirmatory Factor Analysis (CFA) was conducted to assess the measurement model. Standardized factor loadings were examined as an indicator-level criterion for retaining the observed measures, with 0.50 adopted as the minimum acceptable value. All indicators included in the final measurement model exceeded this threshold. The standardized factor loadings for Green Adaptability (GA) ranged from 0.600 to 0.864; those for Green Supply Chain Management (GSCM) ranged from 0.653 to 0.801; Circular Economy (CE) ranged from 0.675 to 0.903; and Green Innovation (GI) ranged from 0.636 to 0.813. Across all four constructs, the retained indicators therefore exhibited standardized factor loadings between 0.600 and 0.903, indicating that each retained indicator met the specified loading criterion. These results provide indicator-level evidence supporting the adequacy of the retained measurement items for subsequent assessment of construct reliability and convergent validity.

The assessment of the measurement model considered standardized factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR). An AVE of 0.50 or higher was used as the criterion for adequate convergent validity, while CR values exceeding 0.70 indicated acceptable internal consistency.

Assessment of the measurement model confirms that each construct achieved the required levels of reliability and convergent validity. The CR coefficients range from 0.813 to 0.842, with corresponding AVE values ranging between 0.522 and 0.643. Since all constructs exceeded the specified threshold values, the indicators were retained for subsequent evaluation of the structural model.

Hypothesis Testing

Following confirmation of measurement model adequacy, the structural component was examined to evaluate the relationships specified in the research model. Hypothesis testing incorporated the unstandardized coefficients (b), standard errors (S.E.), Critical Ratios (C.R.), and p-values obtained from the AMOS output. In view of the cross-sectional design, these estimates are interpreted as indicating the direction and strength of associations among the constructs and are not taken as definitive evidence of causality.

The results show that three of the six hypothesized associations were statistically supported, namely H3, H4, and H6. The largest standardized association identified in the structural model involved Green Adaptability and Green Innovation (H4: $b = 0.396$, $p < 0.001$). The positive estimate indicates a statistically significant association, whereby batik SMEs with stronger Green Adaptability tend to exhibit higher Green Innovation. Substantively, this finding suggests that the ability of SMEs to respond to environmental changes, adapt to market and regulatory demands, and develop organizational capabilities is closely related to their capacity to generate green innovation. Among the relationships examined, this association represents the largest estimated

coefficient and therefore indicates the most prominent relationship within the model.

The estimated path from Circular Economy to Green Innovation was positive and statistically significant (H3: $b = 0.119$, $p < 0.001$). Despite its smaller magnitude relative to the Green Adaptability coefficient, the result indicates that greater engagement in circular practices is accompanied by higher Green Innovation among the sampled batik SMEs. Practices involving efficient resource utilization, waste reduction, material reuse, and circularization of production activities may consequently serve as enabling conditions for product and process improvements. However, because the coefficient is smaller than that of Green Adaptability, the empirical results suggest that circular economy practices alone may not be as strongly associated with green innovation as the organizational capacity to adapt.

Furthermore, Green Adaptability was positively and significantly associated with Circular Economy (H6) ($b = 0.149$, $p < 0.001$). This finding suggests that SMEs with greater capacity to adapt to environmental and market changes tend to demonstrate stronger circular economy practices. The result provides an important indication that organizational adaptability may serve as an enabling capability for the implementation of circular practices. In practical terms, SMEs that are more responsive to changing environmental requirements and stakeholder expectations may be better positioned to adopt resource efficiency, waste reduction, and resource reuse practices.

In contrast, Green Supply Chain Management did not show statistically significant associations with Green Adaptability (H1) ($b = -0.009$, $p = 0.795$), Circular Economy (H2) ($b = -0.002$, $p = 0.958$), or Green Innovation (H5) ($b = 0.019$, $p = 0.501$). The estimates are very close to zero, indicating that the observed associations between GSCM and the three outcome constructs are negligible within the sample. These findings suggest that the implementation of GSCM practices among the studied batik SMEs has not yet translated into stronger adaptive capabilities, circular economy practices, or green innovation.

The near-zero estimates for GSCM may be understood from the characteristics and operational conditions of batik SMEs. Although environmental supply chain practices may already be implemented, their implementation may still be largely focused on routine operational activities, regulatory compliance, waste handling, and resource management. Limited financial resources, access to appropriate technology, managerial capabilities, and organizational capacity may constrain SMEs from transforming these operational practices into strategic capabilities that generate broader organizational outcomes. Consequently, GSCM may exist as an environmental management practice without yet becoming a sufficiently developed strategic capability to support adaptation, circularity, or innovation.

The structural estimates suggest that Green Adaptability is the most strongly associated construct with Green Innovation in the proposed model, followed by Circular Economy. The significant relationship between Green Adaptability and Circular Economy further suggests that adaptive organizational capabilities are relevant to the development of circular practices. Conversely, the near-zero and statistically insignificant GSCM estimates indicate that the current implementation of green supply chain practices has not yet been sufficiently translated into broader organizational capabilities or innovation outcomes. The evidence indicates that operational improvements in green supply chain management need to be supported by stronger organizational capabilities and greater adaptive capacity.

The findings of this study provide an important explanation of how sustainability-oriented practices are associated with green innovation among batik SMEs in Pekalongan City.

Overall, the results indicate that Green Adaptability (GA) has the strongest estimated association with Green Innovation (GI), while Circular Economy (CE) also shows a positive and significant association with GI. The analysis indicates that GSCM is not significantly associated with GA, CE, or GI. This finding implies that adopting environmentally oriented supply chain practices, by itself, may not be sufficient to advance sustainability transformation among batik SMEs. The realization of such transformation may instead require adequate internal capabilities, technological readiness, managerial resources, and organizational responsiveness to changing environmental and market conditions.

The insignificant associations between GSCM and Green Adaptability, Circular Economy, and Green Innovation are particularly noteworthy. The coefficients are very close to zero, indicating that the current implementation of GSCM among the sampled batik SMEs has a negligible association with the development of adaptive capability, circular practices, and green innovation. This finding should not be interpreted as meaning that GSCM is unimportant; rather, it indicates that GSCM practices have not yet developed into an integrated strategic capability within the studied SMEs. In the Pekalongan batik industry, green supply-chain practices may still be concentrated on operational activities such as purchasing materials, managing production waste, complying with environmental requirements, and maintaining relationships with suppliers. Such activities can provide environmental benefits, but they do not automatically generate organizational capabilities for innovation.

The specific characteristics of the batik industry provide an important contextual explanation for this finding. Batik production involves environmentally sensitive activities, particularly dyeing, washing, finishing, and wastewater management. The use of synthetic dyes and other production materials can generate wastewater requiring appropriate treatment, while many SMEs continue to face limitations in financial resources, access to green technologies, environmental infrastructure, and managerial expertise. This condition is particularly relevant in Pekalongan, where [Fadhila et al., \(2023\)](#) found that the availability of wastewater treatment plants (IPAL) remained insufficient relative to the volume of batik wastewater generated, indicating that environmental infrastructure continues to be an important constraint in the implementation of sustainable batik production. Recent studies in Pekalongan have documented continuing challenges in batik wastewater management, including limitations in the implementation and optimization of wastewater treatment facilities. [Musawwa et al., \(2026\)](#) highlight that batik production generates complex wastewater containing dyes, heavy metals, and other contaminants, while many Indonesian batik MSMEs still face limitations in wastewater treatment facilities. The authors emphasize the need for low-cost, effective, and context-specific treatment technologies that are appropriate for MSME operating conditions. This evidence further supports the argument that technological and infrastructural constraints may limit the ability of batik SMEs to transform environmental practices into strategic sustainability capabilities.

Other evidence from Pekalongan also identifies limited access to environmentally friendly technologies, high implementation costs, and insufficient knowledge as barriers to green-economy practices among batik SMEs. [Santoso et al., \(2024\)](#), for example, reported that batik craftsmen in Pekalongan had begun adopting natural dyes and improving waste management, but continued to face significant constraints related to environmentally friendly technology, implementation costs, and knowledge. These conditions reinforce the argument that green practices may remain operational rather than developing into strategic capabilities when complementary resources are limited. These conditions

suggest that many SMEs may prioritize immediate operational and compliance requirements rather than investing in the integration of suppliers, technologies, knowledge, and environmental practices into a strategic green supply-chain capability.

Viewed through an RBV lens, organizational practices do not inherently constitute strategic resources. Their contribution to organizational value is shaped by the resources available to the firm and its capacity to combine and deploy those resources effectively. In the present context, GSCM may represent an important environmental practice, but its strategic value remains limited when SMEs lack the financial, technological, human, and managerial resources required to integrate those practices into broader organizational processes. This interpretation also helps explain why evidence regarding the relationship between GSCM and innovation is not always consistent across organizational contexts. While research in manufacturing SMEs has reported positive relationships among GSCM, eco-innovation, and circular economy capability, the strength of these relationships may depend on organizational maturity, environmental collaboration, technological readiness, and complementary capabilities ([Bag et al., 2022](#); [Jo & Kwon, 2022](#)). Therefore, the present findings suggest that relationships established in larger or more technologically advanced manufacturing settings should not automatically be generalized to traditional, resource-constrained SMEs such as batik enterprises.

The findings further identify Circular Economy as a significant positive correlate of Green Innovation. SMEs demonstrating greater commitment to circular resource and production practices also tend to report stronger innovation-oriented environmental outcomes. In the batik context, circular practices may include reducing production waste, improving material efficiency, reusing materials, recovering production residues, recycling wastewater where technically feasible, and developing products from production waste. These activities encourage entrepreneurs to reconsider how materials are purchased, processed, reused, and disposed of, thereby creating opportunities for product and process improvement. This interpretation is particularly relevant to batik SMEs because the management of dyeing and production waste is an important environmental issue in Pekalongan. Recent studies have identified waste management and the use of more environmentally friendly materials as important elements of green-economy implementation among batik SMEs, although their adoption remains constrained by technology, cost, and knowledge limitations.

The coefficient for CE is smaller than that of Green Adaptability, but the significant positive association remains substantively meaningful. Circular practices can create opportunities for resource efficiency, waste reduction, and sustainable product development, but these practices do not necessarily result in innovation unless SMEs possess the ability to recognize opportunities, acquire relevant knowledge, reconfigure resources, and implement new processes. Thus, circular economy practices can provide an important foundation for green innovation, whereas organizational adaptability determines how effectively those opportunities can be recognized and converted into innovative outcomes. This interpretation is consistent with recent research suggesting that circular-economy implementation in SMEs requires not only environmental practices but also organizational capabilities, stakeholder collaboration, innovation capacity, and appropriate supporting resources ([Bag et al., 2022](#)).

The strongest estimated association in the model is found between Green Adaptability and Green Innovation. This result indicates that SMEs with greater capacity to respond to environmental requirements, technological developments, and changing market expectations tend to demonstrate stronger green innovation. The practical meaning of this finding is

particularly relevant to batik SMEs because the industry operates within a changing environment characterized by increasingly demanding environmental expectations, technological developments in production and dyeing processes, and growing consumer interest in environmentally responsible products. SMEs that are able to learn, modify production routines, adopt new technologies, and respond to market changes are therefore better positioned to develop environmentally friendly products and processes.

Dynamic Capability Theory provides an explanation for this result by emphasizing the importance of organizational processes through which firms identify external changes, act upon emerging opportunities, and modify their resource configurations. In the context of batik SMEs, Green Adaptability captures this capacity by enabling firms to adjust their responses to environmental and market developments and embed those adjustments in evolving capabilities and practices. Recent research also indicates that green dynamic capabilities can strengthen green innovation by enabling SMEs to translate stakeholder pressures and environmental challenges into innovation outcomes (Singh et al., 2022). Therefore, the strong association between GA and GI suggests that innovation in batik SMEs is not generated merely by adopting environmental practices, but also by the organization's ability to learn, adapt, and reconfigure its resources.

The significant positive association between Green Adaptability and Circular Economy further strengthens this interpretation. The adoption of circular practices requires changes in production routines, resource allocation, material use, waste management, and sometimes supplier relationships. Such transformation is difficult when SMEs rely heavily on established routines and have limited resources. SMEs with greater adaptive capacity are more likely to experiment with alternative materials, modify production processes, learn from environmental requirements, and respond to changing customer expectations. Green Adaptability can therefore be viewed as an enabling organizational capability associated with the implementation of circular practices. However, because mediation was not formally tested in this study, this result should not be interpreted as evidence that GA statistically mediates the relationship between GSCM or CE and GI. Rather, the findings demonstrate a significant pattern of associations in which adaptability is related to both circular practices and green innovation.

Taken together, the findings provide a more nuanced explanation of sustainability transformation among batik SMEs. GSCM, although important as an operational environmental practice, does not appear to have developed into a strategic capability that is directly associated with adaptability, circularity, or innovation. In contrast, Green Adaptability and Circular Economy show stronger and statistically significant associations with Green Innovation. This suggests that the transition from environmental practice to innovation requires more than implementing green activities along the supply chain. It requires SMEs to develop internal capabilities that enable them to learn, respond, reorganize resources, and convert environmental challenges into opportunities for innovation. From an RBV perspective, this means that environmental practices need to be supported by valuable organizational resources and embedded capabilities. From a Dynamic Capability perspective, organizations must also possess the ability to adapt and reconfigure these resources as environmental and market conditions change.

These findings contribute to sustainability research in two important ways. First, they demonstrate that the relationship between GSCM and green innovation is context-dependent and should not be assumed to be universally positive. In

traditional SMEs with limited resources and technological capabilities, green supply-chain practices may remain operational and compliance-oriented rather than becoming strategic capabilities. Second, the findings highlight the importance of organizational adaptability in explaining how SMEs move from environmental practices toward circularity and green innovation. This extends the application of sustainability theories to a traditional cultural industry that remains relatively underrepresented in empirical research. The Pekalongan batik context demonstrates that the effectiveness of sustainability practices is strongly influenced by local production characteristics, wastewater-management challenges, supplier structures, technological availability, and the capabilities of individual SMEs.

From a practical perspective, the findings imply that programs aimed at increasing green innovation among batik SMEs should not focus solely on encouraging the adoption of GSCM practices. Greater attention should be given to strengthening adaptive capabilities, technological readiness, managerial competencies, and circular production capabilities. Government agencies, industry associations, and SME-support institutions can support this process through training in environmentally friendly dyeing technologies, wastewater treatment, resource efficiency, recycling, circular production, digital technologies, and sustainable product development. Shared or communal wastewater treatment facilities may also be important because individual SMEs often face financial and technical limitations in developing their own treatment systems. For SME owners and managers, environmental practices should increasingly be integrated with organizational learning and innovation activities so that waste reduction, resource efficiency, and environmental compliance become sources of information for improving production processes, developing new products, and identifying new market opportunities.

Overall, the results indicate that Green Adaptability has the strongest estimated association with Green Innovation, while Circular Economy also shows a positive and significant association with Green Innovation. In contrast, the near-zero and statistically insignificant coefficients for GSCM indicate that its current implementation has not yet been sufficiently transformed into a strategic capability within the studied batik SMEs. The findings therefore suggest that strengthening organizational adaptability and circular capabilities, together with improvements in technology, managerial capacity, and environmental infrastructure, may provide a more effective pathway for advancing green innovation in the Pekalongan batik industry.

The findings indicate that Green Adaptability and Circular Economy are the main drivers of Green Innovation among batik SMEs in Pekalongan City. Green Adaptability has a positive and significant effect on both Green Innovation ($\beta = 0.396$, $p < 0.001$) and Circular Economy ($\beta = 0.149$, $p < 0.001$), while Circular Economy also positively influences Green Innovation ($\beta = 0.119$, $p < 0.001$). In contrast, Green Supply Chain Management (GSCM) does not significantly affect Green Adaptability, Circular Economy, or Green Innovation. These findings suggest that sustainable innovation in batik SMEs is shaped more by firms' adaptive capabilities and circular production practices than by the implementation of green supply chain initiatives alone.

These results support Dynamic Capability Theory (Teece et al., 1997; Teece, 2007), which emphasizes that an organization's ability to adapt to environmental changes is essential for fostering innovation and maintaining long-term competitiveness. Furthermore, the positive contribution of Circular Economy reinforces previous studies (Geissdoerfer et al., 2017; Kirchherr et al., 2017), highlighting that resource efficiency and waste reduction stimulate sustainable innovation. Conversely, the insignificant effect of GSCM

suggests that green supply chain practices in batik SMEs have not yet evolved into strategic organizational capabilities, as proposed by the Resource-Based View (Barney, 1991), due to limited financial, technological, and managerial resources. These findings contribute to the sustainability literature by demonstrating that adaptive capability plays a more decisive role than GSCM in promoting Green Innovation within traditional SMEs.

The findings of this study partially support previous research on sustainability-oriented innovation. The significant positive effects of Green Adaptability on Green Innovation and Circular Economy are consistent with the studies of Teece (2007) and Jum'a et al., (2021), which emphasize that adaptive capabilities enable firms to respond effectively to environmental changes and develop sustainable innovations. Likewise, the positive relationship between Circular Economy and Green Innovation corroborates the findings of Geissdoerfer et al., (2017) and Kirchherr et al., (2017), who argue that resource efficiency, waste reduction, and material recirculation create opportunities for environmentally sustainable product and process innovation.

However, the insignificant influence of Green Supply Chain Management (GSCM) on Green Adaptability, Circular Economy, and Green Innovation contrasts with studies by Zhu et al., (2012) and Aboelmaged and Hashem (2019), which reported that GSCM positively enhances organizational innovation and environmental performance. These inconsistencies may be explained by differences in research context. While previous studies primarily examined large manufacturing firms with relatively mature sustainability systems, the present study focused on batik SMEs, which generally face limitations in financial resources, technology adoption, and managerial capabilities. Consequently, GSCM practices among batik SMEs remain largely operational rather than strategic, limiting their direct contribution to sustainable innovation. These findings suggest that organizational adaptability and internal capabilities play a more critical role than supply chain initiatives in driving Green Innovation within traditional SMEs.

An important consideration concerns the temporal dimension of the research design. Because the data were collected cross-sectionally, the study observes GSCM, CE, GA, and GI within a single period and therefore cannot establish how changes in one construct precede changes in another. The reported coefficients consequently represent associations rather than definitive causal relationships. An alternative explanation is also possible: SMEs with established Green Innovation capabilities may be better positioned to develop Green Adaptability and expand their use of circular and green supply-chain practices. Longitudinal and panel-data research would be valuable in addressing this issue by tracing the evolution of these constructs and providing stronger evidence about their temporal ordering.

Second, the study relies primarily on self-reported perceptual data collected through questionnaires from SME owners and managers. This approach may introduce response bias and social desirability bias, particularly for questions concerning environmental practices and sustainability performance. Respondents may tend to report their practices more positively than their actual implementation. In addition, collecting predictor and outcome variables from the same respondents using the same measurement method creates the potential for common method bias/common method variance. Although this potential bias cannot be confirmed without specific statistical diagnostics, it may contribute to an upward bias in some estimated relationships, particularly the relatively strong association between Green Adaptability and Green Innovation. Future studies should therefore combine perceptual measures with objective indicators of

environmental performance, such as wastewater volume and treatment performance, energy and water consumption, material efficiency, waste-recycling rates, and the proportion of environmentally friendly materials used in production.

Third, the use of purposive sampling and the concentration of respondents in batik SMEs in Pekalongan City limit the external validity of the findings. The characteristics of the Pekalongan batik industry, including its traditional production processes, supplier structures, environmental challenges, and technological constraints, may differ from those of other manufacturing sectors or regions. Consequently, the findings should not be generalized automatically to SMEs in other industries or geographical settings. Future research should employ broader samples covering different regions and sectors, as well as comparative studies between traditional and technology-oriented SMEs, to examine whether the observed relationships remain consistent across different organizational and institutional contexts.

Fourth, the study focuses on four main constructs GSCM, CE, GA, and GI and therefore does not capture all factors that may contribute to green innovation. Other variables, such as environmental commitment, green entrepreneurial orientation, digital transformation, environmental knowledge, stakeholder pressure, financial capability, technological readiness, and government support, may also influence the development of green innovation. Future research could extend the model by incorporating these variables and examining potential moderating or mediating mechanisms.

A more comprehensive understanding could be achieved in future studies through methodological triangulation, where statistical analysis is complemented by evidence from interviews, observations, and detailed case studies. Quantitative data can identify the strength and direction of relationships, while qualitative evidence can provide deeper explanations of why certain practices, particularly GSCM, have not yet developed into strategic capabilities among batik SMEs. Such methodological integration would enable future research to move beyond statistical relationships by examining the organizational processes underlying environmental practice adoption, capability development, and the emergence of green innovation in traditional SME environments.

The research agenda can be extended in three directions. First, longitudinal or panel-data evidence is needed to capture the dynamic development of sustainability-related constructs and clarify the temporal ordering of their relationships. Second, replication across different industries and geographical contexts would allow the robustness and generalizability of the findings to be evaluated. Third, future studies could enrich the conceptual model by examining factors such as environmental commitment, green absorptive capacity, green entrepreneurial orientation, digital transformation, institutional pressure, and organizational resilience as additional explanatory conditions for Green Innovation. Finally, adopting mixed-methods approaches by combining SEM with qualitative interviews or case studies would provide deeper insights into how sustainability practices are implemented and translated into innovation within traditional SMEs.

Conclusion

This study finds that Green Innovation among batik SMEs in Pekalongan is primarily associated with Green Adaptability and Circular Economy practices. Green Adaptability shows the strongest estimated association with Green Innovation and is also positively associated with Circular Economy. In contrast, Green Supply Chain Management does not show significant associations with Green Adaptability, Circular Economy, or Green Innovation. This finding suggests that GSCM practices in the studied batik SMEs have not yet developed into sufficiently

integrated strategic capabilities to support broader sustainability-oriented innovation.

The study contributes to the sustainability literature by connecting the Dynamic Capability perspective and Circular Economy with the context of traditional cultural SMEs. The findings highlight that organizational adaptability is particularly important in translating environmental challenges and sustainability practices into innovation. The study also complements the Resource-Based View by suggesting that environmental practices alone may not generate strategic value unless they are supported by organizational resources, capabilities, and effective integration.

The findings suggest that policymakers, SME development institutions, and batik entrepreneurs should prioritize the development of managerial capabilities, environmental knowledge, technological readiness, and practical circular production systems. Training in environmentally friendly production and dyeing technologies, wastewater management, resource efficiency, recycling, and sustainable product development can help SMEs strengthen their adaptive capabilities and improve their capacity for green innovation. Such interventions should be designed according to the operational and resource constraints of batik SMEs in Pekalongan.

The scope of the conclusions is bounded by several features of the research design. Observations collected at a single point in time, purposive participant selection, and reliance on respondents' perceptions constrain causal interpretation and the extent to which the results can be generalized. Such reliance on a single source of perceptual data may also create common method and response-related biases. Future investigations should address these issues through longitudinal or panel-data research, the inclusion of objective environmental-performance measures, and broader sampling across sectors and geographical contexts. Combining quantitative analysis with qualitative inquiry would provide an additional means of examining the organizational processes underlying the observed relationships. Future studies may also examine additional factors such as green entrepreneurial orientation, environmental commitment,

green absorptive capacity, digital transformation, technological readiness, and government support to provide a more comprehensive understanding of green innovation development in traditional SMEs.

Author Contributions

Willy Nurhayadi led the conceptualization, research design, conceptual framework development, data analysis, interpretation, and manuscript preparation and revision. Meutia conducted field data collection and contributed to instrument validation, data verification, and validation of the findings. Imam Abu Hanifah contributed to the literature review, theoretical development, and methodological oversight. Munawar Muchlish was responsible for advanced statistical analysis, methodological validation, manuscript editing, and critical review. All authors reviewed and approved the final manuscript and accept responsibility for its accuracy, integrity, and ethical conduct.

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Conflict Of Interest

The author declares no conflicts of interest related to the research or publication of this manuscript

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