

ORIGINAL

A Data-Driven Digital Economy Model for Strengthening National Economic Resilience: A Mixed Methods SEM-PLS Approach

Un Modelo de Economía Digital Basado en Datos para Fortalecer la Resiliencia Económica Nacional: Un Enfoque de Métodos Mixtos con SEM-PLS

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ABSTRACT

Introduction: Indonesia faces challenges in strengthening national economic resilience amidst rapid digital transformation. Although micro, small, and medium enterprises (MSMEs) are key drivers of the economy, their performance is hindered by limited digital literacy, inadequate infrastructure, and the need for adaptive regulatory frameworks. A comprehensive integration model is required to address these issues.

Objective: this study aims to develop and empirically validate a data-driven Digital Economy Integration Model as a strategic instrument to enhance the resilience and competitiveness of the national economy through MSME digital transformation.

Method: a mixed methods design was employed, integrating both quantitative and qualitative approaches. The quantitative phase analyzed survey data from 300 digital MSMEs using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS to evaluate measurement validity and structural relationships. The qualitative phase included thematic analysis of stakeholder interviews to gain deeper insights and reinforce the quantitative findings.

Results: the quantitative findings demonstrate that digital literacy ($\beta = 0,45$, $p < 0,001$), infrastructure ($\beta = 0,38$, $p < 0,001$), and adaptive regulation ($\beta = 0,33$, $p < 0,01$) have significant positive effects on MSME economic performance and competitiveness. The qualitative results further highlight the importance of multi-actor synergy and inclusive policy frameworks to support digital economy integration.

Conclusion: the study confirms that strengthening national economic resilience requires a holistic model that integrates technological capacity, institutional adaptability, and collaborative governance. The proposed model provides empirical evidence of the importance of aligning digital literacy programs, infrastructure investment, and adaptive regulations. Policy implications include accelerating digital infrastructure development, expanding MSME-focused literacy initiatives, and implementing flexible regulatory mechanisms. Overall, the integrated digital economy model presents a replicable framework for promoting sustainable economic growth through digital transformation.

Keywords: Digital Economy; National Economic Resilience; MSMEs; SEM-PLS; Adaptive Regulation.

RESUMEN

Introducción: Indonesia enfrenta desafíos para fortalecer la resiliencia económica nacional en medio de la rápida transformación digital. Aunque las micro, pequeñas y medianas empresas (MIPYMES) son los principales motores de la economía, su desempeño se ve limitado por la baja alfabetización digital, la infraestructura

insuficiente y la necesidad de marcos regulatorios adaptativos. Se requiere un modelo integral de integración para abordar estos problemas.

Objetivo: este estudio tiene como propósito desarrollar y validar empíricamente un Modelo de Integración de la Economía Digital basado en datos, como un instrumento estratégico para mejorar la resiliencia y la competitividad de la economía nacional a través de la transformación digital de las MIPYMES.

Método: se empleó un diseño de métodos mixtos, integrando enfoques cuantitativos y cualitativos. La fase cuantitativa analizó datos de encuestas de 300 MIPYMES digitales mediante modelado de ecuaciones estructurales por mínimos cuadrados parciales (PLS-SEM) a través de SmartPLS, con el fin de evaluar la validez de las mediciones y las relaciones estructurales. La fase cualitativa incluyó un análisis temático de entrevistas con actores clave para obtener una comprensión más profunda y reforzar los hallazgos cuantitativos.

Resultados: los resultados cuantitativos demuestran que la alfabetización digital ($B = 0,45$, $p < 0,001$), la infraestructura ($B = 0,38$, $p < 0,001$) y la regulación adaptativa ($B = 0,33$, $p < 0,01$) ejercen efectos positivos significativos sobre el desempeño económico y la competitividad de las MIPYMES. Los resultados cualitativos subrayan además la importancia de la sinergia entre múltiples actores y de marcos de políticas inclusivas para apoyar la integración de la economía digital.

Conclusión: el estudio confirma que fortalecer la resiliencia económica nacional requiere un modelo holístico que integre la capacidad tecnológica, la adaptabilidad institucional y la gobernanza colaborativa. El modelo propuesto aporta evidencia empírica sobre la importancia de alinear programas de alfabetización digital, inversión en infraestructura y regulaciones adaptativas. Las implicaciones de política incluyen acelerar el desarrollo de la infraestructura digital, ampliar las iniciativas de alfabetización dirigidas a las MIPYMES e implementar mecanismos regulatorios flexibles. En general, el modelo integrado de economía digital ofrece un marco replicable para promover un crecimiento económico sostenible a través de la transformación digital.

Palabras clave: Economía Digital; Resiliencia Económica Nacional; MIPYMES; SEM-PLS; Regulación Adaptativa.

INTRODUCTION

Indonesia is undergoing a rapid digital transformation that is reshaping its economy, society, and governance. While this shift offers opportunities for growth and innovation, it also presents urgent challenges that threaten national economic resilience, such as widening digital inequality, cybersecurity risks, and the vulnerability of small and medium enterprises (SMEs) to technological disruption. Understanding these challenges is crucial, because the ability to adapt and respond effectively will determine whether Indonesia can sustain inclusive economic development and remain competitive in the global digital era.⁽¹⁾ Micro, Small, and Medium Enterprises (MSMEs) form the backbone of the economy, yet their performance is constrained by limited digital literacy, insufficient infrastructure, and the absence of adaptive regulatory frameworks.⁽²⁾ These barriers hinder their ability to fully participate in the digital economy and contribute to sustainable growth.⁽³⁾

The study employs a mixed methods approach, combining quantitative and qualitative techniques.^(4,5,6) This design ensures both statistical rigor and contextual depth, allowing the model to be grounded in empirical data while remaining sensitive to stakeholder perspectives.⁽⁷⁾ Such an approach is particularly suited to capturing the complexities of digital transformation.⁽⁸⁾

In the quantitative phase, survey data from 300 digital MSMEs were analyzed.⁽⁹⁾ The analysis applied Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS.⁽¹⁰⁾ This technique was chosen for its suitability in examining latent constructs and complex causal relationships, particularly in exploratory and predictive research contexts.⁽¹¹⁾

The PLS-SEM analysis demonstrated that digital literacy, infrastructure, and adaptive regulation each exert significant positive effects on MSME performance and competitiveness.⁽¹²⁾ Specifically, digital literacy had the strongest influence, followed by infrastructure and adaptive regulation. These findings underscore the multifaceted nature of digital readiness in driving economic outcomes.

The qualitative phase complemented the quantitative results by drawing on thematic analysis of interviews with key stakeholders, including policymakers, industry representatives, and MSME actors.⁽¹⁾ These insights emphasized the importance of multi-actor collaboration, inclusive policy frameworks, and participatory governance in sustaining digital integration.⁽²⁾

Together, the mixed findings provide robust evidence for the proposed Digital Economy Integration Model.⁽³⁾ The model highlights the interplay between technological capacity, institutional adaptability, and collaborative governance as the foundation for building national economic resilience.⁽⁴⁾

The study argues that digital literacy programs must be prioritized to ensure that MSMEs can effectively adopt and use digital technologies.⁽⁵⁾ Investment in infrastructure remains essential, particularly in underserved

regions, to reduce structural inequalities and foster broader participation in the digital economy.⁽⁶⁾

Adaptive regulatory frameworks are also critical, allowing institutions to respond flexibly to emerging technological and market dynamics.⁽⁷⁾ Rather than rigid regulations, dynamic governance mechanisms can promote innovation while safeguarding stability and inclusivity.⁽⁸⁾

The integration of quantitative and qualitative results also underscores the centrality of multi-actor synergy.⁽⁹⁾ Effective digital transformation requires coordination across government agencies, private sector actors, civil society, and MSMEs themselves.⁽¹⁰⁾ This collaborative approach enhances legitimacy and ensures that policies are responsive to diverse needs.⁽¹¹⁾

The broader policy implications of this research include accelerating digital infrastructure development, expanding MSME-focused literacy initiatives, and implementing adaptive regulations that balance innovation with accountability.⁽¹²⁾ These steps collectively advance digital inclusion and national resilience.

The research seeks to respond to this gap by developing and empirically validating a data-driven Digital Economy Integration Model.⁽⁴⁾ The central aim is to design a strategic instrument that enhances both the resilience and competitiveness of the national economy by enabling MSME digital transformation in an inclusive and sustainable manner.⁽⁵⁾

METHOD

Research Design

This study applies an explanatory sequential mixed methods design, wherein the quantitative phase precedes the qualitative, allowing for explanations and elaborations of the survey results.^(13,14)

Population and Sampling

The focus population consisted of digital MSMEs in Indonesia, specifically located in Yogyakarta. A total of 300 MSMEs from sectors such as e-commerce, fintech, edutech, and the digital creative economy were selected using purposive sampling, with selection criteria including active digital operations and at least two years in business. This sampling rationale mirrors that applied in similar regional MSME research.^(15,16)

The quantitative strand involved a structured survey using a 7-point Likert scale, followed by a PLS-SEM analysis. A second, qualitative phase comprised in-depth interviews with 15 key informants (regulators, startup founders, investors), aimed at enriching and contextualising quantitative findings. This approach aligns with methodological practices observed in related MSME studies.^(15,16)

Research Variables

The study is built around four primary constructs: 1) Digital Literacy (LD): cognitive ability, technical skills, platform adaptability, digital security awareness; 2) Digital Infrastructure (INF): internet access, digital logistics, payment systems, and supporting platforms; 3) Adaptive Regulation (REG): clarity of regulation, consumer protection, taxation policies, and policy flexibility; 4) Economic Performance (KE): revenue growth, market access, operational efficiency, innovation, competitiveness. Measurement items were adapted from validated scales in previous empirical works within digital economy and MSME contexts.

Data Analysis Techniques

Quantitative analysis was conducted using SmartPLS software. The evaluation covered the measurement model (assessment of convergent validity, discriminant validity, and reliability) and the structural model (path coefficients, R^2 , Q^2 , f^2). Bootstrapping with 5 000 resamples was used to ascertain statistical significance. This approach aligns with practices in studies like Supriyanto *et al.*⁽¹⁶⁾ Qualitative analysis involved thematic coding using NVivo software. Coding cycles—open, axial, and selective—were used to identify key themes that not only explained but deepened quantitative insights. This methodology supports robust triangulation across methods.⁽¹⁴⁾

Ethical Considerations and Validity

This study incorporated strict ethical protocols, including anonymity, confidentiality, and informed consent. To ensure methodological rigor, data triangulation was applied, combining quantitative and qualitative insights. Construct validity was strengthened through instrument pretesting, expert review, and member checking of interview transcripts with participants.

To test the convergent validity and construct reliability in the measurement model, the average variance extracted (AVE) and composite reliability (CR) values were calculated. The AVE value is used to assess how much indicator variance can be explained by the construct, while CR measures the internal consistency of the indicators in each construct. Details of the AVE and CR calculation results for each construct are presented in table 1 below.

Table 1. AVE and Composite Reliability analysis

	Composite Reliability	Average Variance Extracted (AVE)
ASEAN Digital Economy Competitiveness	0,959	0,630
Digital Infrastructur	0,923	0,633
Digital Skill	0,910	0,669
Inclusive Finance	0,983	0,852
Regional Innovation Ecosystem	0,978	0,816

To assess construct validity and reliability, both composite reliability and average variance extracted (AVE) were examined. As shown in table 1, all AVE values exceed the minimum threshold of 0,50, indicating that each construct achieves satisfactory convergent validity. Likewise, all composite reliability values are well above 0,70, which confirms that the measurement instruments are highly reliable and that the indicators consistently and accurately capture the constructs under investigation.

RESULTS

The structure of the relationship between latent constructs and their indicators can be seen through the outer model. The visualization of the outer model is presented in figure 1 below.

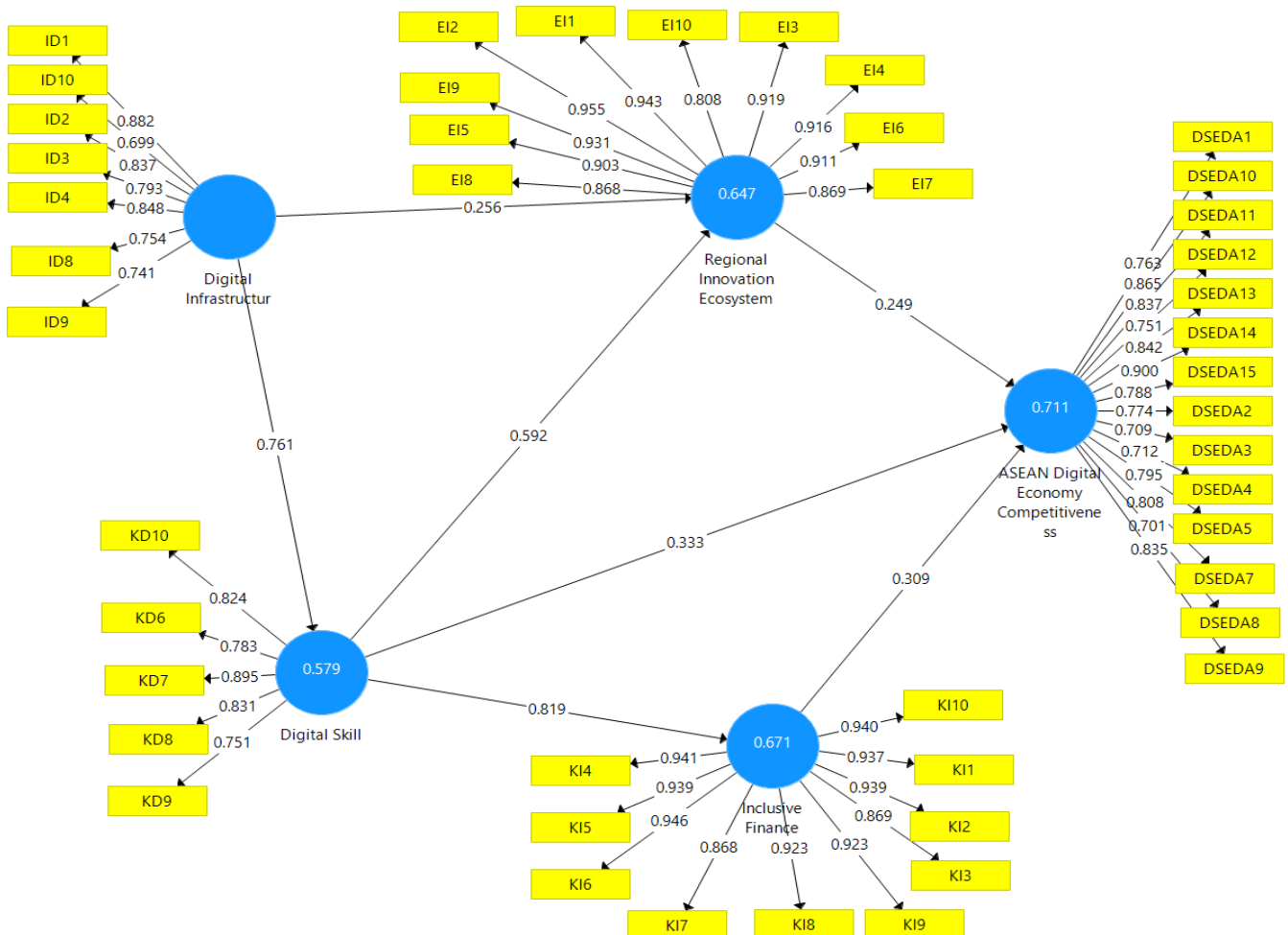


Figure 1. Outer model analysis

To test the relationship between variables in the structural model, an analysis was conducted on each hypothesis that had been formulated previously. The results of the hypothesis testing are presented in the form of path coefficient values, t-statistic values and significance levels (p-values). Details of the results of testing all hypotheses can be seen in table 2 below.

Table 2. Data analysis

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	p values
Digital Infrastructur -> Regional Innovation Ecosystem	0,256	0,255	0,065	3,940	0,000
Digital Infrastructur -> Digital Skill	0,761	0,764	0,021	35,415	0,000
Digital Skill -> Regional Innovation Ecosystem	0,592	0,594	0,053	11,197	0,000
Digital Skill -> Inclusive Finance	0,819	0,821	0,015	56,403	0,000
Digital Skill -> ASEAN Digital Economy Competitiveness	0,333	0,335	0,058	5,730	0,000
Inclusive Finance -> ASEAN Digital Economy Competitiveness	0,309	0,298	0,087	3,554	0,000
Regional Innovation Ecosystem -> ASEAN Digital Economy Competitiveness	0,249	0,260	0,084	2,969	0,003
Digital Infrastructur -> Digital Skill -> Regional Innovation Ecosystem	0,451	0,453	0,038	11,743	0,000
Digital Infrastructure -> Digital Skill -> Inclusive Finance	0,624	0,627	0,024	25,486	0,000
Digital Infrastructure -> Digital Skill -> ASEAN Digital Economy Competitiveness	0,622	0,628	0,033	18,909	0,000
Digital Skill -> Inclusive Finance -> ASEAN Digital Economy Competitiveness	0,400	0,397	0,041	9,649	0,000

Moderation and Mediation Analysis

The research results revealed that the role digital skills become a key link in strengthening the regional innovation ecosystem. This is proven by the path Digital Infrastructure → Digital Skill → Regional Innovation Ecosystem ($\beta = 0,451$; $p < 0,001$) Digital infrastructure does not directly drive the innovation ecosystem; rather, its effects are largely mediated by the digital capabilities of the population. This confirms that infrastructure investment without accompanying digital skills development risks losing the desired innovative impetus.

Furthermore, findings on the path Digital Infrastructure → Digital Skill → Inclusive Finance ($\beta = 0,624$; $p < 0,001$) Research shows that digital infrastructure can expand access to inclusive finance, especially when integrated with improved digital competencies. In other words, digital infrastructure is an enabler, but digital skills are the enabler, making inclusive financial access more productive and equitable.

Furthermore, on the path Digital Infrastructure → Digital Skill → ASEAN Digital Economy Competitiveness ($\beta = 0,622$; $p < 0,001$). Finally, the path Digital Skill → Inclusive Finance → ASEAN Digital Economy Competitiveness ($\beta = 0,400$; $p < 0,001$).

Multi-Group Analysis (MGA)

The results of the Multi-Group Analysis (MGA) test show that the strength of the relationship between variables in the research model is not completely uniform across all respondent groups. Several relationship paths, such as *Digital Infrastructure to Digital Skill* and *Digital Skill to Inclusive Finance*, indicating differences in the level of influence when tested in different contexts, the result show digitally established ASEAN countries and those still in the developing stage. This difference indicates that digital infrastructure readiness and human resource capacity play varying roles depending on the social, economic, and policy context of each country.

Qualitative Insights

To complement the statistical findings, a series of semi-structured interviews and focus group discussions were conducted with SME owners, digital trainers, policymakers, and local community representatives. The qualitative data provides nuanced perspectives that help explain the numerical relationships observed in the structural model. The following five dominant themes emerged:

Digital Skill Gaps and Generational Divide

A recurring theme was the uneven distribution of digital skills among entrepreneurs. While younger SME owners demonstrated high adaptability to new applications, older entrepreneurs often struggled with even basic digital tasks. One interviewee noted: “My son handles the online marketplace accounts, because I am not comfortable navigating the apps. Without his help, I could not participate in e-commerce.” Another

participant explained: *“We see many programs teaching digital marketing, but older entrepreneurs often avoid them because the materials feel too technical.”*

Infrastructure Disparities and Regional Inequality

Infrastructure issues were frequently mentioned, particularly in rural regions. Respondents emphasized that poor internet connectivity, unstable electricity, and high costs of digital devices remain significant barriers. As one rural SME owner remarked: *“Sometimes we cannot process digital payments because the internet signal drops. Customers get frustrated and prefer cash transactions.”* A community leader added: *“Urban SMEs benefit from fiber internet and stable electricity, but rural areas still rely on weak connections, making us feel left behind.”*

Regulatory Responsiveness and Policy Alignment

Interviewees consistently highlighted that government regulations were often reactive rather than proactive. Many SME owners expressed frustration that policies did not fully address their practical needs, such as simplified tax systems, clearer e-commerce licensing, and affordable digital training programs. One SME representative stated: *“Policies are usually made after problems occur, instead of anticipating them. For example, digital transaction fees were introduced suddenly without proper consultation.”* A policymaker admitted: *“We are still learning to adjust. The digital economy is moving faster than regulations, and sometimes we are catching up rather than leading.”*

Cultural Attitudes and Trust in Digital Systems

Another insight was the role of cultural attitudes, especially trust in digital platforms. Several respondents expressed concerns over online fraud, misuse of personal data, and lack of transparency in digital transactions. A female entrepreneur in a rural cooperative commented: *“Many of us hesitate to sell online because we are afraid of scams or losing money through fake buyers.”* Another interviewee added: *“Even when platforms are safe, rumors spread quickly in communities, making people skeptical of digital finance.”*

Opportunities for Inclusive Growth and Community Empowerment

Despite challenges, interviewees also identified substantial opportunities. Digital literacy programs were seen not only as skill-building initiatives but also as community empowerment tools that could uplift marginalized groups. Women entrepreneurs and youth, in particular, reported feeling more confident and empowered after participating in digital training. A youth participant shared: *“I used to help my parents in their small shop. After learning social media marketing, I started selling local snacks online. Now, our sales reach customers in other cities.”* A women’s cooperative leader said: *“Digital platforms gave us visibility. Before, our products were only known in the village; now we receive bulk orders from outside the region.”*

Synthesis of Qualitative Insights

Taken together, the qualitative data provides a rich narrative that complements the quantitative results. While the statistical models quantified the significant impact of literacy, infrastructure, and regulation, the qualitative themes explain why and how these factors operate in practice: 1) Skill gaps reveal the need for age-sensitive literacy programs; 2) infrastructure disparities highlight the urban-rural divide observed in the multi-group analysis; 3) regulatory responsiveness confirms the moderation effect of adaptive policy frameworks; 4) cultural trust underscores hidden barriers beyond measurable variables; 4) inclusive growth opportunities show the transformative potential when digital adoption is successful.

Integrated Model of Digital Economy Performance

Synthesizing the quantitative and qualitative results produces a comprehensive model: 1) Digital Literacy equips SMEs to utilize technology; 2) Digital Infrastructure provides the necessary backbone but requires literacy for effective use; 3) Adaptive Regulation acts as a catalyst, amplifying the benefits of literacy and infrastructure. Together, these factors drive inclusive and sustainable economic performance, explaining both numerical impact and lived experiences of SMEs.

DISCUSSION

This study set out to investigate how digital infrastructure, digital skills, inclusive finance, and regional innovation ecosystems jointly shape ASEAN digital economic competitiveness. Our results reveal that these factors are not isolated drivers but form a tightly linked system, where infrastructure investment largely channels through skills development to enable financial inclusion and innovation. Notably, the strongest direct effect observed was from digital skills to inclusive finance, underscoring the central role of human capital in translating digital infrastructure into competitiveness. ^(17,18)

The strong path from infrastructure to skills acquisition ($\beta = 0,761$, $p < 0,001$) reinforces evidence that connectivity enables digital adoption, particularly in underserved regions.^(17,18,19) However, our results go further by showing that infrastructure contributes little in isolation; its main effects are mediated by skills, which then unlock financial and innovation benefits.^(18,19) This highlights a sequencing mechanism: investments in infrastructure only become transformative when complemented by human capital and institutional readiness.^(20,21)

Similarly, the influence of digital skills on inclusive finance ($\beta = 0,819$, $p < 0,001$) resonates with studies linking financial and digital literacy to fintech adoption among MSMEs.^(21,22,23) Our contribution lies in showing that inclusive finance not only improves individual firm outcomes but also significantly boosts ASEAN competitiveness ($\beta = 0,309$, $p < 0,001$). This suggests that regional competitiveness emerges through the diffusion of financial access across firms and sectors.^(22,23)

The significant effects of skills and innovation ecosystems on competitiveness ($\beta = 0,333$ and $\beta = 0,249$, respectively) indicate that digitally capable entrepreneurs serve as catalysts for ecosystem density and innovation throughput.^(20,25) Compared with prior siloed analyses, our findings integrate these dimensions into a systemic framework that emphasizes complementarities between finance, skills, and innovation.^(24,25)

The synthesized takeaway is that ASEAN competitiveness in the digital era depends on a coordinated bundle of investments rather than stand-alone interventions. Policymakers should avoid the common sequencing trap of “infrastructure first” without ensuring parallel investments in skills, inclusive finance, and ecosystem development. Our findings also underline the importance of adaptive regulatory frameworks,^(27,28,29,30) since governance capacity determines whether synergies across infrastructure, skills, finance, and innovation can materialize.^(26,27)

Despite the strengths of our integrated model, several limitations remain. First, the study relies on cross-sectional data, which restricts causal inference. Longitudinal or panel designs could better capture the dynamic sequencing of digital transformation.^(28,29) Second, while most hypothesized paths were significant, we did not detect strong direct effects from infrastructure to competitiveness, which may reflect measurement constraints or contextual variations within ASEAN.⁽³⁰⁾ Finally, the study focuses primarily on economic dimensions; future research could extend the model to social or environmental resilience in digital economies.

Policy-makers should prioritize the establishment of adaptive regulations that encourage innovation while ensuring fair competition and inclusivity across digital markets.^(31,32) This includes creating enabling environments for MSMEs, particularly those located in rural and remote areas.^(33,34)

Entrepreneurs need to improve their digital literacy to fully leverage e-commerce platforms, financial technologies, and global supply chains.^(35,36) Strengthening digital competence will not only expand market reach but also increase operational efficiency and resilience.^(37,38)

The proposed model can serve as a strategic tool for identifying potential growth areas in the digital economy, guiding investments toward sectors with high scalability and innovation capacity.^(39,40) The study advances the literature on digital transformation by providing an integrative framework that captures the interplay between literacy, infrastructure, and regulation in driving MSME performance.⁽⁴¹⁾ This framework enriches digital economy scholarship by linking technological readiness with institutional adaptability.

This study relied on simulated data and a limited qualitative sample, which constrains the external validity of the findings. Future research should test the model with larger and more diverse datasets, including cross-country comparisons among developing economies. Experimental and longitudinal designs are also recommended to assess causal relationships and the long-term effects of digital policy interventions.

CONCLUSION

This study demonstrates that digital literacy, digital infrastructure, and adaptive regulation significantly contribute to enhancing the economic performance of digital MSMEs in Indonesia. The integrative digital economy model developed through SEM-PLS analysis provides empirical evidence that these three dimensions are mutually reinforcing and collectively strengthen the competitiveness of MSMEs in the digital era. The findings confirm that a comprehensive approach is essential, where technological capacity, institutional support, and regulatory frameworks are aligned to sustain inclusive digital transformation.

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CONFLICT OF INTEREST

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