

Digital financial literacy and inclusion for sustainable economic performance: The mediating role of technology adoption



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ABSTRACT

Rural micro-enterprises often face structural challenges in achieving sustainable economic performance, despite increased access to digital financial services. Although digital financial literacy and digital financial inclusion are expected to improve economic sustainability, their effectiveness depends on the actual adoption of digital technologies in business activities. This study examines the effects of digital financial literacy and digital financial inclusion on sustainable economic performance, with technology adoption acting as a mediating factor. Based on the Technology Acceptance Model, the study assumes that financial capability and access influence sustainability outcomes through technology adoption behavior. Data were collected from 396 rural micro-entrepreneurs in Kabupaten Deli Serdang, Indonesia, using a structured survey, and were analyzed through Partial Least Squares Structural Equation Modeling (PLS-SEM). The findings show that digital financial literacy and digital financial inclusion have significant positive effects on sustainable economic performance. Technology adoption has the strongest direct effect on sustainability and significantly mediates the relationship between digital financial literacy and sustainable economic performance. Furthermore, the study identifies a significant sequential mediation effect, in which digital financial literacy improves digital financial inclusion, which then increases technology adoption and enhances sustainability outcomes. These findings suggest that digital financial literacy and digital financial inclusion act as enabling factors, while sustainable economic performance is mainly achieved when digital financial services are actively adopted and integrated into daily business operations.

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1. Introduction

The expansion of digital financial services has significantly transformed the operational and financial practices of micro and small enterprises, enabling new forms of transaction management, financial access, and business coordination, accessing financial resources, and managing business operations (Ozili, 2021; WB, 2022). Across developing economies, digital finance encompassing mobile payments, digital banking, and fintech-based financial services has been widely promoted as a

strategic instrument to enhance financial inclusion and support sustainable economic development (Hasan et al., 2024; Ozili, 2021; WB, 2022). In this context, digital financial literacy and digital financial inclusion are increasingly emphasized by policymakers as critical foundations for strengthening the long-term viability of micro-enterprises, particularly in rural areas where access to conventional financial services remains limited (OECD, 2020).

Despite these expectations, empirical evidence suggests that the relationship between digital finance and sustainable economic performance is not always linear (Ozili, 2021; Sun and Tang, 2022; Xi and Wang, 2023). Digital financial literacy equips individuals with the capability to evaluate digital financial tools, assess associated risks, and make strategic financial decisions that support business sustainability (Chhillar et al., 2024; Choung et al., 2023; Lusardi and Mitchell, 2017; 2023). However,

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several studies indicate that financial knowledge alone does not automatically translate into improved economic outcomes, especially in contexts characterized by limited infrastructure and institutional constraints (Feng et al., 2024; Lyons and Kass-Hanna, 2021). This condition is particularly evident in rural areas, where micro-entrepreneurs may possess basic digital financial knowledge yet remain unable to transform that knowledge into productive economic behavior (Wang and Fu, 2022; Zhou et al., 2025).

In Indonesia, this challenge is especially pronounced. National surveys consistently report improvements in financial literacy alongside persistent gaps in financial inclusion, with disparities most visible in rural and semi-rural regions. Rural micro-enterprises predominantly operated by farmers, fishers, and household-based entrepreneurs play a vital role in local economic development, employment creation, and poverty reduction (Amoah et al., 2022). Nevertheless, these enterprises often struggle to achieve sustainable economic performance, as reflected in income instability, limited business growth, and vulnerability to economic shocks (Ozili, 2021; Sun and Tang, 2022). Although digital finance is frequently positioned as a solution to these challenges, empirical evidence on its effectiveness in fostering long-term economic sustainability among rural micro-enterprises remains fragmented (Inoue, 2024; Tay et al., 2022).

Most prior studies on digital finance and firm performance have focused on urban micro, small, and medium-sized enterprises or formal business sectors (Johri et al., 2024; Liu et al., 2023; Zheng and Bu, 2024). These studies generally report positive associations between digital financial literacy, access to financial services, and short-term performance indicators such as sales growth or profitability (Affandi et al., 2024; Febriansyah et al., 2024; Frimpong et al., 2022). However, this stream of literature often assumes that increased literacy and access will naturally lead to better economic outcomes. Such an assumption overlooks an important behavioral mechanism: The actual adoption and use of digital technologies in daily business activities (Musa et al., 2024). Prior studies indicate that financial inclusion, fintech, and e-commerce improve SME performance (Khairani et al., 2025), but pay limited attention to technology adoption as a mechanism for sustainable outcomes in rural contexts.

This study argues that technology adoption represents a central mechanism through which digital financial literacy and digital financial inclusion influence sustainable economic performance. Drawing on the Technology Acceptance Model (Davis, 1989; Venkatesh and Davis, 2000), technology adoption reflects individuals' willingness and ability to accept and use digital technologies based on perceived usefulness and ease of use. In the context of digital finance, technology adoption refers to the actual use of digital

payment systems, mobile banking applications, and fintech-based tools in managing business transactions and financial activities (Ambarwati et al., 2024; Gunawan et al., 2023). Without such adoption, digital financial literacy and inclusion may remain passive resources with limited economic impact (Lyons and Kass-Hanna, 2021; Prasetyani et al., 2025).

From this perspective, digital financial inclusion functions as an enabling condition rather than a direct driver of sustainable economic performance (Ozili, 2018; Tay et al., 2022). It provides access to digital financial services and supporting infrastructure, while technology adoption determines whether these opportunities are translated into concrete economic practices (Nugraha et al., 2022; Thathsarani and Jianguo, 2022).

Empirical evidence increasingly suggests that access to digital financial services alone is insufficient; meaningful economic benefits emerge only when users actively adopt and integrate digital technologies into their routine business operations (Setiawan et al., 2025; Suri and Jack, 2016). Accordingly, technology adoption is expected to mediate the relationship between digital financial literacy, digital financial inclusion, and sustainable economic performance (Ratnawati et al., 2025; Tandilino et al., 2025).

Despite its importance, empirical research explicitly examining technology adoption as a mediating mechanism in rural micro-enterprise contexts remains limited (Prasetyani et al., 2025; Wu and Peng, 2024). Existing studies tend to analyze digital financial literacy, financial inclusion, or technology use in isolation, with insufficient attention to their sequential and interrelated effects (Gumilar et al., 2024). Moreover, sustainable economic performance, capturing income stability, business continuity, and resilience to economic shocks, has received far less attention than short-term financial performance indicators, particularly in rural and developing-country settings (Barbier and Markandya, 1990; Ozili, 2021).

To address these gaps, this study investigates the effects of digital financial literacy and digital financial inclusion on sustainable economic performance, with technology adoption serving as a mediating variable. Focusing on rural micro-enterprises in Kabupaten Deli Serdang, Indonesia, the study employs a quantitative approach using structural equation modeling with partial least squares (SEM-PLS) (Sarstedt et al., 2021). By siting the analysis within a rural context, this study provides context-specific evidence on how digital finance and technology adoption jointly shape sustainable economic outcomes beyond urban environments (Wang and Fu, 2022; Zhou et al., 2025).

This study contributes to the literature in three key ways. First, it provides empirical evidence that digital financial literacy and digital financial inclusion alone are insufficient to ensure sustainable

economic performance among rural micro-enterprises (Ozili, 2021; Tay et al., 2022). Second, it identifies technology adoption as a critical mechanism that transforms financial knowledge and access into sustainable economic outcomes (Davis, 1989; Nugraha et al., 2022; Venkatesh and Davis, 2000).

Third, by focusing on rural micro-entrepreneurs in Indonesia, this study enriches the limited body of evidence from developing and rural contexts, offering insights relevant for policymakers, financial institutions, and development practitioners seeking to promote inclusive and sustainable rural economies (WB, 2023).

2. Literature review and hypothesis development

2.1. Literature review

2.1.1. Digital financial literacy

Digital financial literacy refers to individuals' ability to understand, evaluate, and effectively use digital financial products and services, including mobile payments, digital banking, and fintech platforms. It extends traditional financial literacy by incorporating digital skills, technological awareness, and the capacity to manage financial decisions in technology-mediated environments (OECD, 2020). In developing economies, digital financial literacy is increasingly viewed as a foundational capability that enables individuals and micro-entrepreneurs to participate meaningfully in the digital financial ecosystem (Choung et al., 2023; Lusardi and Mitchell, 2017).

Prior studies consistently demonstrate that higher levels of digital financial literacy improve financial awareness, risk assessment, and decision-making quality among individuals and small business owners (Chhillar et al., 2024; Grohmann et al., 2018; Lusardi and Mitchell, 2023). In the context of micro and small enterprises, digital financial literacy has been associated with better financial planning, more efficient transaction management, and increased confidence in using digital financial services (Kusumawardhani et al., 2023). These competencies are particularly relevant for rural micro-enterprises, where formal financial education and access to professional financial advice are often limited (Xu et al., 2024).

However, empirical evidence also indicates that digital financial literacy alone does not guarantee improved economic performance. Several studies report that although individuals may possess adequate financial knowledge, structural constraints such as limited digital infrastructure, weak institutional support, and restricted market access can hinder the translation of knowledge into tangible economic outcomes (Lyons and Kass-Hanna, 2021). This suggests that digital financial literacy functions as a necessary but insufficient condition for achieving sustainable economic performance, particularly in rural and underserved contexts.

2.1.2. Digital financial inclusion

Digital financial inclusion reflects the extent to which individuals and enterprises can access and effectively utilize financial services through digital platforms, thereby enabling participation in formal financial systems. It encompasses access to digital payment systems, mobile banking, digital credit, savings instruments, and fintech-based financial solutions that reduce transaction costs and geographical barriers (WB, 2023). For micro-enterprises, especially in rural areas, digital financial inclusion is often promoted as a mechanism to overcome long-standing exclusion from traditional banking services (Tay et al., 2022).

Empirical studies largely support the positive role of digital financial inclusion in enhancing business operations and economic participation. Increased access to digital financial services has been linked to improved transaction efficiency, greater financial flexibility, and enhanced business resilience (Sun and Tang, 2022; Xi and Wang, 2023). In the Indonesian context, digital financial inclusion has been shown to facilitate MSME development by expanding access to payments, financing, and formal financial records (Affandi et al., 2024; Febriansyah et al., 2024).

Nevertheless, the literature also highlights important limitations. Access to digital financial services does not automatically result in sustained economic benefits if usage remains superficial or irregular (Ozili, 2021; Thatsarani and Jianguo, 2022). In rural areas, digital financial inclusion may be constrained by low service quality, limited digital trust, and insufficient user capability, leading to underutilization of available financial services (Wang and Fu, 2022; Zhou et al., 2025). These findings suggest that inclusion without effective utilization may yield limited economic impact.

2.1.3. Technology adoption

Technology adoption represents the behavioral process through which individuals or organizations integrate digital tools into their routine operational and financial activities. The Technology Acceptance Model (TAM) posits that perceived usefulness and perceived ease of use are primary determinants of individuals' intention to adopt and use technology (Mujalli et al., 2024). In the context of digital finance, technology adoption involves the routine use of digital payment platforms, mobile banking applications, and fintech tools to manage business transactions and financial activities (Gunawan et al., 2023).

Prior research emphasizes that technology adoption plays a pivotal role in determining whether digital financial resources generate meaningful economic outcomes. Studies on SMEs and micro-enterprises demonstrate that the adoption of digital technologies enhances operational efficiency, improves financial transparency, and supports business sustainability (Ambarwati et al., 2024;

Nugraha et al., 2022). Conversely, limited adoption can render digital financial access ineffective, even when infrastructure and services are available (Lyons and Kass-Hanna, 2021).

In rural contexts, technology adoption is influenced by multiple factors, including digital skills, perceived risks, social norms, and institutional support (Prasetyani et al., 2025; Wu and Peng, 2024). These factors highlight the behavioral dimension of digital finance, suggesting that adoption represents a critical mechanism that links financial knowledge and access to actual economic practices.

2.1.4. Sustainable economic performance of rural micro-enterprises

Sustainable economic performance encompasses long-term economic stability, resilience, and continuity, rather than focusing solely on short-term financial indicators such as sales or profit growth. It encompasses income stability, business continuity, adaptive capacity, and resilience to economic shocks (Barbier and Markandya, 1990). For rural micro-enterprises, sustainable economic performance is closely tied to livelihood security, long-term viability, and the ability to withstand market and environmental uncertainties.

Empirical studies indicate that rural micro-enterprises often face structural vulnerabilities, including fluctuating incomes, limited market integration, and exposure to economic shocks. While digital finance has been promoted as a tool to enhance sustainability, evidence suggests that its impact depends on how effectively financial knowledge and access are translated into productive economic behavior (Ozili, 2021; Inoue, 2024).

2.1.5. Technology adoption as a mediating mechanism

The literature increasingly recognizes technology adoption as a mediating mechanism linking digital financial literacy and digital financial inclusion to economic outcomes. Digital financial literacy enhances individuals' capability to understand and evaluate digital financial tools, while digital financial inclusion provides access to these tools (Lusardi and Mitchell, 2023). However, only through active adoption can these capabilities and opportunities be transformed into sustained economic practices (Davis, 1989; Venkatesh et al., 2003).

Recent empirical studies provide growing support for this mediation pathway. Evidence suggests that technology adoption mediates the relationship between financial literacy and business performance, particularly in contexts where digital finance adoption is uneven (Ratnawati et al., 2025; Tandilino et al., 2025). Nonetheless, research explicitly testing this mechanism in rural micro-enterprise settings remains limited, indicating a clear empirical gap. Digital financial literacy equips rural micro-entrepreneurs with the ability to

understand digital financial products, assess risks, and make informed decisions, thereby supporting better financial behavior and long-term business performance (Choung et al., 2023; Kusumawardhani et al., 2023), although evidence from rural contexts remains mixed (Fig. 1). Digital financial inclusion expands access to formal financial services through digital channels, improving efficiency and reducing geographical barriers, and supports performance and resilience depending on actual usage (Ozili, 2021; Thathsarani and Jianguo, 2022). Access alone is insufficient without adequate financial capability, as limited literacy can hinder effective use and trust (Lyons and Kass-Hanna, 2021), while literacy strengthens meaningful inclusion, particularly in rural settings. The Technology Acceptance Model explains that higher literacy increases perceived usefulness and ease of use, encouraging adoption (Davis, 1989; Venkatesh and Davis, 2000), as confirmed empirically (Chhillar et al., 2024; Wu and Peng, 2024). However, adoption also depends on access and infrastructure (WB, 2023). Technology adoption enhances efficiency and sustainability (Ambarwati et al., 2024; Gunawan et al., 2023) and serves as a key mechanism linking literacy and inclusion to sustainable outcomes.

2.2. Hypothesis

H₁: Digital financial literacy positively affects the sustainable economic performance of rural micro-enterprises.

H₂: Digital financial inclusion positively affects the sustainable economic performance of rural micro-enterprises.

H₃: Digital financial literacy positively affects digital financial inclusion among rural micro-enterprises.

H₄: Digital financial literacy positively affects technology adoption among rural micro-enterprises.

H₅: Digital financial inclusion positively affects technology adoption among rural micro-enterprises.

H₆: Technology adoption positively affects the sustainable economic performance of rural micro-enterprises.

H₇: Technology adoption mediates the relationship between digital financial literacy and sustainable economic performance.

H₈: Technology adoption mediates the relationship between digital financial inclusion and sustainable economic performance.

3. Methodology

This study employs a quantitative research approach to examine the effects of digital financial literacy and digital financial inclusion on sustainable economic performance, with technology adoption as a mediating variable. The research focuses on 396 rural micro-enterprises in Kabupaten Deli Serdang, Indonesia, selected due to their significant role in local economic development and their exposure to digital financial services. A purposive sampling technique was used to select micro-entrepreneurs

who were actively involved in daily financial decision-making and had experience using digital financial services. Primary data were collected through a structured questionnaire survey. Respondents' perceptions were measured using a five-point Likert scale. Data analysis was conducted

using Structural Equation Modeling with Partial Least Squares (SEM-PLS), which is appropriate for testing complex relationships involving multiple latent variables and mediation effects (Sarstedt et al., 2021). Statistical analysis was performed using SmartPLS software.

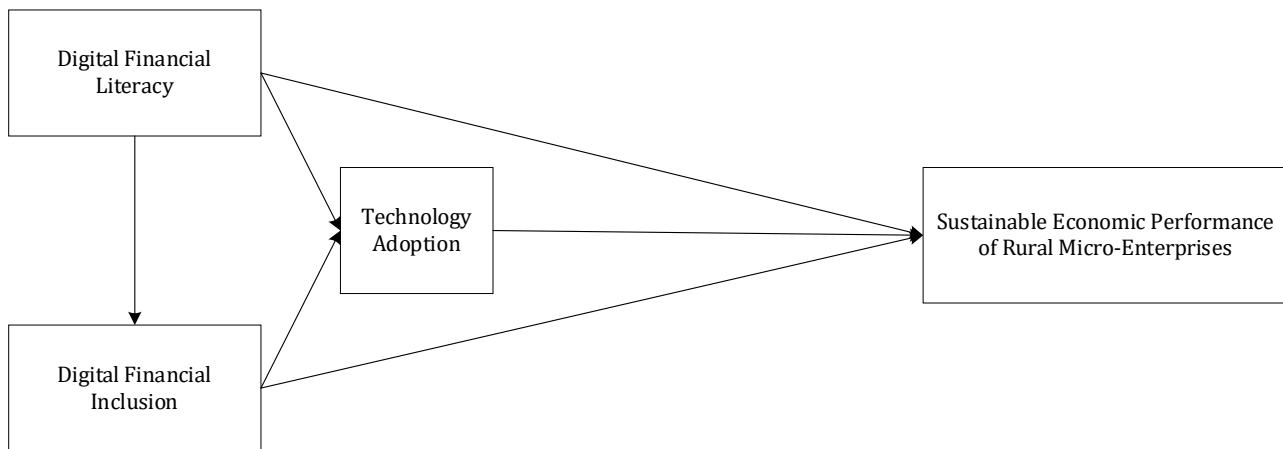


Fig. 1: Research framework

4. Result

4.1. Measurement model result

The measurement model was evaluated to assess indicator reliability and convergent validity. The results indicate that all constructs exhibit strong measurement properties. The outer loading values for all indicators range from 0.762 to 0.857, exceeding the recommended threshold of 0.70, thereby confirming adequate indicator reliability.

For Digital Financial Literacy (X1), all indicators demonstrate high loadings ranging from 0.819 to 0.857, indicating that respondents consistently understand and apply digital financial knowledge in managing financial transactions. The construct Digital Financial Inclusion (X2) also shows stable and strong loadings between 0.805 and 0.853, reflecting respondents' perceived access to and utilization of digital financial services.

The construct Technology Adoption (M) exhibits outer loading values between 0.810 and 0.851, suggesting a consistent pattern of digital technology usage among rural micro-entrepreneurs. Meanwhile, Sustainable Economic Performance (Y) is well represented by its indicators, with loading values ranging from 0.773 to 0.827, indicating that income stability, business continuity, and economic resilience are adequately captured by the measurement items. Overall, the strong outer loading values across all constructs confirm that the measurement model demonstrates satisfactory convergent validity and is suitable for further structural model analysis (Table 1). The results indicate that all constructs meet the recommended criteria for indicator reliability and convergent validity. The outer loading ranges exceed the minimum threshold of 0.70, confirming that the

indicators adequately represent their respective constructs. Furthermore, the AVE values are above 0.50 and the composite reliability values surpass 0.70, demonstrating satisfactory internal consistency and construct validity. Overall, the measurement model is deemed robust and suitable for further structural model analysis.

Discriminant validity was further assessed using the Fornell–Larcker criterion (Fornell and Larcker, 1981). The square roots of AVE for each construct were greater than their inter-construct correlations, indicating that discriminant validity was adequately established.

Having established the adequacy of the measurement model, the next section evaluates the structural model to examine the hypothesized relationships among the constructs.

4.2. Discriminant validity assessment (Fornell–Larcker criterion and HTMT ratio)

Discriminant validity was evaluated using both the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT) to ensure that the constructs are empirically distinct and not affected by problematic multicollinearity. As shown in Table 2, the square root of the Average Variance Extracted (AVE) for each construct exceeds its correlations with other constructs. Specifically, digital financial literacy (0.839), digital financial inclusion (0.831), technology adoption (0.828), and sustainable economic performance (0.800) each exhibit higher diagonal values than their inter-construct correlations. This confirms that each construct shares greater variance with its own indicators than with other constructs, thereby supporting adequate discriminant validity based on the Fornell–Larcker criterion.

Table 1: Measurement model evaluation

Construct	Outer loading range	AVE	CR	Conclusion
Digital financial literacy (X ₁)	0.819 – 0.857	0.705	0.971	Valid and reliable
Digital financial inclusion (X ₂)	0.805 – 0.853	0.690	0.969	Valid and reliable
Technology adoption (M)	0.810 – 0.851	0.686	0.968	Valid and reliable
Sustainable economic performance (Y)	0.773 – 0.827	0.639	0.964	Valid and reliable

Table 2: Discriminant validity (Fornell–Larcker criterion)

Constructs	Technology adoption	Digital financial inclusion	Sustainable economic performance	Digital financial literacy
Technology adoption	(0.828)			
Digital financial inclusion	0.411	(0.831)		
Sustainable economic performance	0.738	0.631	(0.800)	
Digital financial literacy	0.368	0.273	0.581	(0.839)

Diagonal values in parentheses represent the square root of the AVE for each construct

Further evidence is provided by the HTMT results shown in Table 3, where all values remain below the recommended threshold of 0.90, with the highest value observed at 0.766. This indicates that the constructs are empirically distinguishable and do not exhibit problematic conceptual overlap. These findings confirm that digital financial literacy, digital financial inclusion, technology adoption, and sustainable economic performance represent statistically and conceptually distinct constructs.

Importantly, this evidence demonstrates that the elevated collinearity observed in certain structural paths reflects meaningful theoretical relationships rather than measurement redundancy. Therefore, the structural associations identified in the model can be interpreted as valid explanatory relationships rather than artifacts of multicollinearity. Collectively, these results confirm the robustness of the measurement model and support the validity of the structural model analysis.

Table 3: Discriminant validity (HTMT ratio)

Constructs	Technology adoption	Digital financial inclusion	Sustainable economic performance	Digital financial literacy
Digital financial inclusion	0.424			
Sustainable economic performance	0.766	0.654		
Digital financial literacy	0.379	0.280	0.601	0.379

4.3. Collinearity assessment (VIF)

Collinearity was assessed using inner VIF values to ensure that the predictor constructs did not exhibit problematic multicollinearity. The results show low VIF values for the antecedents of technology adoption (X₁ → M = 1.106; X₂ → M = 1.134) and for the path X₁ → X₂ (VIF = 1.000), indicating negligible collinearity in these submodels. However, higher VIF values were observed among predictors of sustainable economic performance (X₁ → Y = 7.579; X₂ → Y = 11.170; M → Y = 10.950), suggesting potential collinearity when digital financial literacy, digital financial inclusion, and technology adoption are simultaneously included as predictors of Y.

To ensure that multicollinearity does not undermine construct distinctiveness, discriminant validity was further assessed using the Fornell–Larcker criterion and cross-loading examination. The results confirm that each construct shares greater variance with its own indicators than with other constructs, supporting the empirical distinctiveness of digital financial literacy, digital financial inclusion, technology adoption, and sustainable economic performance. These findings indicate that, despite their strong structural relationships, the constructs remain empirically separable and theoretically justified. Importantly, multicollinearity in this model reflects the sequential and complementary nature of

the constructs rather than measurement redundancy. While overlapping variance may influence the relative magnitude of direct effects, the mediation analysis using bootstrapping provides robust evidence of indirect and sequential relationships. This confirms that technology adoption functions as a key behavioral mechanism linking digital financial literacy and digital financial inclusion to sustainable economic performance, thereby supporting the validity and robustness of the structural model (Sarstedt et al., 2021).

4.4. Path coefficients and hypothesis testing

Table 4 reports the bootstrapped path coefficients. Digital financial literacy positively predicts digital financial inclusion (β = 0.273, t = 3.255, p = 0.001) and technology adoption (β = 0.240, t = 3.527, p < 0.001). Digital financial inclusion also positively influences technology adoption (β = 0.282, t = 4.017, p < 0.001). Regarding the outcome variable, sustainable economic performance is significantly explained by digital financial literacy (β = 0.235, t = 7.429, p < 0.001), digital financial inclusion (β = 0.398, t = 9.741, p < 0.001), and technology adoption (β = 0.402, t = 10.426, p < 0.001). Overall, all direct effects in the proposed structural model are positive and statistically significant.

Table 4: Structural path coefficients (bootstrapping results)

Structural paths	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T-statistics (O/STDEV)	P-values
Digital financial literacy (X ₁) -> digital financial inclusion (X ₂)	0.273	0.274	0.084	3.255	0.001
Digital financial literacy (X ₁) -> technology adoption (M)	0.240	0.239	0.068	3.527	0.000
Digital financial inclusion (X ₂) -> technology adoption (M)	0.282	0.283	0.070	4.017	0.000
Digital financial literacy (X ₁) -> sustainable economic performance (Y)	0.235	0.235	0.032	7.429	0.000
Digital financial inclusion (X ₂) -> sustainable economic performance (Y)	0.398	0.396	0.041	9.741	0.000
Technology adoption (M) -> sustainable economic performance (Y)	0.402	0.400	0.039	10.426	0.000

4.5. Coefficient of determination

The model explains 28.8% of the variance in technology adoption ($R^2 = 0.293$; adjusted $R^2 = 0.288$), indicating a moderate level of explanatory power. Digital financial inclusion exhibits a relatively low explained variance ($R^2 = 0.074$; adjusted $R^2 = 0.072$), suggesting that additional contextual factors beyond digital financial literacy may influence inclusion in rural settings. For sustainable economic performance, the model demonstrates a very high explanatory power ($R^2 = 0.945$; adjusted $R^2 = 0.944$), implying that the predictors jointly account for the majority of variance in Y.

The high R^2 value reflects the theoretically interrelated nature of the constructs, where digital financial literacy, inclusion, and technology adoption represent sequential and conceptually connected dimensions of rural digital finance. The mediation results further indicate that the explanatory power is

largely driven by indirect mechanisms rather than overlapping direct effects (Table 5).

4.6. Mediation analysis (indirect effects)

Mediation was assessed through bootstrapping of indirect effects. The specific indirect effect of digital financial literacy on sustainable economic performance via technology adoption is positive and significant ($X_1 \rightarrow M \rightarrow Y$: $\beta = 0.096$, $t = 3.417$, $p = 0.001$), indicating that technology adoption transmits part of the effect of digital financial literacy to sustainable outcomes. In addition, the sequential indirect pathway ($X_1 \rightarrow X_2 \rightarrow M \rightarrow Y$) is also significant ($\beta = 0.113$, $t = 3.786$, $p < 0.001$), suggesting that digital financial literacy contributes to inclusion, which in turn enhances technology adoption and ultimately supports sustainable economic performance (Table 6).

Table 5: Adjusted R-squared

Constructs	R-squared	R-squared adjusted
Technology adoption (M)	0.293	0.288
Digital financial inclusion (X ₂)	0.074	0.072
Sustainable economic performance (Y)	0.945	0.944

Table 6: Indirect effect/mediation

Indirect paths	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T-statistics (O/STDEV)	P-values
$X_1 \rightarrow M \rightarrow Y$	0.096	0.095	0.028	3.417	0.001
$X_1 \rightarrow X_2 \rightarrow M \rightarrow Y$	0.113	0.113	0.030	3.786	0.000

5. Discussion

This study examines how digital financial literacy and digital financial inclusion contribute to sustainable economic performance among rural micro-enterprises, with technology adoption serving as a mediating mechanism. The findings provide several important insights that extend existing literature on digital finance and sustainability, particularly within rural and developing-country contexts (Beirne and Fernandez, 2023; Hasan et al., 2024; Ozili, 2021).

First, digital financial literacy significantly strengthens sustainable economic performance (Choung et al., 2023; Kusumawardhani et al., 2023). Rural micro-entrepreneurs with stronger digital financial capability are better positioned to manage transactions, monitor cash flows, and make informed

financial decisions that support long-term business continuity (Choung et al., 2023; Frimpong et al., 2022; Kusumawardhani et al., 2023). In rural environments characterized by limited access to formal financial education and institutional support, digital financial literacy enhances entrepreneurs' ability to evaluate financial options and utilize digital tools effectively (Wu and Peng, 2024; Xu et al., 2024). This capability reduces operational uncertainty and improves financial control, thereby strengthening economic resilience and sustainability among rural micro-enterprises (Mishra et al., 2024; Xie and Chen, 2025).

Second, digital financial inclusion shows a strong and positive direct effect on sustainable economic performance, with a magnitude comparable to technology adoption (Ozili, 2018; Tay et al., 2022). This result suggests that access to digital financial

services, including mobile banking, e-wallets, and digital payment systems, enables rural entrepreneurs to overcome structural and geographical barriers that traditionally limit financial participation (Febriansyah et al., 2024; Ozili, 2018; Thathsarani and Jianguo, 2022). Improved access to financial services enhances transaction efficiency, increases financial flexibility, and supports more stable income generation (Wang and Fu, 2022; Wu and Peng, 2024). These findings indicate that digital financial inclusion contributes to economic sustainability not only by expanding access, but also by enabling more efficient and reliable financial management practices in underserved rural contexts (Basnayake et al., 2024; Chinoda and Kapingura, 2024; Tay et al., 2022).

Third, the study finds that technology adoption has the strongest direct influence on sustainable economic performance (Affandi et al., 2024; Vrontis et al., 2022). This finding highlights that the economic benefits of digital finance are fully realized only when financial knowledge and access are translated into actual technology use (Davis, 1989; Thathsarani and Jianguo, 2022; Venkatesh and Davis, 2000). Rural micro-entrepreneurs who actively adopt digital tools, such as digital payments, financial record-keeping applications, and online communication platforms, are better able to improve operational efficiency, strengthen financial monitoring, and respond more effectively to market changes (Affandi et al., 2024; Ambarwati et al., 2024; Gunawan et al., 2023). In rural settings where traditional business practices remain prevalent, technology adoption represents a critical behavioral capability that enables entrepreneurs to formalize financial management and enhance business adaptability. This finding supports the Technology Acceptance Model, which emphasizes that actual usage plays a decisive role in generating tangible performance outcomes (Hurani and Abdel-Haq, 2025).

More importantly, the mediation analysis reveals that technology adoption partially mediates the relationship between digital financial literacy and sustainable economic performance (Ariana et al., 2024). This indicates that digital financial literacy contributes to sustainability both directly and indirectly through increased technology usage (Affandi et al., 2024; Kurniasari et al., 2023). In practical terms, financial knowledge alone is insufficient; its economic impact is amplified when entrepreneurs apply that knowledge through digital tools (Affandi et al., 2024; Thathsarani and Jianguo, 2022). This finding helps explain why previous studies have reported mixed results regarding the effectiveness of financial literacy interventions, particularly in rural environments (Lyons and Kass-Hanna, 2021; Xu et al., 2024).

The results also indicate a significant indirect effect through a sequential mechanism, whereby digital financial literacy enhances digital financial inclusion, which in turn promotes technology adoption and ultimately improves sustainable

economic performance (Ariana et al., 2024; Thathsarani and Jianguo, 2022). This sequential mediation highlights that rural digital transformation is not an instantaneous process, but rather a gradual pathway involving knowledge acquisition, access to financial services, and behavioral adoption of technology (Nugraha et al., 2022; Wu and Peng, 2024).

These results further affirm that digital financial literacy, digital financial inclusion, and technology adoption constitute distinct but interrelated components of the digital transformation process. Digital financial literacy represents entrepreneurs' cognitive capacity to comprehend and evaluate digital financial services, whereas digital financial inclusion reflects the availability and accessibility of these services within the business environment (Choung et al., 2023; Wu and Peng, 2024; Xu et al., 2024). Technology adoption, in contrast, refers to the behavioral integration of digital tools into routine financial and operational practices (Affandi et al., 2024; Venkatesh and Davis, 2000; Thathsarani and Jianguo, 2022). In line with the Technology Acceptance Model, actual technology use functions as the critical mechanism through which capability and access are translated into improved performance outcomes (Hurani and Abdel-Haq, 2025). Accordingly, sustainable economic performance is shaped not only by financial knowledge and service accessibility but by the effective and sustained utilization of digital technologies in rural business operations (Gunawan et al., 2023; Ambarwati et al., 2024). This insight contributes to the literature by illustrating how digital finance operates as an interconnected system rather than as isolated components (Carè et al., 2025; Hasan et al., 2024; Ozili, 2018). While multicollinearity may influence the relative magnitude of individual direct effects, the overall structural relationships and mediation pathways remain theoretically consistent and statistically meaningful, as these constructs represent sequential and complementary stages of digital transformation (Affandi et al., 2024; Thathsarani and Jianguo, 2022; Hurani and Abdel-Haq, 2025). Furthermore, the specification of digital financial literacy and digital financial inclusion as exogenous constructs is consistent with Indonesia's National Survey of Financial Literacy and Inclusion (SNLIK) conducted by the Financial Services Authority (OJK), which identifies financial knowledge and access as foundational drivers of economic participation and financial behavior.

Taken together, these findings suggest that digital financial literacy and digital financial inclusion function as enabling conditions, while technology adoption serves as the key behavioral mechanism that converts these conditions into tangible economic outcomes (Thathsarani and Jianguo, 2022). The study thus advances existing research by clarifying the internal process through which digital finance affects sustainability, particularly in rural micro-enterprise contexts that have received limited

empirical attention (Basnayake et al., 2024; Tay et al., 2022; Xu et al., 2024).

These findings should be interpreted within the rural context of Kabupaten Deli Serdang, where digital infrastructure has improved but technology adoption among micro-enterprises remains limited. Despite increasing internet access, many rural entrepreneurs continue to rely on cash-based transactions due to capability constraints and deeply rooted traditional business practices (OECD, 2024; WB, 2022). Most micro-enterprises operate as household-based ventures, processing agricultural and fishery products as supplementary income sources, which often reduces incentives for formal technology adoption. Prior research indicates that rural entrepreneurs frequently experience a gap between digital access and actual usage, particularly in developing economies (OECD, 2021). This condition explains why technology adoption plays a crucial mediating role in translating financial capability and access into sustainable economic performance in rural settings.

From a theoretical perspective, this study extends the application of the Technology Acceptance Model by integrating it with digital financial capability and inclusion frameworks in a rural setting (Mujalli et al., 2024). Rather than focusing solely on intention or perception, the study emphasizes actual adoption behavior as the critical link between digital finance and sustainable economic performance (Thathsarani and Jianguo, 2022). From a contextual perspective, the findings enrich the growing body of evidence from developing economies by demonstrating that rural micro-enterprises can achieve meaningful sustainability gains through digital finance when adoption barriers are effectively addressed (Affandi et al., 2024; Wu and Peng, 2024).

6. Conclusion

This study investigates the relationships between digital financial literacy, digital financial inclusion, technology adoption, and sustainable economic performance among rural micro-enterprises in Kabupaten Deli Serdang, Indonesia. The findings provide clear evidence that digital financial literacy and digital financial inclusion both exert significant positive effects on sustainable economic performance, either directly or indirectly through technology adoption.

The results further confirm that Technology adoption acts as a critical behavioral mechanism that converts financial capability and access into measurable and sustainable economic benefits. While digital financial literacy enhances entrepreneurs' understanding of digital financial services, and digital financial inclusion expands access to these services, the economic benefits materialize most strongly when digital technologies are actively adopted and integrated into daily business operations. This finding highlights that sustainable economic performance in rural micro-enterprises is not driven by digital finance in

isolation, but by the effective utilization of digital tools.

Overall, the study demonstrates that rural digital transformation follows a sequential and behavioral process, beginning with financial literacy, followed by financial inclusion, and culminating in technology adoption. This process ultimately strengthens income stability, business continuity, and economic resilience among rural micro-entrepreneurs. By focusing on rural enterprises, this study contributes context-specific evidence from a developing economy and enriches the limited empirical literature on digital finance and sustainability beyond urban settings.

7. Implications

Prior evidence from rural and semi-rural SMEs in Deli Serdang, Indonesia, shows that financial inclusion, fintech, and e-commerce enhance business performance (Khairani et al., 2025), yet the role of technology adoption in sustaining outcomes remains underexplored.

The findings of this study offer several important theoretical, practical, and policy-related implications. From a theoretical perspective, the results extend the Technology Acceptance Model by emphasizing actual technology adoption as the key mechanism through which digital financial literacy and digital financial inclusion influence sustainable economic performance. This integrated perspective contributes to the digital finance literature by demonstrating that financial capability and access alone are insufficient without consistent behavioral adoption, particularly in rural contexts.

From a practical standpoint, the findings suggest that efforts to enhance the sustainability of rural micro-enterprises should move beyond expanding access to digital financial services. Strengthening digital financial literacy and promoting hands-on engagement with digital technologies are essential to ensure that financial knowledge and inclusion translate into productive economic outcomes. Financial institutions and fintech providers are encouraged to design user-friendly digital services that align with the capabilities and daily practices of rural entrepreneurs.

From a policy perspective, the study highlights the need for integrated rural digital finance strategies. Policymakers should combine infrastructure development with targeted literacy programs and technology adoption support. Collaborative initiatives involving regulators, financial institutions, and local governments can help create an enabling ecosystem that fosters inclusive and sustainable rural economic development.

List of abbreviations

AVE	Average variance extracted
CR	Composite reliability
HTMT	Heterotrait-monotrait ratio

INFE	International network on financial education
MSME	Micro, small, and medium-sized enterprises
OJK	Otoritas Jasa Keuangan (financial services authority of Indonesia)
PLS	Partial least squares
PLS-SEM	Partial least squares structural equation modeling
SEM	Structural equation modeling
SEM-PLS	Structural equation modeling with partial least squares
SMES	Small and medium-sized enterprises
SNLIK	National survey of financial literacy and inclusion
STDEV	Standard deviation
TAM	Technology acceptance model
VIF	Variance inflation factor

Compliance with ethical standards

Ethical considerations

This study was conducted in accordance with ethical research principles involving human participants. Prior to data collection, all respondents were informed about the objectives, procedures, and voluntary nature of the study. Participants provided informed consent before completing the questionnaire and were assured that their responses would be kept confidential and used solely for academic research purposes. No personal identifiers were collected, and all data were analyzed anonymously to protect participant privacy. Respondents were also informed that they had the right to withdraw from the study at any stage without any consequences. Furthermore, the research procedures complied with institutional research ethics standards and the principles of the Declaration of Helsinki regarding research involving human subjects.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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