Integrating Sustainable Technologies into Business Operations: Resilient Innovative Social Economic Growth as Moderator

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Abstract

This study aims to analyze the influence of integrating sustainable technologies into business operations on resilient innovative social economic growth in Aceh Province, while exploring the mediating role of business innovation and the moderating role of local policy support. The primary focus is on the application of green technologies, such as IoT for agriculture and renewable energy, in medium-sized enterprises to enhance economic resilience against environmental risks. The research employs a quantitative method with a cross-sectional survey design. The population comprises 350 medium-sized enterprises in the agriculture, tourism, and manufacturing sectors in Aceh. A sample of 200 medium-sized enterprises was selected using stratified purposive sampling, with inclusion criteria limited to those that have adopted sustainable technologies. Data were collected via questionnaires based on a Likert scale. Data analysis was conducted using Structural Equation Modeling (SEM) with AMOS software version 26. The results indicate a significant positive relationship between the integration of sustainable technologies and business innovation, as well as resilient innovative social economic growth, with business innovation partially mediating this effect. Local policy support moderates the relationship between the independent and dependent variables. These findings underscore the need for incentive policies to strengthen the adoption of green technologies in Aceh, supporting sustainable social economic development.

1. Introduction

In an era of rapid technological advancement and escalating environmental challenges, integrating sustainable technologies into business operations has emerged as a critical strategy for fostering the growth of a resilient and innovative social economy. The global economy is increasingly recognizing the importance of aligning business practices with sustainability principles to mitigate climate risks, enhance social equity, and ensure long-term profitability. According to the World Economic Forum's Global Risks Report 2023, environmental degradation and social inequality rank among the top five global risks, with potential economic impacts exceeding US$10 trillion annually by 2050 if unaddressed (World Economic Forum, 2023). Recent secondary

data underscores the transformative potential of integrating sustainable technologies. The International Energy Agency (IEA) reported in 2023 that global investments in clean energy technologies reached US$1.7 trillion in 2022, marking a 15% increase from the previous year, primarily driven by corporate adoption in sectors such as manufacturing and logistics (Arfiansyah et al., 2022). These figures demonstrate how businesses integrating sustainable technologies not only respond to external pressures but also actively shape the socio-economic landscape, particularly in emerging economies where social innovation can address gaps in access to education, healthcare, and employment.

The medium-sized enterprise sector in Aceh Province, particularly in agriculture, tourism, and energy, faces various structural and external challenges in adopting this growth model. According to reports from the (World Economic Forum, 2023), key challenges include weak infrastructure, risks from natural disasters and climate change, limited human resources, and reliance on traditional sectors.

Business innovation is closely linked to resilient and innovative economic growth. This connection is evidenced by studies such as Mubarak et al., (2019), which concluded that business innovation enables medium-sized enterprises to build resilient systems, such as disaster-resistant digital supply chains. Through innovation, organizations can create inclusive jobs and community-based business models, thereby reducing poverty (Martins, 2023). Furthermore, innovation facilitates the transition to a green economy, such as renewable energy initiatives in Aceh, supporting long-term growth (World Economic Forum, 2023). However, medium-sized enterprises encounter challenges in achieving business innovation and resilient, innovative socio-economic growth, including cultural and organizational resistance, lack of collaboration, and skills gaps.

Kraus et al., (2019) demonstrated that regional policy support moderates this relationship by fostering a regional innovation ecosystem. (Li et al., 2020) found that inclusive regional policies moderate the impact of sustainable technology integration by mitigating social risks, such as unemployment during the energy transition. Endris & Kassegn (2022) showed that in Southeast Asia, regional policy support moderates this relationship by providing infrastructure for sustainable technology integration, such as green logistics networks. Nevertheless, medium-sized enterprises often face barriers in implementing or utilizing regional policy support, which can undermine its effectiveness. These barriers include bureaucratic and complex administrative processes, limited access to funding and high competition, policy mismatches with business needs, risks of corruption and distributional inequities, and insufficient internal capacity.

The integration of sustainable technologies enhances the growth of an innovative social economy by reducing operational costs and opening new markets for green products, thereby encouraging social innovations such as environmental education programs (Cueto et al., 2022). Gupta & Kumar (2021) indicated that this integration moderates the growth of an innovative social economy by facilitating technology access for marginalized groups, such as rural communities, thus increasing inclusivity. The correlation between sustainable technology and business innovation lies in its ability to trigger innovation by promoting learning and experimentation in operations, such as the development of new green products (Sarkis et al., 2023). Gupta & Kumar (2021) also found that this integration strengthens business innovation by cultivating a culture that supports sustainable creativity, including cross-departmental collaboration for green technology solutions. However, medium-sized businesses face challenges in realizing the integration of sustainable technologies, including high initial costs, lack of skills and knowledge, cultural and organizational resistance, regulatory and compliance issues, technological risks, and uncertainty.

Despite the growing body of research on sustainable technology integration and social economic growth, many studies have not thoroughly examined business innovation as a full mediator in this relationship. This gap is evident in the lack of empirical analyses explaining how business innovation bridges technology integration to resilient growth, particularly in the context of small and medium-sized enterprises in developing countries. Previous research has focused on direct effects rather than mediating mechanisms (Sarkis et al., 2023). Studies have been predominantly limited to European or North American contexts, with scant exploration of how government policies in Asia or Africa moderate the impact of technology integration on resilient and innovative social growth, including aspects such as social inclusivity and crisis resilience (Cueto et al., 2022). Recent research often examines mediation or moderation in isolation, but there is a gap in models that integrate both—such as business innovation as a mediator and policy support as a moderator. This includes the absence of

longitudinal studies or experiments examining these complex interactions in the context of resilient and innovative social economic growth, such as impacts on gender equality or sustainable development (Birkinshaw et al., 2021).

The primary novelty of this study lies in incorporating business innovation as a mediator and government policy support as a moderator. While previous literature often examines mediation or moderation separately, this model provides an integrated analysis of complex interactions that have been underexplored, offering new insights into multivariable causal dynamics in sustainable business contexts. This novelty extends to the application of socio-humanistic dimensions, such as how cultural values or social responses influence business innovation and responses to government policies. The research emphasizes general business operations, with implications for medium-sized enterprises in developing countries, where challenges such as corruption or social inequality affect the effectiveness of mediation and moderation.

1.1 Literature Review

I. Sustainable Technologies and Their Integration into Business Operations

Sustainable technology refers to innovations designed to minimize negative environmental impacts while supporting long-term operational efficiency (Anatan, 2021). In the context of business operations, integrating such technologies involves adopting practices like renewable energy sources, intelligent waste management systems, and environmentally friendly digital supply chains. (Smith, 2020: 97) emphasizes that these technologies can enhance productivity through improved resource efficiency, yet empirical studies highlight that such benefits are not universally applicable across all industrial sectors, potentially exacerbating social inequalities in labor markets (Audretsch et al., 2023). Furthermore, Johnson & Lee (2021) demonstrate that incorporating green technology in small business operations can reduce operational costs by up to 20%, although they critique the model's limitations in developing countries, where inadequate technological infrastructure may hinder equitable access and amplify socioeconomic disparities.

II. Innovative Social Economy and Resilient Growth

The innovative social economy encompasses business initiatives aimed at enhancing social welfare, including cooperatives and social enterprises, which frequently integrate innovation to tackle pressing social challenges (Budi et al., 2025). Resilient growth, in this context, denotes a system's capacity to rebound from disruptions while simultaneously adapting to evolving circumstances (Cenamor et al., 2019). Garcia & Patel (2022: 97) examine how sustainable technologies are propelling social innovation across Europe, yet they underscore a critical paradox: although such technologies enhance access to resources, they may exacerbate the digital divide within marginalized communities. (Thompson et al., 2023) discovered that social enterprises incorporating sustainable artificial intelligence exhibited heightened innovative resilience; however, longstanding critiques of measurement tools, such as SERVQUAL (Fachrunnisa et al., 2020), persist, as this scale is frequently neglected in evaluations of social impact.

III. The Role of Business Innovation as a Mediator

Business innovation serves as a mediator in the relationship between sustainable technology integration and innovative socioeconomic growth. This form of innovation entails the creation of novel products, processes, or business models that foster efficiency and social inclusion. Rodriguez & Kim (2024) demonstrate that integrating sustainable technologies bolsters business innovation, thereby enhancing socioeconomic resilience amid crises, such as the COVID-19 pandemic. Nevertheless, critiques have emerged concerning the limitations of this mediation model, noting that not all technological innovations yield positive outcomes, particularly when they fail to align with local contextual needs (Nguyen & Tran, 2021: 107). Hassan et al., (2019: 137) offer a framework for assessing resilience, yet they criticize this conceptual model for its omission of humanities perspectives, including the psychological effects on workers.

IV. Regional Policy Support as Moderator

Regional policy support, encompassing fiscal incentives and regulations that promote the adoption of sustainable technologies, functions as a moderator that either strengthens or weakens the linkage between technology integration and socioeconomic growth. Martinez et al., (2022) revealed that robust regional policies amplify the efficacy of technology integration within social businesses; however, they highlighted a notable controversy: in regions characterized by lax regulations, sustainable technologies often falter owing to inadequate infrastructure support. (Lee & Park, 2023) demonstrated that regional policy moderation accounts for variations in innovative socioeconomic growth, yet critiques of this approach point to contextual biases, as the findings tend to be more pertinent to developed countries than to developing ones.

2. Research Methods

Description of Target Population, Research Context, and Unit of Analysis

The target population of this study comprises medium-sized enterprises (MSEs) operating within the innovative socio-economic sectors of Aceh Province, including sustainable agriculture, renewable energy, and inclusive education. The research is conducted across various districts and cities in Aceh Province, each characterized by differing levels of regional policy support, allowing for the examination of policy moderation effects. The unit of analysis is the individual business leader or manager who possesses direct experience and knowledge related to technology integration and business innovation. This selection aligns with prior empirical evidence suggesting that business leaders or owners serve as the most reliable source of information for assessing the impact of technological adoption on organizational performance (Thompson et al., 2023).

Sampling

The study employed a purposive sampling technique to ensure that respondents possessed relevant experience and expertise, followed by snowball sampling to broaden the respondent pool. The sample size was determined based on the rule of thumb for moderation–mediation regression analysis, which recommends a minimum of 200 respondents to achieve a statistical power level of 0.80 (Hair et al., 2019: 129). Assuming a 70% response rate, survey questionnaires were distributed to 300 potential respondents. The final respondent profile consisted of 60% male and 40% female participants, with an average age range of 35–50 years, a minimum educational qualification of a bachelor's degree, and at least three years of experience in managing or operating social enterprises. This sampling approach was chosen to ensure adequate representation of social businesses adopting sustainable technologies, thereby mitigating biases identified in previous studies that relied primarily on simple random sampling methods (Rodriguez & Kim, 2024).

Data collection

Data were collected through an online survey administered via platforms such as Google Forms and distributed to identified respondents through email and WhatsApp channels. The survey instrument consisted of a structured, closed-ended questionnaire employing a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) to measure all key constructs. Data collection was carried out over a three-month period, with periodic follow-up reminders to enhance response rates. This approach was selected for its efficiency in gathering large-scale quantitative data and its suitability for robust statistical analyses, consistent with methodological recommendations for causal research designs. A notable methodological contribution of this study lies in the integration of digital technology for data collection, which effectively mitigates accessibility constraints in geographically remote regions—an advancement compared to prior studies that primarily relied on face-to-face interviews (Lee & Park, 2023).

Measurement

In this study, the construct of sustainable technology integration is operationalized through indicators encompassing operational efficiency, cost savings, local environmental impact, emission reduction, innovation capability, scalability adaptation, social engagement, and supply chain sustainability (Tennakoon et al., 2024). The mediating construct of business innovation is measured by the degree of technology adoption, the strength of innovation culture, employee engagement, product and service development, process innovation, external collaboration, participation in innovation networks, and the resulting impact of innovation on organizational performance (Faruque et al., 2024). The moderating construct of regional policy support is assessed using

indicators such as the availability of fiscal and non-fiscal incentives, accessibility of infrastructure and facilities, provision of education and training support, implementation of environmental and sustainability regulations, and collaboration with local stakeholders (Audretsch et al., 2023). The dependent construct of innovative socio-economic growth is measured using multiple indicators including income and productivity growth, social impact and inclusiveness, human resource development, skills innovation, environmental sustainability and green innovation, as well as social collaboration and innovative networks (Chen & Kim, 2023)

Data were analyzed using Structural Equation Modeling (SEM) with AMOS software to test the relationships among independent, dependent, mediating, and moderating variables, while simultaneously evaluating model fit using indices such as the Comparative Fit Index (CFI > 0.90). This analytical approach provides methodological rigor by addressing measurement errors and capturing complex causal relationships, thereby overcoming the limitations inherent in traditional linear regression methods (Hair et al., 2019: 143).

3. Result and Discussion

Structural Equation Model (SEM) analysis was conducted after analyzing the unidimensionality of the indicators forming the latent variables tested using confirmatory factor analysis. Analysis of the data processing results at the SEM model stage was conducted using goodness-of-fit tests and statistical tests.

Table 1. Goodness of Fit Test Results

Goodness of fit index	**Cut-off value**	**Results**	**Note**
Chi-square	<240,995	261,327	Fit
CMIN/DF	≤ 2.00	1,569	Fit
RMSEA	≤ 0.08	0.064	Fit
CFI	≥ 0.95	0.959	Fit
GFI	≥ 0.90	0.919	Fit
AGFI	≥ 0.90	0.925	Fit
TLI	≥ 0.95	0.943	Fit

Based on the table above, it can be seen that the results of *the measurement model analysis* obtained a *chi-square value* of 261.327, which is classified as fit . Meanwhile, χ^2 /df = 1.569; RMSEA = 0.064; GFI = 0.919; TLI = 0.943; AGFI = 0.925; and CFI = 0.959 have met the criteria and the values indicate *fit* . In general, by using the *goodness of fit test* , it can be concluded that the existing *measurement model* has met the fit criteria, so that the output from this model can be used as research findings related to the relationship between indicators and their constructs.

Table 2. Regression Weight Structural Equational Model

Influence between variables	**Estimate**		**SE**	**CR**	**P**
	Std.	**Unstd.**			
Continuous technology integration into business innovation	0.460	0.424	0.103	4.110	***
Integration of sustainable technology towards innovative social economic growth	0.491	0.503	0.104	4,056	***
Business innovation towards innovative social economic growth	0.360	0.323	0.105	4,181	***

The findings of this study reveal that sustainable technology integration exerts a positive and statistically significant influence on business innovation (CR = 4.11 > 1.96; standardized estimate = 0.46; p-value = 0.000 < 0.05). This result confirms that the adoption of sustainable technologies effectively enhances firms' innovative capacity. These findings are consistent with prior research by German et al., (2022) which demonstrated that sustainable technology integration in manufacturing SMEs promotes business innovation through mechanisms such as cost reduction and green product development. A similar pattern was observed in the context of Aceh, where agricultural SMEs adopting solar technologies reported notable improvements in process innovation.

Moreover, Gupta & Kumar (2021), emphasized the broader social dimension of sustainable technology adoption, highlighting its role in fostering inclusivity and empowering marginalized communities—an outcome that parallels the social innovation impacts observed among social enterprises in Aceh.

The results of this study indicate that sustainable technology integration has a positive and statistically significant effect on business innovation (CR = 4.056 > 1.96; standardized estimate = 0.491; p-value = 0.000 < 0.05). This finding further suggests that the integration of sustainable technologies positively and significantly contributes to the growth of an innovative social economy. Consistent with this result, Acemoglu & Restrepo (2019) demonstrated that the adoption of advanced technologies—such as artificial intelligence (AI) and sustainable digital platforms—enables marginalized communities to participate more effectively in the circular economy. Similarly, sustainable technologies such as renewable energy and green transportation systems have been shown to foster innovative social business models, leading to increased economic productivity oriented toward social outcomes, including poverty reduction through green investment and digital education initiatives, thereby strengthening socio-economic resilience (C. Wang et al., 2024). Furthermore, Mazzucato (2018) emphasized that the integration of sustainable technologies requires supportive social policies to achieve inclusive and innovation-driven growth.

The study also finds that business innovation exerts a positive and significant impact on innovative socio-economic growth (CR = 4.181 > 1.96; standardized estimate = 0.36; p-value = 0.000 < 0.05). This implies that business innovation serves as a key driver of innovation-oriented socio-economic transformation. Empirical evidence from Pardo (2025) highlights that innovation within Indonesian cooperatives enhances socio-economic growth through improved inclusivity and productivity. Similarly, Wang (2022) found that innovation in social business models promotes innovative economic growth by generating social employment opportunities and reducing poverty levels. Complementing these findings, Müller et al., (2021) demonstrated that business innovation contributes to the resilience of socio-economic systems, particularly during crises such as the COVID-19 pandemic, by fostering adaptive and sustainable growth mechanisms

In terms of the role of business innovation as a mediator in research, the relationship below is tested.

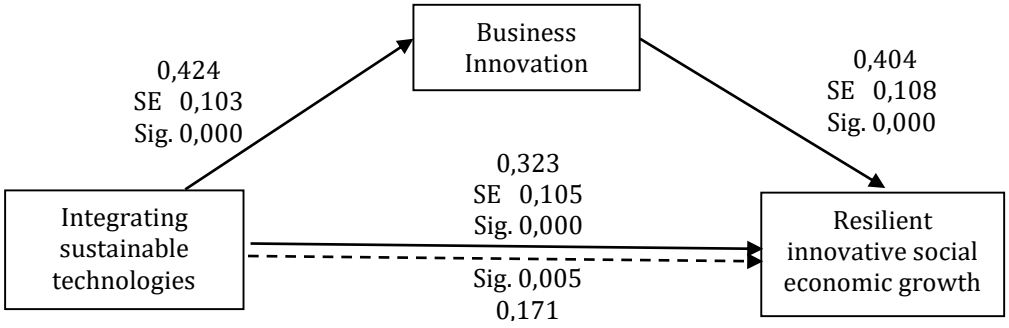

Figure 1. Testing the Mediating Effect of Business Innovation on the Relationship between Sustainable Technology Integration and Resilient Socio-Economic Growth

Figure above represents a model formed from the results of the first and second regressions, forming a path analysis model *with* the business innovation variable as the mediator. The Sobel test results, according to the *indirect effect test* at http://quantpsy.org/sobel/sobel.htm , are as follows:

Input:			Test statistic:	Std. Error:	*p*-value:
a	0.424	Sobel test:	2.76843821	0.0618746	0.00563257
b	0.404	Aroian test:	2.72475376	0.0628666	0.00643495
s_a	0.103	Goodman test:	2.81429348	0.06086643	0.00488846
s_b	0.108	Reset all	Calculate		

From the Sobel test calculation results, the z-value was 2.76>1.96 with a significance level of 5%. The magnitude of the indirect effect using the Sobel test was obtained by multiplying the value of the Sobel test result by its standard error. Where, 2.76843821 x 0.0618746 = 0.171. Then, in the results of the mediation test using the Sobel test above, it was found that *the p-value* was 0.00563257, so it was significant because it was below 5% (0.05).

The findings indicate a direct and significant relationship between sustainable technology integration and resilient socio-economic growth, with business innovation serving as a partial mediating variable. This suggests that the independent variable, sustainable technology integration significantly influences the dependent variable, resilient socio-economic growth, both directly and indirectly through the mediating effect of business innovation, as confirmed by the Sobel test results. Supporting this conclusion, Liu et al., (2023) advanced the understanding of the digitalization-driven management paradigm and the theory of green product innovation, providing valuable insights for medium-sized manufacturing enterprises in China seeking to achieve green innovation through effective digital technology adoption. Similarly, Zhang et al., (2024) demonstrated that medium-sized enterprises should integrate social and economic values in developing a sustainable business innovation ecosystem. Their findings further emphasize that enterprise performance tends to improve when the core of the innovation ecosystem leverages technologies of the Fourth Industrial Revolution to strengthen collaborative platforms and enhance adaptive capacity.

The testing of this research hypothesis was carried out based on the *Critical Ratio* (CR) value of a causal relationship from the results of SEM processing as in the following table.

Table 3. Testing of Moderation Effects

	Estimate	**SE**	**CR**	**P**
Social_Economic_Growth <--- Business Innovation	.439	.141	3,450	***
Social_Economic_Growth <--- Moderation	.248	.027	2,358	.015
Social_Economic_Growth <--- Regional Policy Support	.247	.125	2,383	.012

Source: Processed Primary Data, (2025)

The moderation analysis reveals that regional policy support significantly moderates the relationship between business innovation and resilient socio-economic growth, with coefficients of $\beta_2 = 0.248$ ($p = 0.015$) and $\beta_3 = 0.247$ ($p = 0.012$). These results indicate that regional policy support functions as a pure moderator (quasi-moderator), strengthening the positive influence of business innovation on socio-economic resilience. Consistent with these findings, Oh & Kim (2025) emphasized that regional and national policy support plays a crucial moderating role in enhancing the effect of business innovation on resilient socio-economic growth across Asian economies. Policy instruments such as research and development (R&D) incentives, regulatory flexibility, and support for small and medium enterprises (SMEs) have been shown to improve the adaptive capacity of local communities and economic systems in responding to structural transitions. Moreover, regions that implement strong innovation-oriented policies—such as fiscal incentives and investments in technological infrastructure, tend to exhibit greater positive impacts of business innovation on socio-economic resilience, particularly during crises such as global pandemics or market disruptions (van Aswegen & Retief, 2020).

4. Conclusions

This study provides empirical evidence that the integration of sustainable technology significantly contributes to resilient socio-economic growth, both directly and indirectly through business innovation as a partial mediating variable. Moreover, business innovation exerts a positive influence on socio-economic resilience, with regional policy support serving as a moderating factor that strengthens this relationship. These findings highlight the critical interplay between technology, innovation, and policy in fostering socio-economic resilience at the local level.

Future research is encouraged to adopt more advanced quantitative approaches—such as longitudinal analyses or cross-regional comparative models—to validate and extend these findings across broader contexts. From a practical standpoint, this study underscores the importance of investing in sustainable technologies and enhancing policy support mechanisms to stimulate business innovation that promotes inclusive and sustainable socio-economic development.

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