

Climate Change, Global Uncertainty, and Operational Costs: Evidence from Indonesian SMEs

Syaiful Hasani¹, Danardana Murwani¹, Sopiah¹,
Agung Winarno¹, Dinda Fatmah^{2*}

¹ Management Science Doctoral Program, Faculty of Economics and Business, State University of Malang, Malang 65145, Indonesia.

² Department of Management, Faculty of Economics, School of Economics Al-Anwar, Mojokerto 61361, Indonesia.

* Corresponding author Email: fatmah.dinda@gmail.com

* ORCID iD: 0000-0002-1839-797X

Received: 26 December 2025; Received in revised form: 8 March 2026; Accepted: 22 May 2026

Abstract

Background and Objectives: Small and Medium Enterprises (SMEs) play a crucial role in economic development and employment generation, particularly in emerging economies. In Indonesia, SMEs represent more than 99% of business entities, contribute approximately 61% of national GDP, and employ about 97% of the workforce. Despite their economic importance, SMEs are increasingly exposed to environmental and macroeconomic pressures that threaten operational sustainability. Climate change disrupts production through extreme weather events, energy price volatility, and instability in raw material supply chains. At the same time, global economic uncertainty reflected in inflationary pressures, exchange-rate volatility, and geopolitical tensions creates additional operational risks that may increase firms' cost structures. These challenges are particularly relevant for SMEs in the garment and clothing sector, which is characterized by labor intensive production and strong supply chain dependence. Although previous studies have examined environmental uncertainty and firm performance, limited research has explored the mechanisms through which climate change and global uncertainty influence SMEs' operational costs. In particular, digital technology adoption and digital financial literacy may function as adaptive capabilities that help SMEs respond to environmental turbulence, although such investments may also generate short-term adjustment costs. In addition, the role of financial inclusion in shaping these cost dynamics remains underexplored. Therefore, this study examines how climate change and global economic uncertainty influence SMEs' operational costs through the mediating roles of digital technology adoption and digital financial literacy, as well as the moderating role of financial inclusion.

Methodology: This study employs a quantitative research design using cross-sectional survey data collected from 270 owners and managers of SMEs operating in Indonesia's garment and clothing sector. Respondents were selected through purposive sampling to ensure their involvement in business operations, digital technology adoption, and financial decision-making. Data were collected using a structured questionnaire with Likert-scale indicators adapted from established studies. The main constructs include climate change exposure, global uncertainty, digital technology adoption, digital financial literacy, financial inclusion, and operational costs. The analysis also includes control variables, namely firm size, firm age, sub-sector, regional characteristics, and

input utilization. The empirical analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM), which is suitable for examining complex mediation and moderation relationships.

Key Findings: The empirical results reveal several important findings. First, climate change has a positive and significant effect on SMEs' operational costs, indicating that environmental disruptions increase production, energy, and logistics expenses. Second, both climate change and global economic uncertainty significantly stimulate the development of adaptive capabilities, particularly through increased digital technology adoption and improved digital financial literacy. Third, digital technology adoption and digital financial literacy significantly increase operational costs in the short term. This finding reflects adjustment costs associated with digital transformation, including investments in digital infrastructure, employee training, and system integration. Fourth, digital capabilities play a significant mediating role, suggesting that environmental and macroeconomic pressures influence operational costs indirectly through capability development. Finally, the moderating effect of financial inclusion is not statistically significant, indicating that access to financial services alone does not substantially alter how digital capability investments affect SMEs' operational cost outcomes.

Policy Implications: The findings offer several policy implications. First, policymakers should strengthen SME resilience by improving logistics infrastructure, promoting energy-efficient production technologies, and stabilizing supply chain systems to reduce climate-related cost pressures. Second, governments should expand SME digital transformation initiatives, including training programs in e-commerce management, digital accounting systems, and digital supply chain platforms. Third, because digital capability development requires substantial initial investment, financial policy support is needed to reduce SMEs' transitional cost burdens. Policy instruments such as tax incentives for digital technology adoption, subsidized digital infrastructure, and low-interest financing programs can facilitate SME digitalization. Strengthening digital capabilities and digital financial literacy can ultimately enhance SME resilience and support sustainable economic development under climate-related risks and global economic uncertainty.

Keywords: Climate Change; Digital Technology; Operational Costs; Financial Literacy; Indonesian SMEs

JEL Classification Codes: M21; Q54; O33; G53

1. Introduction

Small and Medium Enterprises (SMEs) are widely recognized as the backbone of Indonesia's economy. According to Statistics Indonesia (Badan Pusat Statistik [BPS], 2024), SMEs account for more than 99% of all business entities and contribute approximately 61% of Indonesia's Gross Domestic Product (GDP), while employing around 97% of the national workforce (BPS, 2024; Ministry of Cooperatives and SMEs, 2024). These figures underscore the critical role of SMEs in supporting economic growth, employment generation, and regional development across the country. In Indonesia, SMEs are legally defined under Law No. 20 of 2008 on Micro, Small, and Medium Enterprises (2008), which classifies firms based on asset ownership and annual turnover. Micro enterprises possess assets of up to IDR 50 million and annual sales of up to IDR 300 million; small enterprises have assets between IDR 50 million and IDR 500 million with annual sales of up to IDR 2.5 billion; and medium enterprises hold assets between IDR 500 million and IDR 10 billion with annual sales reaching up

to IDR 50 billion. Among the various SME sectors, the garment and batik industry plays an important role in Indonesia's manufacturing economy. The textile and apparel sector contributes substantially to manufacturing output and exports while generating employment for millions of workers, particularly within labor-intensive SMEs (Ministry of Industry, 2024). Many SMEs operate in clothing production, batik manufacturing, and related creative industries, making this sector an important driver of local economic activity and cultural heritage preservation.

However, SMEs in the clothing and batik sector are increasingly confronted with rising operational costs resulting from the combined pressures of climate change and global economic uncertainty. Climate change intensifies energy consumption, disrupts raw material supply, and increases logistics expenses through extreme weather events and supply chain instability (Hügel & Davies, 2024; Tang et al., 2024). At the same time, global uncertainties including inflation, exchange-rate volatility, and geopolitical tensions further increase production costs and weaken SME competitiveness (Hoekman et al., 2002; Martos-Pedrero et al., 2025). These challenges are exacerbated by limited digital capability and low financial literacy, which constrain firms' ability to improve efficiency and manage operational costs effectively (Lontchi et al., 2023; Nguyen et al., 2024). Although Indonesia has expanded financial inclusion through national policy initiatives and fintech development programs, the impact remains uneven due to low utilization and weak integration with digital transformation and financial literacy initiatives (Beck, 2020; Faruq et al., 2023). This issue is particularly important because SMEs must strengthen resilience and mitigate rising operational costs under increasingly uncertain environmental and economic conditions. Existing studies also provide mixed evidence regarding the effects of digitalization and financial literacy on operational efficiency (Kroh et al., 2024; Truong & Nguyen, 2024), while the moderating role of financial inclusion in shaping operational cost dynamics remains insufficiently explored (Grohmann et al., 2017).

Despite the growing literature on SME resilience and digital transformation, several important gaps remain. First, most previous studies examine digitalization or financial literacy as independent drivers of firm performance, while limited attention has been paid to how these capabilities emerge as adaptive responses to environmental shocks such as climate change and global economic uncertainty. Second, empirical findings regarding the relationship between digitalization, financial literacy, and operational costs remain inconclusive. While some studies suggest that digital transformation improves efficiency and reduces operational costs, others indicate that the early stages of digital adoption may increase operational expenditures due to investment and adjustment costs. Third, although financial inclusion has been widely discussed in development and financial economics literature, its role as a moderating factor influencing how digital capabilities affect SME operational cost dynamics remains underexplored, particularly in emerging economies.

To address these gaps, this study investigates how climate change and global uncertainty influence SMEs' operational costs through the development of digital technology adoption and digital financial literacy, while also examining the moderating role of financial inclusion. Focusing on SMEs in Indonesia's clothing and batik sector, where adaptive capacity remains relatively limited, this study contributes to the literature in three ways. First, it integrates environmental and macroeconomic pressures into a unified analytical framework explaining SMEs' operational cost dynamics. Second, it introduces digital financial literacy as a distinct capability affecting operational cost structures. Third, it extends Dynamic Capabilities Theory and

Financial Intermediation Theory by explaining how environmental pressures, digital capability development, and financial access interact in shaping SME resilience.

The findings are expected to provide valuable insights for policymakers, financial institutions, and SME practitioners in designing targeted digital training programs, strengthening financial literacy initiatives, and developing inclusive financing policies that support SME resilience. The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the conceptual framework and hypothesis development. Section 4 describes the methods and data. Section 5 reports the empirical results. Section 6 discusses the findings. Finally, Sections 7 and 8 present the conclusions and policy implications, respectively.

2. Literature Review

2.1 Climate Change and Global Uncertainty

The influence of climate change and global uncertainty on SME performance can be understood primarily through the lens of Dynamic Capabilities Theory. This theory argues that firms must continuously sense environmental changes, seize emerging opportunities, and reconfigure resources to survive under turbulent conditions (Teece, 2017). In the context of Indonesia's clothing-sector SMEs, climate volatility and global uncertainty represent major external shocks that increase production risk, disrupt supply chains, and elevate operational costs (Bloom, 2014; Schaeffer et al., 2012). SMEs possessing strong adaptive capabilities are generally better able to mitigate these pressures by adjusting their strategies, technologies, and financial practices. Empirical evidence also suggests that firms with superior dynamic capabilities are more capable of maintaining cost efficiency under environmental and market instability (Tang et al., 2024; Zhao et al., 2024).

Climate change has become an increasingly important determinant of business sustainability, particularly for SMEs operating in labor-intensive manufacturing sectors. Extreme weather events, disruptions in raw material supply, and rising energy costs can significantly affect production continuity and operating efficiency. These risks are especially relevant in developing economies where SMEs often have limited adaptive capacity and restricted access to technological and financial resources. At the same time, global economic uncertainty reflected in inflationary pressures, exchange-rate fluctuations, geopolitical tensions, and market instability further complicates business operations and increases financial vulnerability. Consequently, SMEs must continuously adapt to external pressures to sustain competitiveness and operational resilience.

2.2 Digital Technology Adoption

The adoption of digital technology among SMEs can be explained through the Diffusion of Innovation (DOI) theory and the Technology Acceptance Model (TAM). DOI explains how innovations spread within organizations based on perceived advantages and compatibility with existing practices (Feeny & Rogers, 2003), while TAM emphasizes that technology adoption is primarily driven by perceived usefulness and ease of use (Davis, 1993). These frameworks suggest that SMEs are more likely to adopt digital technologies when they perceive improvements in operational efficiency and business performance.

Under increasing climate pressure and global uncertainty, digital technologies such as e-commerce platforms, digital supply-chain systems, and electronic payment services become important mechanisms for improving operational flexibility, reducing transaction costs, and maintaining competitiveness. Digitalization also enables firms to

improve communication, manage inventory more efficiently, and respond more effectively to changing market conditions. However, digital adoption among SMEs remains constrained by several factors, including high investment costs, limited technological capability, inadequate infrastructure, and weak institutional support (Feeny & Rogers, 2003; Le et al., 2023). These constraints are particularly evident among SMEs in developing economies, where digital transformation often requires substantial organizational adjustment and resource commitment.

2.3 Financial Literacy

Financial literacy functions as an important strategic resource within the Resource-Based View (RBV) framework. RBV argues that competitive advantage depends on a firm's ability to manage valuable, rare, inimitable, and non-substitutable resources effectively (Peteraf & Barney, 2003). In this context, financial knowledge and managerial competence enable SME owners to make better decisions regarding budgeting, investment, financing, and risk management.

Improved financial literacy strengthens firms' ability to cope with external shocks such as climate risk and macroeconomic volatility by enhancing financial planning and operational decision-making. SMEs with stronger financial literacy are generally better able to allocate resources efficiently, evaluate financing alternatives, and manage liquidity pressures. Prior studies have shown that financial literacy contributes positively to operational efficiency, business sustainability, and organizational resilience, particularly among SMEs facing uncertain economic environments (Liu et al., 2024; Nguyen Thanh et al., 2024). In the digital era, digital financial literacy has become increasingly important because firms are required not only to understand conventional financial management but also to utilize digital financial services and technologies effectively.

2.4 Financial Inclusion

The role of financial inclusion can be explained through Financial Intermediation Theory, which emphasizes how access to formal financial services improves resource allocation, liquidity management, and transaction efficiency (Beck, 2020). For SMEs, broader access to banking services, digital finance, and credit facilities can reduce financing constraints, support technological investment, and improve operational performance (Ayyagari et al., 2011; Beck et al., 2005).

Financial inclusion has become increasingly important in emerging economies due to the rapid development of digital financial services and fintech platforms. Easier access to financial services may help SMEs adopt digital technologies, manage working capital, and respond more effectively to economic uncertainty. Nevertheless, the benefits of financial inclusion depend heavily on firms' managerial and financial capabilities. SMEs with limited financial literacy may not fully utilize available financial services or may face difficulties integrating financial access with operational and technological strategies. Consequently, financial inclusion alone may be insufficient to improve firm performance unless accompanied by adequate digital capability and financial knowledge (Faruq et al., 2023).

2.5 Operational Costs

The relationship between digitalization, financial capability, and operational costs can be further explained through Transaction Cost Economics (TCE). TCE argues that firms seek to minimize transaction, coordination, and monitoring costs through efficient governance mechanisms and technological solutions (Teece, 2014). Digital technologies, electronic financial services, and integrated supply-chain systems can reduce information asymmetry, improve coordination efficiency, and enhance financial

transparency, thereby lowering operational costs over time (Nguyen Thanh et al., 2024; Wang et al., 2025).

However, digital transformation may also increase operational costs in the short run due to adjustment expenses associated with technology adoption, employee training, system integration, and organizational restructuring. SMEs often face significant transitional costs before efficiency gains can be fully realized. These adjustment costs are particularly important in developing economies where SMEs may have limited technological readiness and financial resources. Consequently, the relationship between digital capability development and operational costs remains complex and may vary depending on the stage of digital adoption, organizational capacity, and external business conditions.

Overall, the literature suggests that climate change and global uncertainty increase operational pressures on SMEs, while digital technology adoption and digital financial literacy function as important adaptive capabilities that may shape operational cost dynamics. At the same time, financial inclusion may influence how effectively SMEs utilize these capabilities in responding to environmental and economic challenges.

3. Conceptual Framework and Hypotheses Development

This study examines how environmental and economic pressures influence SMEs' operational costs through capability development and financial access. The conceptual framework is primarily grounded in Dynamic Capabilities Theory, which explains how firms respond to environmental turbulence by sensing threats, seizing opportunities, and reconfiguring resources to maintain competitiveness (Teece, 2017). Complementary theoretical perspectives further strengthen the framework. The Resource-Based View (RBV) emphasizes the importance of strategic resources such as digital capabilities and managerial knowledge in enhancing firm performance (Barney, 1995), while Transaction Cost Economics (TCE) explains how technological innovation can reduce coordination and transaction costs. In addition, Financial Intermediation Theory highlights the role of financial access in supporting investment and operational efficiency (Beck, 2020). Accordingly, SMEs are expected to respond to environmental pressures by developing digital capabilities that subsequently shape operational cost dynamics.

3.1 Climate Change and Global Uncertainty on Digital Technology Adoption and Digital Financial Literacy

The relationship between environmental pressures and digital capability development can be explained through Dynamic Capabilities Theory, which emphasizes firms' ability to sense environmental changes, seize opportunities, and reconfigure resources to remain competitive under uncertainty (Teece, 2017). Climate change and global economic uncertainty increase operational volatility, supply chain disruptions, and market instability, encouraging SMEs to strengthen adaptive capabilities.

From the perspective of the Resource-Based View, digital technologies and digital financial literacy represent strategic organizational resources that improve information management, financial decision-making, and operational coordination (Barney, 1995). Under uncertain business conditions, SMEs increasingly rely on digital tools and financial knowledge to improve efficiency, reduce information asymmetry, and strengthen resilience. Empirical evidence indicates that climate risks and economic uncertainty accelerate digital transformation and financial capability development as

firms seek greater flexibility and risk-management capacity (Faruq et al., 2023; Parra-López et al., 2024).

Based on these arguments, the following hypothesis is proposed:

Hypothesis 1 (H1): Climate change and global uncertainty positively influence SMEs' digital technology adoption and digital financial literacy.

3.2 Climate Change, Global Uncertainty, and Operational Costs

The relationship between environmental pressures and rising operational costs can be explained through Dynamic Capabilities Theory and Transaction Cost Economics. Dynamic Capabilities Theory suggests that firms operating in turbulent environments must continuously adjust operational processes and resource configurations to respond to external changes (Teece, 2017). Such adjustments often generate additional coordination, monitoring, and adaptation costs.

Similarly, Transaction Cost Economics argues that environmental uncertainty increases transaction and coordination costs because firms must allocate more resources to secure supply chains, manage risks, and maintain operational continuity (Eccles & Williamson, 1987). Climate change and global economic uncertainty therefore increase operational complexity through supply chain disruptions, energy price volatility, inflationary pressures, and unstable market conditions. Previous studies confirm that climate-related risks and macroeconomic volatility increase operational expenditures through higher input prices, logistics costs, and supply chain instability (Agrawal et al., 2024; Schaeffer et al., 2012).

Accordingly, the following hypothesis is formulated:

Hypothesis 2 (H2): Climate change and global uncertainty positively influence SMEs' operational costs.

3.3 Digital Technology Adoption, Digital Financial Literacy, and Operational Costs

The relationship between digital capability development and operational costs can be explained through Dynamic Capabilities Theory and Adjustment Cost Theory. Dynamic Capabilities Theory suggests that firms must continuously develop and reconfigure internal resources to adapt to changing business environments (Teece, 2017). In this context, digital technology adoption and digital financial literacy represent organizational capabilities that improve operational coordination, financial management, and strategic decision-making.

However, Adjustment Cost Theory argues that investments in new technologies and organizational capabilities often generate short-term adjustment costs before long-term efficiency gains emerge. SMEs adopting digital systems typically incur expenditures related to technology acquisition, software implementation, employee training, and organizational restructuring. As a result, digital transformation may initially increase operational costs before improving productivity and efficiency over time.

Empirical studies support this argument by showing that digital transformation and enhanced financial literacy frequently increase operational expenditures during the early stages of implementation due to investment and adjustment requirements (Kroh et al., 2024; Nguyen Thanh et al., 2024).

Therefore, the following hypothesis is proposed:

Hypothesis 3 (H3): Digital technology adoption and digital financial literacy positively influence SMEs' operational costs.

3.4 Mediating Role of Digital Technology Adoption and Digital Financial Literacy

The relationship between environmental pressures and firms' operational outcomes can also be explained through Dynamic Capabilities Theory, which emphasizes firms' ability to develop adaptive capabilities in response to environmental turbulence (Teece, 2017). Climate change and global uncertainty increase operational risks, cost volatility, and supply chain instability, thereby encouraging firms to strengthen digital capabilities as adaptive responses.

From the Resource-Based View, digital technologies and digital financial literacy represent strategic resources that improve information processing, financial planning, and operational coordination (Barney, 1995). Prior studies indicate that climate risks and economic uncertainty accelerate digital transformation and the adoption of digital financial services as firms seek to improve operational flexibility and resilience (Abu et al., 2025; Elfaki & Ahmed, 2024).

Consequently, environmental pressures are expected to affect SMEs' operational costs indirectly through digital capability development. This leads to the following hypothesis:

Hypothesis 4 (H4): Digital technology adoption and digital financial literacy mediate the relationship between climate change, global uncertainty, and SMEs' operational costs.

3.5 Moderating Role of Financial Inclusion

The relationship between digital capabilities and operational costs may depend on firms' access to formal financial services. Financial Intermediation Theory suggests that financial systems improve resource allocation by reducing transaction costs and easing financing constraints (Alshater et al., 2021). For SMEs, financial inclusion reflected in access to banking services, digital finance, and credit facilities can influence how digital investments affect operational cost structures.

From the perspective of Dynamic Capabilities Theory, the effectiveness of capability development also depends on the availability of complementary external resources (Teece, 2017). SMEs with greater financial access may be better positioned to finance technological investments, absorb adjustment costs, and utilize digital systems more effectively. Empirical evidence also suggests that firms with broader financial access tend to achieve better operational outcomes from digital transformation initiatives (Ayyagari et al., 2011; Beck, 2020).

Therefore, the following hypothesis is proposed:

Hypothesis 5 (H5): Financial inclusion moderates the relationship between digital technology adoption, digital financial literacy, and SMEs' operational costs.

Based on the theoretical framework and the proposed hypotheses, the conceptual model of this study is presented in Figure 1.

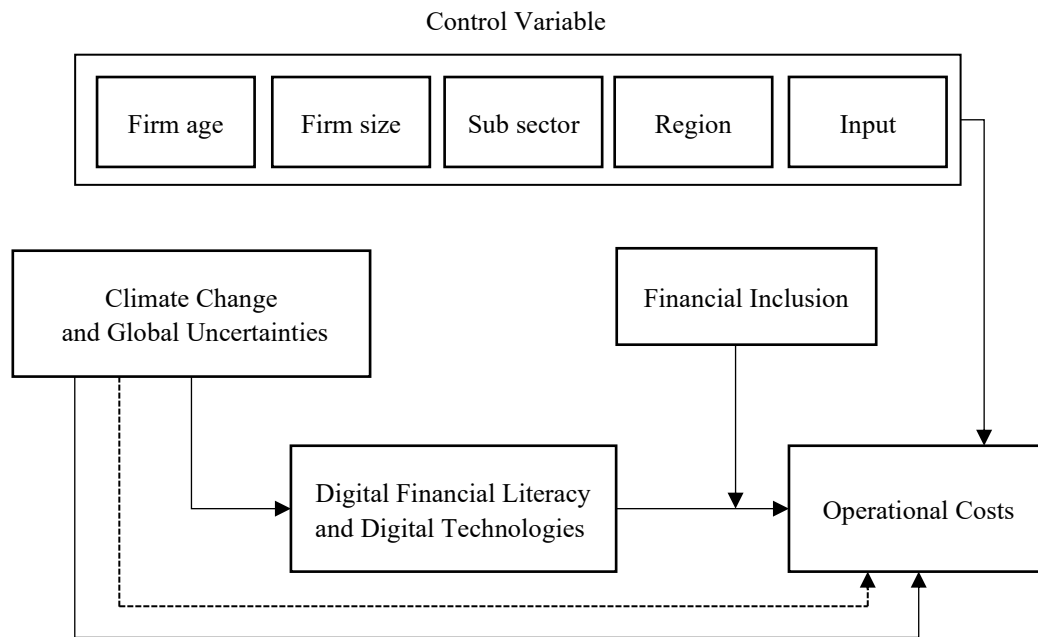


Figure 1. Conceptual Framework

Source: Authors' compilation.

4. Methods and Data

4.1 Research Design and Sampling Strategy

This study investigates the impact of climate change and global uncertainty on the operational costs of Indonesian SMEs, with particular emphasis on the mediating roles of digital technology adoption and digital financial literacy, as well as the moderating role of financial inclusion. To examine these relationships, the study employs a quantitative cross-sectional research design, which is appropriate for analyzing structural relationships among multiple constructs at a specific point in time (Harrison et al., 2020). Although cross-sectional data cannot fully capture long-term dynamic adjustments, this design is suitable for evaluating complex causal relationships within an integrated empirical framework.

The study focuses on SMEs operating in Indonesia's manufacturing sector, particularly the garment and clothing industry, which has experienced increasing operational pressures arising from climate-related disruptions and global economic volatility. These SMEs are considered highly relevant because they are labor-intensive, strongly dependent on supply chains, and relatively vulnerable to environmental and macroeconomic shocks.

Data were collected using a structured survey targeting SME owners and managers actively involved in strategic decision-making, digital technology adoption, and financial management. Respondents were selected using purposive sampling to ensure that participants possessed sufficient managerial knowledge and operational experience relevant to the study objectives. Specifically, respondents were required to be SME owners or managers aged at least 17 years, and their businesses must have operated for a minimum of two years to ensure organizational stability and adequate business experience.

The final sample consisted of 270 SMEs, which satisfies the recommended sample size requirements for Partial Least Squares Structural Equation Modeling (PLS-SEM). According to Sarstedt et al. (2022), PLS-SEM is appropriate for studies

involving relatively small samples, non-normal data distributions, and complex structural models containing mediating and moderating relationships.

4.2 Data Collection

Data were collected between September and November 2024 using a structured questionnaire consisting of Likert-scale measurement items. The survey targeted SME owners and managers in Indonesia who were directly involved in business operations and strategic decision-making. Participation in the survey was voluntary, and respondents were assured of anonymity and confidentiality throughout the data collection process. The study complied with applicable research ethics standards and institutional guidelines.

The measurement items used in this study were adapted from previously validated scales in the literature to ensure content validity and conceptual consistency. Indicators measuring climate change exposure were adapted from C. Huang et al. (2024), while global uncertainty indicators were derived from Martos-Pedrero et al. (2025). Digital technology adoption measures were adapted from Sucahyo et al. (2024), digital financial literacy indicators from Amnas et al. (2024), financial inclusion indicators from Wahyudiono et al. (2022), and operational cost indicators from Liu et al. (2023).

All perceptual variables were measured using a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Several questionnaire items were slightly modified to reflect the operational conditions and business environment of Indonesian SMEs while maintaining the conceptual meaning of the original constructs. The operational definitions, indicators, and measurement items are presented in Table 1.

Table 1. Operational Variables and Measurement Indicators

Variable	Indicator Code	Indicator Description	Sample Questionnaire Item	Scale	Source
Climate Change (CC)	CC1	Extreme weather disruption	Extreme weather disrupts our production activities.	Likert 1–5	Y. Huang et al. (2024)
	CC2	Raw material instability	Climate change affects the availability of raw materials.	Likert 1–5	
	CC3	Energy cost volatility	Climate-related conditions increase energy costs.	Likert 1–5	
	CC4	Logistics disruption	Climate risks disrupt logistics and distribution.	Likert 1–5	
	CC5	Environmental business risk	Climate change increases overall business risk.	Likert 1–5	
Global Uncertainties (GU)	GU1	Market volatility	Global uncertainty affects our market stability.	Likert 1–5	Martos-Pedrero et al. (2025)

Variable	Indicator Code	Indicator Description	Sample Questionnaire Item	Scale	Source
	GU2	Exchange-rate instability	Exchange-rate changes increase business uncertainty.	Likert 1–5	
	GU3	Inflation pressure	Inflation increases operational challenges.	Likert 1–5	
	GU4	Policy uncertainty	Policy uncertainty complicates business planning.	Likert 1–5	
	GU5	Pandemic & geopolitical shocks	Global crises affect business performance.	Likert 1–5	
	DT1	Digital production systems	We use digital systems in production activities.	Likert 1–5	
Digital Technologies (DT)	DT2	Online marketing adoption	We actively use online platforms for marketing.	Likert 1–5	Sucahyo et al. (2024)
	DT3	Digital accounting systems	Our accounting system is digitally managed.	Likert 1–5	
	FL1	Digital budgeting skills	I manage budgets using digital tools.	Likert 1–5	
Digital Financial Literacy (FL)	FL2	Online transaction knowledge	I understand digital financial transactions well.	Likert 1–5	Amnas et al., (2024)
	FL3	Digital financial planning	I use digital tools for financial planning.	Likert 1–5	
	FL4	Digital risk management	Digital tools help manage financial risks.	Likert 1–5	
	FL5	Financial app utilization	I regularly use financial applications.	Likert 1–5	
	FI1	Banking service access	We have easy access to banking services.	Likert 1–5	
Financial Inclusion (FI)	FI2	Credit accessibility	Access to business credit is easy for us.	Likert 1–5	Wahyudiono et al. (2022)
	FI3	Digital payment usage	We use digital payment services frequently.	Likert 1–5	
	FI4	Financial product diversity	We use various financial products.	Likert 1–5	
	FI5	Financial service satisfaction	We are satisfied with available financial services.	Likert 1–5	

Variable	Indicator Code	Indicator Description	Sample Questionnaire Item	Scale	Source
Operational Costs (OC)	OC1	Production cost level	Our production costs have increased.	Likert 1–5	Liu et al. (2023)
	OC2	Labor costs	Labor expenses are increasing.	Likert 1–5	
	OC3	Energy & logistics costs	Energy and logistics costs are increasing.	Likert 1–5	
	OC4	Administrative expenses	Administrative costs continue to rise.	Likert 1–5	
	OC5	Technology-related expenses	Technology investment increases operating costs.	Likert 1–5	
Firm Age (Control)	Age1	Years since establishment	Number of years of business operation.	Ratio	Behl et al. (2022)
	Age2	Business maturity stage	Business life-cycle stage.	Ordinal	
	Age3	Operational stability	Degree to which operational processes are standardized and stable over time.	Likert 1–5	
	Age4	Experience-based routines	Extent to which routines and decision-making are shaped by accumulated business experience	Likert 1–5	
Firm Size (Control)	Size1	Number of employees	Total number of employees.	Ratio	Audretsch et al. (2020)
	Size2	Annual revenue	Annual sales revenue.	Ratio	
	Size4	Market reach	Geographic scope of market served	Likert 1–5	
	Size4	Production volume	Monthly production volume.	Ratio	
	Size5	Asset ownership	Estimated business assets.	Ratio	
Sub sector (Control)	Sector1	Clothing manufacturing	Type of clothing business.	Nominal	Porter (1985)
	Sector2	Fashion services	Business category (e.g., tailoring, fashion).	Nominal	
	Sector3	Textile-based production	Engagement in textile processing or fabric-based inputs as a primary activity	Nominal	
	Sector4	Apparel retail-oriented activities	Focus on retailing, branding, or	Nominal	

Variable	Indicator Code	Indicator Description	Sample Questionnaire Item	Scale	Source
Region (Control)			distribution of apparel products.		
	Region1	Quality of transport and logistics	Our region supports smooth operational logistics.	Likert 1–5	
	Region2	Local legal and regulatory support	Local regulations facilitate our business operations.	Likert 1–5	
	Region3	Access to suppliers and customers	We can easily reach suppliers and customers in our region.	Likert 1–5	Dimaggio & Powell (1983)
Input (Control)	Region4	Regional environmental risks	Our business faces challenges due to regional climate conditions.	Likert 1–5	
	Input1	Expenses on raw materials	Raw material costs strongly influence our operational costs.	Likert 1–5	
	Input2	Wage and benefit expenses	Labor costs are a major component of our expenses.	Likert 1–5	Bartik et al. (2020)
	Input3	Utility expenditures	Energy consumption significantly affects our costs.	Likert 1–5	
	Input4	Machinery/facility upkeep	Maintenance costs contribute to overall operational costs.	Likert 1–5	

Source: Authors' compilation.

4.3 Data Analysis Techniques

This study employs Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze the proposed relationships among climate change, global uncertainty, digital capability development, financial inclusion, and operational costs. PLS-SEM is considered appropriate because the study involves a relatively complex structural model that includes both mediation and moderation effects, while also accommodating non-normal data distributions and moderate sample sizes (Hair et al., 2010).

PLS-SEM is particularly suitable for exploratory and predictive research that emphasizes variance explanation and theory development. In this study, the method is used to examine how environmental and macroeconomic pressures influence SMEs' operational costs directly and indirectly through digital technology adoption and digital financial literacy. In addition, financial inclusion is incorporated as a moderating variable affecting the relationship between digital capabilities and operational costs.

The analysis was conducted in two stages: measurement model evaluation and structural model evaluation. This two-step approach ensures that the constructs used in

the model are both reliable and valid before testing the hypothesized structural relationships.

4.4 Measurement and Structural Model Evaluation

The measurement model assessment focused on evaluating construct reliability and validity. Convergent validity was assessed using the Average Variance Extracted (AVE), where values exceeding 0.50 indicate that the construct explains more than half of the variance of its indicators (Henseler et al., 2015). Internal consistency reliability was evaluated using Composite Reliability (CR) and Cronbach's alpha, with values above 0.70 considered acceptable.

Discriminant validity was assessed using both the Fornell–Larcker criterion and the Heterotrait-Monotrait ratio (HTMT). Under the Fornell–Larcker criterion, the square root of the AVE for each construct must exceed its correlations with other constructs. For HTMT, values below 0.85 generally indicate satisfactory discriminant validity (Henseler et al., 2015).

After confirming the adequacy of the measurement model, the structural model was evaluated by examining path coefficients, coefficients of determination (R^2), effect sizes (f^2), and predictive relevance (Q^2). The significance of the structural relationships was tested using bootstrapping procedures with 5,000 resamples, following the recommendation of Hair et al. (2011). In addition, Variance Inflation Factor (VIF) values were assessed to detect potential multicollinearity among predictor constructs.

Overall, the analytical framework enables a comprehensive evaluation of the direct, indirect, and moderating relationships among environmental pressures, digital capabilities, financial inclusion, and SMEs' operational costs.

5. Results

5.1 Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics presented in this study describe the profile of the sampled respondents rather than the overall population of Indonesian SMEs. The results indicate that most respondents are male (62.6%), although female entrepreneurs and managers also constitute a substantial proportion of the sample (38.4%). This finding reflects the relatively active participation of both men and women in Indonesia's garment and clothing SME sector.

In terms of age distribution, the majority of respondents fall within the productive working-age category, with 42.7% aged between 35 and 52 years. This suggests that most SME owners and managers possess considerable managerial and business experience. Regarding educational attainment, a relatively large proportion of respondents hold bachelor's degrees (38.5%) or master's degrees (23.8%), indicating that many SME operators possess relatively strong educational backgrounds that may support digital adaptation and financial decision-making.

Most surveyed businesses have operated for more than ten years (62.3%), suggesting a relatively high level of organizational stability and business continuity. In addition, approximately 64.1% of firms employ between 10 and 49 workers, indicating that the sample primarily consists of small and medium-sized enterprises within the garment and clothing sector. Overall, these characteristics suggest that the respondents possess sufficient managerial experience and operational knowledge relevant to the study objectives.

5.2 Descriptive Statistics of Variables

Table 2 presents the descriptive statistics of the variables used in the study based on 270 observations. Overall, the results indicate moderate to relatively high levels across the major constructs examined in the analysis.

Climate change and global uncertainties exhibit the highest mean value ($M = 29.9$, $SD = 10.1$), suggesting that Indonesian SMEs experience considerable environmental and macroeconomic pressures. This finding indicates that climate-related disruptions and global economic instability are perceived as important operational challenges among SMEs in the garment and clothing sector.

Digital financial literacy and digital technologies also demonstrate relatively high mean values ($M = 23.8$, $SD = 8.5$), indicating that many SMEs have begun integrating digital capabilities into their operational and financial activities. Financial inclusion records a moderate mean value ($M = 15.8$, $SD = 6.0$), suggesting that access to financial services remains uneven among SMEs.

Operational costs display a mean value of 17.7 ($SD = 6.1$), reflecting increasing cost pressures faced by SMEs due to environmental disruptions, rising input prices, and operational adjustments associated with digital transformation. The control variables, including firm age, firm size, sub-sector, regional conditions, and input structure, exhibit noticeable variability, indicating heterogeneity among the sampled firms. This variability strengthens the robustness of the subsequent structural analysis because the sample captures diverse operational conditions across SMEs.

Table 2. Variable Statistics Description

Statistic	CCGU	DFLDT	FI	OC	FA	FS	SS	RG	IN
N	270.0	270.0	270.0	270.0	270.0	270.0	270.0	270.0	270.0
Mean	29.9	23.8	15.8	17.7	11.9	13.9	12.1	12.0	13.7
Std. Deviation	10.1	8.5	6.0	6.1	3.2	4.9	3.1	4.6	5.2
Minimum	10.0	8.0	5.0	5.0	4.0	5.0	5.0	4.0	4.0
Maximum	48.0	40.0	25.0	25.0	20.0	25.0	20.0	20.0	20.0
Sum	8069.0	6418.0	4272.0	4784.0	3221.0	3761.0	3261.0	3228.0	3699.0

Source: Authors' calculations.

Note: CCGU = Climate Change and Global Uncertainties; DFLDT = Digital Financial Literacy and Digital Technologies; FI = Financial Inclusion; OC = Operational Costs; FA = Firm Age; FS = Firm Size; SS = Sub sector; IN = Input; RG = Region.

5.3 Measurement Model Assessments

The measurement model was evaluated using indicator reliability, internal consistency reliability, convergent validity, and discriminant validity criteria. Table 3 presents the results of convergent validity, Composite Reliability (CR), and Cronbach's alpha assessments.

The results show that all factor loadings exceed the recommended threshold of 0.70 (Hair et al., 2011), ranging from 0.70 to 1.00, indicating satisfactory indicator reliability. Internal consistency reliability is also confirmed, as Cronbach's alpha, rho_A, and Composite Reliability values for all constructs exceed the recommended minimum threshold of 0.70.

For example, the climate change and global uncertainties construct demonstrates strong reliability with Cronbach's alpha of 0.90 and Composite Reliability of 1.00. Similarly, digital financial literacy and digital technologies exhibit excellent reliability indicators, with values approaching 1.00. Financial inclusion and

operational costs also display strong reliability levels, indicating that the indicators consistently measure their respective constructs.

Convergent validity is supported by Average Variance Extracted (AVE) values ranging from 0.60 to 1.00, all exceeding the recommended threshold of 0.50. These results confirm that the constructs adequately explain the variance of their corresponding indicators and that the measurement model possesses satisfactory reliability and convergent validity.

Discriminant validity was further assessed using the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT), as presented in Table 4. According to the Fornell–Larcker criterion, the square root of the AVE for each construct should exceed its correlations with other constructs. The results satisfy this requirement, indicating adequate construct distinction among the variables.

The HTMT results also support discriminant validity, as most values remain below the recommended threshold of 0.85–0.90 (Henseler et al., 2015). Although relatively high HTMT values appear between environmental pressures, digital capabilities, and operational costs, these relationships are theoretically expected because the constructs are conceptually related. Overall, the findings confirm that the measurement model demonstrates satisfactory discriminant validity and is appropriate for structural model analysis.

Table 3. Measurement Model Testing

Variable	λ	Cronbach's α	rho_A	CR	AVE
CCGU	0.9	1.0	1.0	0.7	0.7
CC1	0.7				
CC2	0.9				
CC3	0.9				
CC4	0.8				
CC5	0.8				
GU1	0.8				
GU2	0.9				
GU3	0.9				
GU4	0.8				
GU5	0.7				
DFLDT	1.0	1.0	1.0	0.8	0.8
FL1	1.0				
FL2	1.0				
FL3	1.0				
FL4	1.0				
FL5	0.9				
DT1	0.8				
DT2	0.7				
DT3	0.8				
FI	1.0	1.0	1.0	0.8	0.8
FI1	0.9				
FI2	0.9				
FI3	0.9				
FI4	0.9				
FI5	0.9				
OC	0.9	0.9	0.9	0.8	0.8

Variable	λ	Cronbach's α	ρ_A	CR	AVE
OC1	0.9				
OC2	0.9				
OC3	0.8				
OC4	0.9				
OC5	0.9				
Firm Age	0.9	1.0	1.0	0.8	0.8
Age1	0.9				
Age2	0.9				
Age3	0.9				
Age4	0.9				
Firm Size	0.9	0.9	0.9	0.8	0.8
Size1	0.8				
Size2	0.9				
Size4	0.9				
Size5	0.9				
Sub sector	0.8	0.8	0.9	0.6	0.6
Sector1	0.8				
Sector2	0.8				
Sector3	0.7				
Sector4	0.8				
Region	1.0	1.0	1.0	1.0	1.0
Region1	1.0				
Region2	1.0				
Region3	1.0				
Region4	1.0				
Input	0.9	0.9	1.0	0.8	0.8
Input1	0.9				
Input2	0.9				
Input3	0.9				
Input4	0.9				
MOD	1.0	1.0	1.0	1.0	1.0

Source: Authors' calculations.

Table 4. Discriminant Validity[illegible]

Variable	CCGU	DFLDT	FI	FS	FA	IN	MOD	OC	RG	SS
CCGU										
DFLDT	1.0									
FI	0.3	0.3								
FS	0.5	0.4	0.1							
FA	0.2	0.3	0.7	0.055						
IN	0.5	0.5	0.1	1.0	0.1					
MOD	0.1	0.1	0.1	0.1	0.1	0.1				
OC	1.0	0.9	0.2	0.5	0.2	0.6	0.1			
RG	0.5	0.561	0.2	0.8	0.5	0.9	0.1	0.5		
SS	0.5	0.570	0.1	0.9	0.1	1.0	0.1	0.6	1.0	

Source: Authors' calculations.

Note: CCGU = Climate Change and Global Uncertainties; DFLDT = Digital Financial Literacy and Digital Technologies; FI = Financial Inclusion; FS = Firm Size; FA = Firm Age; IN = Input; MOD = Moderating Financial Inclusion $\times$ Digital Financial Literacy and Digital Technologies; OC = Operational Costs; RG = Region; SS = Sub sector.

5.4 Multicollinearity Assessment

Table 5 presents the inner Variance Inflation Factor (VIF) values used to assess multicollinearity among the predictor constructs in the structural model. In PLS-SEM analysis, VIF values below 5 generally indicate that multicollinearity is not a major concern, although some studies accept values below 10 in exploratory research.

The results indicate that financial inclusion (VIF = 2.0) and the moderating interaction term between financial inclusion and digital capability (VIF = 1.0) fall within acceptable ranges, suggesting low multicollinearity. However, several variables—including climate change and global uncertainties (VIF = 14.8), digital financial literacy and digital technologies (VIF = 16.2), firm size (VIF = 10.1), and region (VIF = 20.1) exceed commonly recommended thresholds.

These elevated values suggest potential multicollinearity issues arising from overlapping variance among predictors. Nevertheless, these constructs remain theoretically important because they represent interconnected dimensions of SME resilience, operational adaptation, and environmental exposure. Similar findings have been reported in previous PLS-SEM studies involving highly related organizational and environmental constructs (Kock, 2015). Therefore, despite the presence of relatively high VIF values, the variables were retained in the model due to their strong theoretical relevance.

Table 5. Inner VIF Values

Variable	DFLDT	OC
CCGU	1.0	14.8
DFLDT		16.2
FI		2.0
FS		10.1
FA		5.5
IN		7.9
MOD		1.0
RG		20.1

Source: Authors' calculations.

5.5 Structural Model Results

The structural model results are presented in Figure 2. The model demonstrates substantial explanatory power, with Digital Financial Literacy and Digital Technologies achieving an R^2 value of 1.0 and Operational Costs achieving an R^2 value of 0.9. These results indicate that the endogenous constructs are strongly explained by the proposed predictors.

In PLS-SEM analysis, the values displayed inside the endogenous construct circles represent coefficients of determination (R^2), which indicate the proportion of variance explained by the predictor variables. Accordingly, Digital Financial Literacy and Digital Technologies, as well as Operational Costs, display R^2 values because they are predicted by other constructs within the model. In contrast, variables such as firm age, firm size, region, sub-sector, climate change and global uncertainties, and financial inclusion function as exogenous variables and therefore do not display R^2 values.

The findings further reveal that Climate Change and Global Uncertainties strongly influence Digital Financial Literacy and Digital Technologies ($\beta = 0.9$), suggesting that environmental and economic pressures stimulate SMEs to strengthen digital capabilities. In addition, Digital Financial Literacy and Digital Technologies positively influence Operational Costs ($\beta = 0.5$), while Financial Inclusion also demonstrates a positive contribution ($\beta = 0.7$). Conversely, firm size and regional factors exhibit relatively weak or negative effects, indicating heterogeneous operational conditions among SMEs.

Overall, the structural model supports the Dynamic Capabilities perspective, emphasizing that digital financial competencies and technological adaptation are important components of organizational resilience and operational sustainability under uncertain environmental and economic conditions.

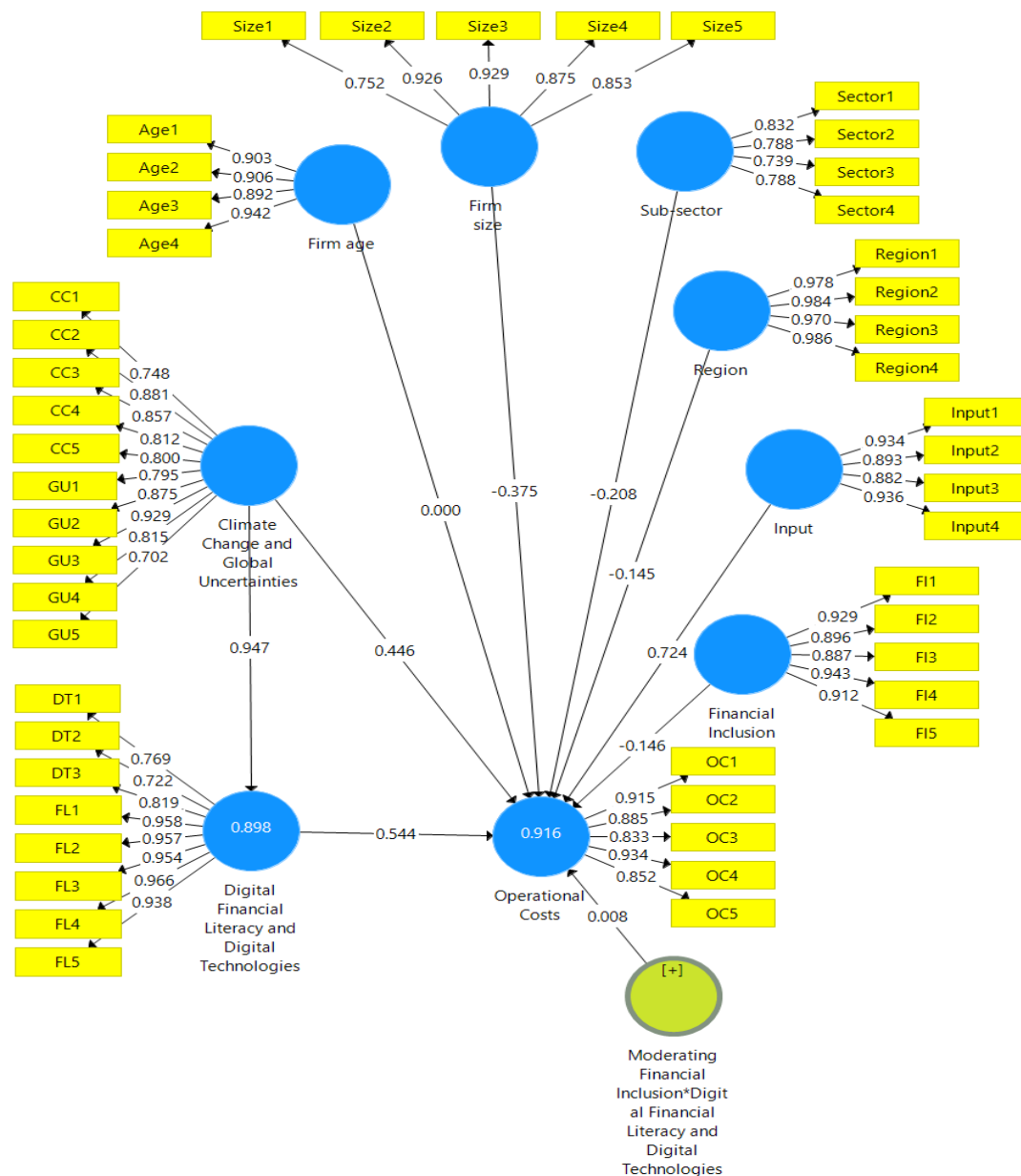


Figure 2. Structural Model

Source: Authors' calculations.

5.6 Hypothesis Testing Results

Table 6 presents the results of hypothesis testing based on the bootstrapping procedure in the PLS-SEM analysis. Following Hair et al. (2019), relationships are considered statistically significant when the t-value exceeds 1.96 and the p-value is below 0.05.

The results indicate that climate change and global uncertainties have a strong positive effect on digital financial literacy and digital technology adoption ($\beta = 0.9$, $p < 0.001$), supporting H1. This finding suggests that SMEs facing environmental disruptions and macroeconomic volatility tend to strengthen digital capabilities as adaptive strategies.

Furthermore, climate change and global uncertainties significantly increase operational costs ($\beta = 0.4$, $p < 0.001$), supporting H2. This result indicates that environmental and economic shocks intensify cost pressures through higher energy consumption, supply chain instability, logistics disruptions, and volatile input prices.

Digital financial literacy and digital technologies also demonstrate a positive and significant effect on operational costs ($\beta = 0.5$, $p < 0.001$), supporting H3. This finding reflects the short-term adjustment costs associated with digital transformation, including investments in digital infrastructure, employee training, and system integration.

The mediation analysis further reveals a significant indirect effect of climate change and global uncertainty on operational costs through digital capabilities ($\beta = 0.5$, $p < 0.001$), supporting H4. This suggests that digital capability development functions as an important transmission mechanism through which environmental pressures influence SMEs' operational cost structures.

However, financial inclusion does not significantly moderate the relationship between digital capabilities and operational costs ($\beta = 0.0$, $p = 0.7$). Therefore, H5 is not supported. This result indicates that access to financial services alone does not substantially alter the cost implications associated with digital capability development among SMEs.

Table 6. Hypothesis Testing

Variable	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values	Decision
Direct Effects						
CCGU on DFLDT	0.9	0.9	0.0	181.4	0.0	H1, Significant
CCGU on OC	0.4	0.5	0.1	5.0	0.0	H2, Significant
DFLDT on OC	0.5	0.5	0.1	5.6	0.0	H3, Significant
Indirect Effects (Mediating)						
CCGU on DFLDT on OC	0.5	0.5	0.1	5.6	0.0	H4, Significant
Moderating Effects						
MOD	0.0	0.0	0.0	0.4	0.7	H5, Not significant

Source: Authors' calculations.

5.7 Coefficient of Determination, Effect Size, and Predictive Relevance

Table 7 reports the coefficient of determination (R^2), effect size (f^2), and predictive relevance (Q^2) values for the endogenous constructs. According to Hair et al. (2019), R^2 values of 0.75 or higher indicate substantial explanatory power.

The results show that Digital Financial Literacy and Digital Technologies and Operational Costs both achieve R^2 values of 0.9, indicating that the model explains a substantial proportion of the variance in these constructs. These findings suggest that environmental pressures, digital capability development, and related predictors strongly influence SMEs' operational outcomes.

The effect size results indicate moderate explanatory effects for the exogenous variables on the endogenous constructs ($f^2 = 0.2$). In addition, the Stone–Geisser predictive relevance values ($Q^2 = 0.9$) exceed zero, confirming strong predictive relevance of the structural model.

Overall, these findings indicate that the proposed framework possesses strong explanatory and predictive capability in explaining how climate change, global uncertainty, digital capability development, and financial inclusion shape SMEs' operational cost dynamics.

Table 6. Coefficient of Determination, Effect Size, and Predictive Relevance

Variable	R ²	f ²	Q ²
DFLDT	0.9	0.2	0.9
OC	0.9	0.2	0.9

Source: Authors' calculations.

6. Discussion

This study investigates how climate change and global uncertainty influence SMEs' operational costs through digital capability development and financial inclusion. Overall, the findings suggest that environmental and macroeconomic pressures significantly shape SMEs' strategic adaptation processes, particularly through the development of digital technology adoption and digital financial literacy. The results also indicate that while digital capabilities improve adaptive capacity, they may simultaneously increase operational expenditures in the short run due to adjustment and implementation costs.

The positive relationship between climate change, global uncertainty, and digital capability development supports the Dynamic Capabilities perspective, which argues that firms respond to environmental turbulence by strengthening adaptive organizational capabilities (Teece, 2017). SMEs experiencing supply chain instability, inflationary pressures, and operational uncertainty appear more likely to adopt digital technologies and improve digital financial literacy to maintain competitiveness and operational continuity. This finding is consistent with previous studies showing that environmental shocks accelerate digital transformation and organizational innovation as firms seek greater flexibility and resilience (Tang et al., 2024; Zhao et al., 2024).

The results also demonstrate that climate change and global uncertainty significantly increase SMEs' operational costs. This finding aligns with Transaction Cost Economics and previous empirical studies suggesting that environmental instability raises coordination costs, logistics expenditures, and production risks (Eccles & Williamson, 1987; Schaeffer et al., 2012). For Indonesian garment and clothing SMEs, climate-related disruptions and global economic volatility likely increase input prices, transportation expenses, and operational uncertainty, thereby intensifying financial pressure on firms with limited adaptive resources.

Interestingly, digital technology adoption and digital financial literacy are found to positively influence operational costs. Although digital transformation is generally associated with efficiency improvement, this finding suggests that SMEs initially face substantial adjustment costs during the early stages of digital implementation. Investments in software systems, employee training, digital infrastructure, cybersecurity, and organizational restructuring may temporarily increase operational expenditures before long-term efficiency gains can be fully realized. This result supports Adjustment Cost Theory and is consistent with prior studies emphasizing the transitional burden associated with digital transformation among SMEs (Kroh et al., 2024; Nguyen Thanh et al., 2024).

The mediation analysis further reveals that digital capability development functions as an important transmission mechanism linking environmental pressures to operational costs. In other words, climate change and global uncertainty encourage SMEs to strengthen digital capabilities, which subsequently affect operational expenditures. This finding reinforces the argument that organizational adaptation is not costless. While digital transformation may enhance long-term resilience and competitiveness, SMEs often incur additional short-run expenses during the adaptation process. The result also extends Dynamic Capabilities Theory by illustrating how

environmental pressures stimulate capability reconfiguration that directly influences firms' cost structures.

However, the moderating role of financial inclusion is statistically insignificant. This finding suggests that access to financial services alone may not substantially alter the relationship between digital capability development and operational costs. One possible explanation is that many SMEs still face practical barriers in utilizing formal financial services effectively despite having access to them. Limited financial management capability, low digital readiness, or inefficient allocation of borrowed resources may reduce the effectiveness of financial inclusion in mitigating digital adjustment costs. This result partially contrasts with previous literature emphasizing the positive role of financial access in supporting SME resilience and digital transformation (Ayyagari et al., 2011; Beck, 2020).

Another possible explanation relates to the uneven quality and utilization of financial services among SMEs in developing economies. Although financial inclusion initiatives have expanded significantly in Indonesia, many SMEs may still rely heavily on informal financing mechanisms or possess limited capacity to integrate financial access with strategic digital investment. Consequently, financial inclusion may improve access to capital without necessarily improving operational efficiency or reducing adjustment costs associated with digital transformation.

The findings of this study contribute to the broader literature in several ways. First, the study integrates environmental pressures, digital capability development, and operational cost dynamics within a unified empirical framework. Previous studies often examined these relationships separately, whereas this study demonstrates their interconnected nature. Second, the study highlights the important role of digital financial literacy alongside digital technology adoption, emphasizing that technological capability alone may be insufficient without adequate financial knowledge and managerial competence. Third, the findings extend Dynamic Capabilities Theory and Financial Intermediation Theory by explaining how environmental shocks, capability development, and financial access jointly influence SME operational resilience.

From a practical perspective, the results suggest that policymakers should not only encourage SME digitalization but also provide support mechanisms that reduce short-term adjustment burdens. These may include subsidized digital training programs, technological assistance, affordable financing schemes, and capacity-building initiatives targeting digital financial literacy. Since environmental uncertainty and operational volatility are likely to persist, strengthening SMEs' adaptive capacity remains essential for sustaining competitiveness and long-term business resilience in emerging economies such as Indonesia.

7. Conclusions

This study provides evidence that climate change and global uncertainty reshape SMEs' operational structures not only through direct cost pressures but also through the strategic development of digital capabilities. The findings show that climate-related disruptions and global economic volatility significantly increase SMEs' operational costs while also encouraging digital technology adoption and digital financial literacy as adaptive responses. These results highlight the importance of digital capabilities in helping SMEs respond to environmental and macroeconomic turbulence.

The study further demonstrates that digital technology adoption and digital financial literacy function as important adaptive mechanisms for SMEs. However, these capabilities also increase operational costs during the transition process. This suggests

that digital transformation should not be viewed merely as a short-term efficiency tool, but rather as a strategic resilience investment that may involve initial adjustment costs before generating longer-term benefits. In this regard, the findings contribute to Dynamic Capabilities Theory by showing how SMEs reconfigure digital and financial capabilities in response to external uncertainty.

In addition, the results reveal that financial inclusion alone is insufficient to reduce the operational burden associated with digital transformation. Although access to financial services is important, its effectiveness depends on complementary factors such as managerial capability, technological readiness, and the ability to use financial resources productively. This finding suggests that financial inclusion must be integrated with broader capacity-building efforts to generate meaningful operational benefits for SMEs.

Overall, this study contributes to the literature by integrating climate change, global uncertainty, digital capability development, financial inclusion, and operational cost dynamics within a unified framework. The findings emphasize that strengthening SMEs' resilience requires more than expanding access to finance or encouraging technology adoption in isolation. Instead, effective SME resilience depends on the combined development of digital infrastructure, financial literacy, managerial capability, and institutional support. In increasingly uncertain environmental and economic conditions, strengthening adaptive digital ecosystems is essential for enhancing the long-term competitiveness and operational sustainability of Indonesian SMEs.

8. Policy Implications

The findings provide several targeted policy implications for SMEs in Indonesia, particularly those operating in climate-sensitive sectors such as textiles, clothing, and batik. First, the government should prioritize differentiated digital transformation programs according to SMEs' level of digital readiness. SMEs with limited digital capability require basic support, including digital financial literacy training, e-commerce onboarding, and simple digital accounting systems. In contrast, more digitally advanced SMEs should receive support for integrated supply chain management, data analytics, and climate-risk monitoring technologies to strengthen operational resilience.

Second, financial support policies should be designed according to SMEs' access to finance and adaptive capacity. SMEs with limited financial access require subsidized financing schemes, low-interest digital transformation loans, and tax incentives for technology adoption. Meanwhile, SMEs with stronger financial capacity should be encouraged through innovation grants and sustainability-linked financing mechanisms to accelerate green and digital transitions. Such support can help reduce the short-term adjustment costs associated with digital transformation while improving firms' long-term efficiency and competitiveness.

Third, policymakers should integrate climate adaptation strategies into SME development policies. This can be achieved by improving logistics infrastructure, expanding regionally inclusive digital and financial services, and establishing early-warning and business-continuity support systems for SMEs exposed to climate-related risks. These measures are particularly important for garment and batik SMEs, which often depend on stable raw material supply, reliable transportation networks, and consistent market access.

Finally, SME support programs should not treat digitalization, financial inclusion, and climate resilience as separate policy areas. Instead, these dimensions should be integrated into a coordinated SME resilience framework. Practically, SMEs should view digital capability development not merely as a technological adjustment, but as a long-term strategic investment to maintain competitiveness and operational sustainability amid increasing climate uncertainty and macroeconomic volatility. This integrated approach would help Indonesian SMEs strengthen their adaptive capacity, reduce vulnerability to external shocks, and support sustainable economic development.

9. Acknowledgement

The authors would like to express their sincere gratitude to the owners and employees of clothing SMEs in Indonesia for their cooperation and willingness to participate in this study by completing the questionnaire. Their valuable contributions were essential to the successful completion of this research.

10. Ethics Statement

This study involved human participants through a questionnaire survey/interviews. The study was reviewed and granted exemption from formal ethics approval by the Institute for Research and Community Service (LPPM), STIE Al-Anwar Mojokerto, approval number/reference 010/073094/LPPM/PL/IX/2025, dated 1 September 2025. Participation was voluntary, informed consent was obtained from all participants, and all responses were anonymized before analysis.

11. References

- Abu, N., da Silva, F. P., & Vieira, P. R. (2025). Government support for SMEs in the fintech era: Enhancing access to finance, survival, and performance. *Digital Business*, 5(1), 100099. <https://doi.org/10.1016/j.digbus.2024.100099>
- Agrawal, R., Agrawal, S., Samadhiya, A., Kumar, A., Luthra, S., & Jain, V. (2024). Adoption of green finance and green innovation for achieving circularity: An exploratory review and future directions. *Geoscience Frontiers*, 15(4), 101669. <https://doi.org/10.1016/j.gsf.2023.101669>
- Alshater, M. M., Hassan, M. K., Khan, A., & Saba, I. (2021). Influential and intellectual structure of Islamic finance: A bibliometric review. *International Journal of Islamic and Middle Eastern Finance and Management*, 14(2), 339–365. <https://doi.org/10.1108/IMEFM-08-2020-0419>
- Amnas, M. B., Selvam, M., & Parayitam, S. (2024). FinTech and financial inclusion: Exploring the mediating role of digital financial literacy and the moderating influence of perceived regulatory support. *Journal of Risk and Financial Management*, 17(3), 108. <https://doi.org/10.3390/jrfm17030108>
- Audretsch, D. B., Belitski, M., Caiazza, R., & Lehmann, E. E. (2020). Knowledge management and entrepreneurship. *International Entrepreneurship and Management Journal*, 16(2), 373–385. <https://doi.org/10.1007/s11365-020-00648-z>
- Ayyagari, M., Demirgüç-Kunt, A., & Maksimovic, V. (2011). Firm innovation in emerging markets: The role of finance, governance, and competition. *Journal of Financial and Quantitative Analysis*, 46(6), 1545–1580. <https://doi.org/10.1017/S0022109011000378>

- Statistics Indonesia (BPS). (2024). *Statistical Yearbook of Indonesia 2024*. Jakarta: BPS-Statistics Indonesia.
<https://www.bps.go.id/en/publication/2024/02/28/c1bacde03256343b2bf769b0/statistical-yearbook-of-indonesia-2024.html>
- Barney, J. B. (1995). Looking inside for competitive advantage. *Academy of Management Executive*, 9(4), 49–61.
<https://doi.org/10.5465/ame.1995.9512032192>
- Bartik, A. W., Bertrand, M., Cullen, Z., Glaeser, E. L., Luca, M., & Stanton, C. (2020). The impact of COVID-19 on small business outcomes and expectations. *Proceedings of the National Academy of Sciences*, 117(30), 17656–17666. <https://doi.org/10.1073/pnas.2006991117>
- Beck, T. (2020). *Fintech and financial inclusion: Opportunities and pitfalls* (ADB Working Paper No. 1165). Asian Development Bank Institute.
<https://www.adb.org/publications/fintech-financial-inclusion-opportunities-pitfalls>
- Beck, T., Demirgüç-Kunt, A., & Maksimovic, V. (2005). Financial and legal constraints to growth: Does firm size matter? *The Journal of Finance*, 60(1), 137–177. <https://doi.org/10.1111/j.1540-6261.2005.00727.x>
- Behl, A., Gaur, J., Pereira, V., Yadav, R., & Laker, B. (2022). Role of big data analytics capabilities to improve sustainable competitive advantage of MSME service firms during COVID-19: A multi-theoretical approach. *Journal of Business Research*, 148, 378–389.
<https://doi.org/10.1016/j.jbusres.2022.05.009>
- Bloom, N. (2014). Fluctuations in uncertainty. *Journal of Economic Perspectives*, 28(2), 153–176. <https://doi.org/10.1257/jep.28.2.153>
- Davis, F. D. (1993). User acceptance of information technology: System characteristics, user perceptions and behavioral impacts. *International Journal of Man-Machine Studies*, 38(3), 475–487.
<https://doi.org/10.1006/imms.1993.1022>
- DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, 48(2), 147–160. <https://doi.org/10.2307/2095101>
- Eccles, R. G., & Williamson, O. E. (1987). The economic institutions of capitalism: Firms, markets, relational contracting. *Administrative Science Quarterly*, 32(4), 602. <https://doi.org/10.2307/2392889>
- Elfaki, K. E., & Ahmed, E. M. (2024). Digital technology adoption and globalization innovation implications on Asian Pacific green sustainable economic growth. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(1), 100221. <https://doi.org/10.1016/j.joitmc.2024.100221>
- Faruq, M. O., Akter, T., & Mizanur Rahman, M. (2023). Does intellectual capital drive bank's performance in Bangladesh? Evidence from static and dynamic approach. *Heliyon*, 9(7), e17656.
<https://doi.org/10.1016/j.heliyon.2023.e17656>
- Feeny, S., & Rogers, M. (2003). Innovation and performance: Benchmarking Australian firms. *Australian Economic Review*, 36(3), 253–264.
<https://doi.org/10.1111/1467-8462.00285>
- Grohmann, A., Klühs, T., & Menkhoff, L. (2017). Does financial literacy improve financial inclusion? Cross-country evidence. *SSRN Electronic Journal*.
<https://doi.org/10.2139/ssrn.3034178>

- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Prentice Hall.
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice*, 19(2), 139–151. <https://doi.org/10.2753/MTP1069-6679190202>
- Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, 31(1), 2–24. <https://doi.org/10.1108/EBR-11-2018-0203>
- Harrison, R. L., Reilly, T. M., & Creswell, J. W. (2020). Methodological rigor in mixed methods: An application in management studies. *Journal of Mixed Methods Research*, 14(4), 473–495. <https://doi.org/10.1177/1558689819900585>
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115–135. <https://doi.org/10.1007/s11747-014-0403-8>
- Hoekman, B. M., Mattoo, A., & English, P. (2002). *Development, trade, and the WTO: A handbook*. World Bank.
- Huang, C., Wang, C., Rani, T., & Rehman, S. A. U. (2024). Digitalization's role in shaping climate change, renewable energy, and technological innovation for achieving sustainable development in top Asian countries. *Energy & Environment*, 37(3). <https://doi.org/10.1177/0958305X241258799>
- Huang, Y., Xu, Y., Zhang, J., Long, Z., Qian, Z., Liu, W., & Chen, L. (2024). Research on factors influencing the academic entrepreneurial ability of teachers in the digital age: Evidence from China. *Heliyon*, 10(2), e24152. <https://doi.org/10.1016/j.heliyon.2024.e24152>
- Hügel, S., & Davies, A. R. (2024). Expanding adaptive capacity: Innovations in education for place-based climate change adaptation planning. *Geoforum*, 150, 103978. <https://doi.org/10.1016/j.geoforum.2024.103978>
- Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of E-Collaboration*, 11(4), 1–10. <https://doi.org/10.4018/ijec.2015100101>
- Kroh, J., Globocnik, D., Schultz, C., Holdhof, F., & Salomo, S. (2024). Micro-foundations of digital innovation capability: A mixed-method approach to develop and validate a multi-dimensional measurement instrument. *Technological Forecasting and Social Change*, 198, 122942. <https://doi.org/10.1016/j.techfore.2023.122942>
- Government of Indonesia. (2008). *Law No. 20 of 2008 concerning Micro, Small, and Medium Enterprises*. Retrieved from <https://peraturan.bpk.go.id/Details/39653/uu-no-20-tahun-2008>.
- Le, D. V., Le, H. T. T., Pham, T. T., & Vo, L. V. (2023). Innovation and SMEs performance: Evidence from Vietnam. *Applied Economic Analysis*, 31(92), 90–108. <https://doi.org/10.1108/AEA-04-2022-0121>
- Liu, F., Yu, Y., Fang, Y., Zhu, M., Shi, Y., & Xiao, S. (Simon). (2024). Lean strategy in SMEs: Inventory leanness, operational leanness, and financial performance. *The Asian Journal of Shipping and Logistics*, 40(2), 109–117. <https://doi.org/10.1016/j.ajsl.2024.02.003>
- Liu, J., Zhou, K., Zhang, Y., & Tang, F. (2023). The effect of financial digital transformation on financial performance: The intermediary effect of

- information symmetry and operating costs. *Sustainability*, 15(6), 5059. <https://doi.org/10.3390/su15065059>
- Lontchi, C. B., Yang, B., & Shuaib, K. M. (2023). Effect of financial technology on SMEs performance in Cameroon amid COVID-19 recovery: The mediating effect of financial literacy. *Sustainability*, 15(3), 2171. <https://doi.org/10.3390/su15032171>
- Martos-Pedrero, A., Cortés-García, F. J., Abad-Segura, E., & Belmonte-Ureña, L. J. (2025). Internationalization, innovation, and resilience: Financial performance of agricultural cooperatives in southeastern Spain's rural economy. *Journal of Rural Studies*, 117, 103682. <https://doi.org/10.1016/j.jrurstud.2025.103682>
- Ministry of Cooperatives and SMEs Republic of Indonesia. (2024). *Official statistics and development information on Micro, Small, and Medium Enterprises (MSMEs)*. Jakarta: Ministry of Cooperatives and SMEs Republic of Indonesia. Retrieved from <https://kemenkopukm.go.id/>.
- Ministry of Industry Republic of Indonesia. (2024). *Textile and apparel industry grows expansively due to exports*. Jakarta: Ministry of Industry. Retrieved from <https://kemenperin.go.id/>.
- Nguyen, P. H., Thi Nguyen, L. A., Thi Nguyen, T. H., & Vu, T. G. (2024). Exploring complexities of innovation capability in Vietnam's IT firms: Insights from an integrated MCDM model-based grey theory. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(3), 100328. <https://doi.org/10.1016/j.joitmc.2024.100328>
- Nguyen Thanh, B., Son, H. X., & Vo, D. T. H. (2024). Blockchain: The economic and financial institution for autonomous AI? *Journal of Risk and Financial Management*, 17(2), 54. <https://doi.org/10.3390/jrfm17020054>
- Parra-López, C., Ben Abdallah, S., Garcia-Garcia, G., Hassoun, A., Sánchez-Zamora, P., Trollman, H., Jagtap, S., & Carmona-Torres, C. (2024). Integrating digital technologies in agriculture for climate change adaptation and mitigation: State of the art and future perspectives. *Computers and Electronics in Agriculture*, 226, 109412. <https://doi.org/10.1016/j.compag.2024.109412>
- Peteraf, M. A., & Barney, J. B. (2003). Unraveling the resource-based tangle. *Managerial and Decision Economics*, 24(4), 309–323. <https://doi.org/10.1002/mde.1126>
- Porter, M. E. (1985). *Competitive advantage: Creating and sustaining superior performance*. Free Press.
- Sarstedt, M., Ringle, C. M., & Hair, J. F. (2022). Partial least squares structural equation modeling. In C. Homburg, M. Klarmann, & A. Vomberg (Eds.), *Handbook of market research* (pp. 587–632). Springer. https://doi.org/10.1007/978-3-319-57413-4_15
- Schaeffer, R., Szklo, A. S., Pereira de Lucena, A. F., Moreira Cesar Borba, B. S., Pupo Nogueira, L. P., Fleming, F. P., Troccoli, A., Harrison, M., & Boulahya, M. S. (2012). Energy sector vulnerability to climate change: A review. *Energy*, 38(1), 1–12. <https://doi.org/10.1016/j.energy.2011.11.056>
- Sucahyo, U. S., Damayanti, T. W., & Supramono, S. (2024). Unlocking success: Nexus between entrepreneurial orientation and financial performance in culinary MSMEs. *Journal of Economics, Business, and Accountancy Ventura*, 27(1), 1–13. <https://doi.org/10.14414/jebav.v27i1.4432>
- Tang, H., Zhu, J., Li, N., & Wu, W. (2024). Impact of enterprise supply chain digitalization on cost of debt: A four-flows perspective analysis using

- explainable machine learning methodology. *Sustainability*, 16(19), 8702. <https://doi.org/10.3390/su16198702>
- Teece, D. J. (2014). A dynamic capabilities-based entrepreneurial theory of the multinational enterprise. *Journal of International Business Studies*, 45(1), 8–37. <https://doi.org/10.1057/jibs.2013.54>
- Teece, D. J. (2017). Dynamic capabilities and digital platform lifecycles. In J. Furman, A. Gawer, B. S. Silverman, & S. Stern (Eds.), *Entrepreneurship, innovation, and platforms* (Vol. 37, pp. 211–225). Emerald Publishing Limited. <https://doi.org/10.1108/S0742-332220170000037008>
- Truong, B. T. T., & Nguyen, P. V. (2024). Driving business performance through intellectual capital, absorptive capacity, and innovation: The mediating influence of environmental compliance and innovation. *Asia Pacific Management Review*, 29(1), 64–75. <https://doi.org/10.1016/j.apmrv.2023.06.004>
- Wahyudiono, T., Rochim, F., & Iswanto, J. (2022). Economic policy from the perspective of siyasah syar'iyah: A case study of Islamic banks. *International Journal of Health, Economics, and Social Sciences (IJHESS)*, 4(4), 325–334. <https://doi.org/10.56338/ijhess.v4i4.6629>
- Wang, X., Li, Y., Fu, C., & Yue, Z. (2025). Does CEO competence affect enterprises' financial performance? *International Review of Economics & Finance*, 99, 104001. <https://doi.org/10.1016/j.iref.2025.104001>
- Zhao, F., Zhu, H., & Chen, Y. (2024). Due responsibility and true responsibility: A moderated-mediation model linking green-harmonious human resource practice to employee organizational citizenship behavior. *Asia Pacific Journal of Human Resources*, 62(2). <https://doi.org/10.1111/1744-7941.12399>