



Temporal Effects of Human Capital and Digital Strategy on MSME Performance in Indonesia: A GMM System Dynamic Panel Approach

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Abstract

This research contributes to the limited empirical literature examining the simultaneous impact of digital marketing intensity and human resource-related capabilities on MSME performance, particularly in turbulent and highly competitive environments. Despite the pressing need for digital adoption across the micro and small business sector, empirical inquiries linking marketing digitalization, human capital quality, and output sustainability over extended timeframes remain sparse. To bridge this literature gap, the study employs a dynamic-panel framework using the system's Generalized Method of Moments estimator, thereby accommodating potential endogeneity between regressors and the presence of autocorrelation in the dependent variable. Drawing on a balanced dataset of 120 MSME-year observations, the analysis reveals that the Digital Marketing Intensity variable (DMI), an aggregated Human Capital Index (HCI), and the intensity of human-resource training exert a statistically positive and economically meaningful influence on performance, with coefficients of 0.241, 0.193, and 0.158, respectively. In contrast, an intensified Market Competition variable correlates with performance deterioration (-0.142), suggesting that intensified rivalry exerts a compressive effect on relative output. Digital literacy emerges as a positive moderating factor, amplifying the DMI-performance coupling with a marginal effect of $r = 0.086$, thereby underscoring the complementary role of digital know-how in reinforcing strategic digital investments. Finally, the statistically significant coefficient on the performance lag variable substantiates the notion of path dependence in the performance trajectories of MSMEs over time. Theoretical validation for these results stems from their consistency with dynamic capabilities, human capital, and market structure frameworks, specifically as they pertain to micro, small, and medium-sized enterprises. From a policy perspective, the results signal a pressing need for initiatives that advance technological assimilation, elevate digital competency levels, and strengthen human resource infrastructures. Moreover, regulatory frameworks should evolve towards adaptable market protections that provide micro, small, and medium-sized enterprises with the necessary freedom to flourish and succeed in the digital economy.

Keywords: MSMEs, digital marketing, human capital, digital literacy, dynamic GMM.

1. Introduction

Against the backdrop of the accelerating worldwide technological upheaval, digital transformation has emerged as an uncompromising driver of economic trajectories, particularly affecting micro, small, and medium enterprises (MSMEs). The digital epoch transcends mere hardware and software updates; it embeds new paradigms in labor organization, reconstitutes market linkages, and redefines the competencies deemed valuable within human resource portfolios. Within this expanded landscape, human capital, defined as the confluence of knowledge, skills, and productive attitudes, constitutes the bedrock upon which MSMEs can cultivate both resilience and the capacity to capitalize on emerging digital opportunities (Hetharie, Ikhwanasyah, & Rahmawati, 2025).

Background to the importance of human capital in the digital era

Human capital continues to be acknowledged as a central driver of economic progress; yet its importance deepens in the digital age, where its dimensions proliferate and intertwine. Digital transformation reshapes production, distribution, and consumption architectures. Technologies

spanning e-commerce, algorithmic marketing, and platform-centric service delivery require a workforce that masters digital tools, possesses a solid foundation in technological principles, engages with data at a critical level, and exhibits agility in the face of rapid evolution (Widarni & Bawono, 2021).

However, a substantial segment of micro, small, and medium-sized enterprises (MSMEs) lacks the human capital to meet these emerging thresholds. Variations in capacity across MSME strata exacerbate the digital divide and dilute regional competitiveness. Consequently, human capital transcends the individual and emerges as a collective construct that conditions the depth of inclusiveness and equity in the economy's digital trajectory (Morris, Morris, & Bowen, 2022; Akpe, Mgbame, Ogbuefi, Abayomi, & Adeyelu, 2023).

Problems faced by MSMEs: digital inequality and strengthening human resource capacity

Indonesian micro, small, and medium enterprises (MSMEs) are integral to the national economic framework, absorbing considerable labour and fuelling regional development. Nevertheless, the sector's overarching digitalisation encounters a tripartite set of structural impediments. The first obstacle is the uneven distribution of technological platforms and infrastructural backbone, whereby rural MSMEs consistently report intermittent internet access and a dearth of suitable digital terminals (Widarni, Bawono, & Chapuzet, 2024).

The second challenge lies in the limited digital literacy and the capacity of MSME personnel to adapt to contemporary technological advancements. Many enterprises do not internalize critical paradigms, such as search engine optimization, social media metric interpretation, or e-commerce logistics management. The third hurdle is the inadequacy of continuous, practice-oriented training; current pedagogic interventions are frequently generic, neglecting the micro-dynamics of local markets and the heterogeneous developmental trajectories observable across MSME portfolios (Reni, Sihite, & Rijal, 2024).

Such unequal absorptive capacity sanctions divergent outcomes: some enterprises report marked gains in operational metrics, whilst others are ensnared in minimal, if not retrogressive, performance. In response, detailed longitudinal studies are required to optimise human capital development through targeted, staggered digital training interventions (Kraugusteeliana & Zaakiyyah, 2024; Rohayati, 2024).

Research Objective: To Explore the Temporal Impact of Digital Strategies and Training on MSME Performance

This investigation aims to elucidate the temporal effects of digital strategies implemented by micro, small, and medium-sized enterprises (MSMEs), most notably digital training programs, on the enterprises' performance outcomes. Employing a panel data methodology, the study will examine the phased evolution of MSME performance by comparing pre- and post-intervention states, thereby enabling the identification of significant effects that manifest in the short, medium, or long term.

The emphasis on temporality is warranted because digital interventions do not produce immediate results. The outcomes of such strategies rely on a succession of adaptations, skill acquisitions, and processes of technological embedment that unfold at different rates. Moreover, each MSME's trajectory is shaped by its unique internal capabilities and the contextual external environment. Consequently, this study goes beyond a mere statistical assessment of the interventions' effectiveness; it carefully charts the ordered progression of performance metrics across defined temporal intervals.

Research Contribution: Bridging Human Capital Theory with the Effectiveness of Digitalization Policy

Theoretically, this study advances scholarly discourse by reconceptualizing human capital through a longitudinal lens in the domain of MSME digitalization. Rather than a static endowment, human capital is operationalized as a continually adaptive resource, acquiring value through iterative engagement, context-sensitive capacity-building, and exposure to digital interfaces. Such a reconceptualization permits the examination of human capital as a catalyst that mediates temporal variations in MSME performance, thereby yielding a more nuanced and practically grounded understanding of its trajectory-related impact.

From a policy perspective, the empirical results provide a foundation for calibrating interventions that are both context-sensitive and temporally cognizant. Public authorities and educational institutions can tailor digitalization curricula to align with the discrete growth trajectories, operational exigencies, and absorptive capacities of MSME human resources. By

anchoring training curricula in longitudinal evidence, resource allocation becomes not only more economical but also more equitable, ensuring that the advantages of digitalization permeate enterprises of varying sizes and maturities.

In synthesizing these insights, the research outlines a pathway for reconciling theoretical imperatives in human capital formation with the execution of digitalization policy. It fosters a conjunctive environment in which cognitive, affective, and technological competencies are concurrently cultivated. Additionally, it catalyzes a triadic conversation among researchers, business practitioners, and policymakers, thereby stimulating the co-production of digitalization strategies that are both contextually attuned and resilient over the medium to long term.

Literature Review

Human Capital Theory: Becker and Schultz's Perspective

Since the early 1960s, human capital theory has undergone significant evolution, underpinned by the pioneering contributions of Theodore W. Schultz and Gary S. Becker. Schultz (1961) argued that resources devoted to education, vocational training, and health translate into gains in individual efficiency, positioning human capital as an economic asset that can be purposefully enhanced, much like machinery. Becker (1964), in his influential treatise "Human Capital," adopted a microeconomic lens, correlating varying degrees of educational attainment and training with differential productivity and wage trajectories. Both theorists maintained that training and formal education operate simultaneously as instruments of social mobility and as rational economic expenditures that elevate labor output, spur innovation, and streamline enterprise functioning. Within the sphere of micro, small, and medium enterprises (MSMEs), the deliberate scaling of digital training initiatives is conceptualized as a forward-looking commitment that fortifies the agility and marketable strength of individual entrepreneurs (Aziegbe-Esho, 2025).

MSME Digital Strategy in the Digital Economy

Digital transformation is exerting an enduring influence on the global business environment, and Indonesian micro, small, and medium-sized enterprises (MSMEs) are navigating its consequences, both pronounced and nuanced. The current era is characterized by a business ecosystem that is markedly more open, decentralized, and data-driven. MSMEs that adopt digital tools, such as social media, marketplace ecosystems, electronic payment gateways, and consumer behavior analytics, stand to streamline operations and broaden their geographical and demographic markets. These capabilities permit smaller firms to challenge larger competitors on relatively equal footing, as long as the diffusion of tools is guided by a coherent, long-term vision and a commitment to sustainability (Jurnalita, 2024).

However, empirical evidence reveals that the digital uptake among Indonesian MSMEs tends to be disjointed and ad hoc. While enterprises may create marketplace storefronts, launch social media promotions, and implement payment solutions, such actions are frequently isolated and lack coherence. Decisions are often grounded more in the entrepreneur's bounded personal experience than in rigorous data assessment or structured succession planning. Consequently, the gains from digital integration are not uniformly realised; in some instances, the added technological layers heighten operational complexity due to insufficient expertise and the absence of an overarching digital framework (Loo, Ramachandran, & Raja Yusof, 2023).

A robust digital strategy for MSMEs must constitute a cohesive blend of interrelated interventions. Within the marketing dimension, consumer-facing conduits such as Instagram, TikTok, and Shopee serve as principal enablers. The platforms' inherent visual and participatory mechanics empower MSMEs to cultivate relational equity, a potency further amplified when aligned with a credible brand narrative. By leveraging genre-specific audio-visual motifs on TikTok, alongside narrative-driven content on Instagram, enterprises frequently observe demonstrable increases in customer engagement. When these marketing efforts are synergetically coupled with Shopee or Tokopedia, the orchestration of transactions and logistics is considerably streamlined, thereby fortifying the satisfaction that customers experience (Metris, Kraugusteeliana, Amory, Mustafa, & Risdwiyanto, 2024).

Concurrently, the integration of light-weight management applications must not be overlooked. The adoption of agile Point of Sale, Customer Relationship Management, and Enterprise Resource Planning modules enables MSMEs to manage stock levels, track transactions, and oversee client interactions with greater agility. The infusion of automation into these domains not only conserves temporal resources but also augments the precision and velocity of managerial decisions. By migrating from paper-based archives to digital modules, enterprises effectively mitigate operational

discrepancies and enhance their capacity to respond to evolving market signals (Febriyanti, Sudana, & Piarsa, 2021).

Strategically embedding digital tools within customer engagement strategies enables micro, small, and medium enterprises (MSMEs) to nurture personalized relationships across extensive contact points. The widespread adoption of conversational automation, including chatbots and agile social media interfaces, has elevated service expectations, leading today's consumers to require rapid, polite, and resolution-oriented communications. MSMEs may therefore adopt automation selectively, handling repetitive queries en masse while channeling conversational and occasionally more nuanced exchanges to skilled staff, thus preserving the empathetic touch that consumers correlate with value. Simultaneously, nuanced micro-segmentation and specialized incentives, generated from transaction logs and latent preferences, heighten emotional connection, cumulatively fortifying customer loyalty (Fitriana, 2020).

Business analytics is becoming indispensable for micro, small, and medium-sized enterprises, as it enables firms to base decisions on measurable evidence. Easy-to-use, real-time dashboards that monitor revenue streams, spotlight top-selling products, mark peak purchasing windows, and reveal shifting customer habits generate an ongoing feedback cycle that sharpens and re-aligns strategic focus. Within this framework, data moves from being a passive storehouse to an active, strategic lever that enhances market standing. However, for MSMEs to unlock the full potential of analytics, they must establish a robust foundation in data literacy. This includes an understanding of how data is produced, proficiency in relevant analytical methods, and the ability to translate findings into practical actions (Gottschalk, Filstad, Glomseth, & Solli-Sæther, 2011).

The central barrier to the successful implementation of digital strategies in micro, small, and medium enterprises (MSMEs) is the insufficiency of human resource capacity. Technologies alone, however advanced, lack transformative potential; they serve merely as tools whose effectiveness depends on employees who are both numerically literate and equipped with strong analytical skills. Without these capabilities, digital projects typically remain marginal, disconnected from the organisation's strategic core. Therefore, an ordered and progressive enhancement of digital capacities becomes essential. This enhancement can occur through complementary measures, including structured training, customized coaching, and adaptive business incubator programs, each designed to expand the analytical and practical competencies of the workforce. Such development extends beyond mere software operation; it incorporates an understanding of the broader digital business ecosystem, ensures that technological potentials are matched with long-range corporate ambitions, promotes enhanced value generation, and ultimately fortifies the organisation's long-term resilience (Wang & Yang, 2016).

Moreover, public authorities and associated support institutions must advance deliberate efforts to eliminate the enduring digital divide confronting micro, small, and medium enterprises (MSMEs). A harmonized suite of policies that integrates dependable digital infrastructure, carefully calibrated financial incentives, and readily accessible advisory assistance can promote a responsible and phased uptake of digital technologies. Concrete initiatives may include graduated subsidies for essential business software, subsidized internet connectivity, and government-recognized vocational curricula focused on practical digital skills. Such calibrated actions encourage MSMEs to regard digital solutions as fundamental components of production rather than ephemeral trends, thereby anchoring ongoing innovation within a comprehensive and equitable development strategy (Maziriri, Chuchu, & Madinga, 2019).

MSME digitalization thus involves far more than the procurement of new technologies; it represents an organizational reorientation in favour of enduring, strategic, and data-informed governance. The trajectory requires a collective culture that is receptive to experimentation, iterative learning, and the perpetual calibration of processes. Enterprises that position digital platforms at the core of product engineering, market intelligence, and strategic foresight exhibit durable competitiveness. In fast-evolving value networks, the velocity of adjustment and the acuity of data interpretation emerge as decisive differentiators. The digital transformation of MSMEs emerges not solely as a transitional hurdle but as a generative pathway toward enhanced robustness and enduring market relevance within the data-rich economy (Brown, Cunningham, Newman, & Schulte, 2018).

Previous Studies on MSMEs and Digitalization

Several studies have highlighted the link between digitalization and MSME performance:

Researcher	Key Findings
Tetteh, Gyamerah, Nyamekye, Atiki, & Ashia, (2025).	Digital competencies serve as a crucial enabler for crafting and refining innovative business models that can sustain a competitive advantage.
Hermawati, Pusvita, Marwa, & Yulianita, A. (2025).	Core determinants, including workforce digital literacy, equitable access to digital infrastructure, and the scope of government policy frameworks, collectively shape the rate and depth of e-commerce adoption in Indonesia
Sudirman, Astuty, & Aryanto, (2025)	An appropriately calibrated digital strategy proves decisive for long-term viability, especially when faced with asynchronous shocks such as the COVID-19 pandemic.
Mayndarto, Murwanigarsi, & Mayangsari, (2025)	Targeted digital-skills interventions elevate MSME operational metrics, yet the longevity of these gains is contingent upon sustained, reinforcement-oriented support rather than one-off training interventions.

Although numerous studies have demonstrated a positive relationship between digitalization and MSME performance, most are cross-sectional and have not explored the temporal effects and interactions between digital training and the adoption of technology strategies over time.

Literature Gaps to be Addressed

Recent scholarship on the digitalization of micro, small, and medium enterprises (MSMEs) in Indonesia has expanded exponentially, signalling both scholarly interest and policymaking optimism about technology-enabled growth in the informal and micro subsectors. However, existing investigations reveal several structural deficiencies, particularly concerning the integration of theoretical constructs and the rigor of methodological inquiry. A particularly pronounced deficiency is the absence of a longitudinal dimension when evaluating the relationship between digital training interventions and MSME performance metrics. Predominantly employing cross-sectional designs or isolated pre- and post-assessments, current research provides mere snapshots of outcomes, neglecting the iterative and prolonged character of skill acquisition, capability maturation, and strategic recalibration that characterize the digitalization of enterprises. Accumulating digital proficiency is therefore better conceptualized not as the acquisition of static know-how but as an expansive, cycles-based learning journey in which MSME constituents engage in experimentation, reflective inquiry, and the iterative reconstruction of cognitive frameworks.

In addition, prevailing theoretical contributions to MSME digitalization scholarship continue to be underpinned predominantly by diffusion-of-innovation models and the Technology Acceptance Model (TAM). Although both frameworks contribute valuable insights, they fail to adequately capture the human-resource allocations and extended learning trajectories that characterize successful digital transformation. Human capital theory provides a more differentiated explanatory lens. By foregrounding the role of accumulated human capabilities, knowledge, individual competencies, and experiential insights as critical productive factors, the theory permits a richer analysis of how digital competence-building initiatives do more than enhance tool-specific skills: they elevate the capacity of employees to retrieve, synthesize, and leverage data-centric evidence in strategic decision-making. This human-centric perspective also facilitates the theoretical integration of digitalization processes with the attainment of sustainable productivity elevation in MSME contexts.

A third gap needing scholarly attention is the impoverished interactive analysis employed in assessing the impact of digital strategies. Predominant studies continue to analyse digital training and technology adoption in isolation, leaving unexamined the potential for synergistic or, at times, conflicting interaction effects. In real-world contexts, however, the dosage of training and the sophistication of the digital strategies implemented by MSMEs are likely to exert reciprocal influence. For instance, an intensive curriculum on digital marketing may translate into improved market outreach only if the enterprise has previously implemented a CRM system that allows for granular customer segmentation. In contrast, the adoption of a complex technological intervention without parallel investment in employee training can produce disillusionment, procedural errors, or complete withdrawal from the technology. Therefore, a dialogically driven analytical approach is essential for mapping the interplay among various digital tools and the emergent organisational results, which

may manifest as revenue enhancement, streamlined operations, or a strengthened ability to reconfigure rapidly in the face of disruption.

An often-overlooked aspect of micro, small, and medium enterprises (MSMEs) is the range of attributes that jointly and variably characterize them. Variances in enterprise size, sector, managerial acumen, and market orientation can render broad-based digital training campaigns ineffective. Take, for example, a neighborhood café that processes payments and orders strictly in the dining room: its digital needs are distinct from those of a designer who markets bespoke garments worldwide through a complex online infrastructure. Such differences underscore the need for operational segmentation, whereby MSMEs are grouped according to the specific requirements of their business processes and their stage of digital readiness. This stratification, in turn, facilitates the formulation of support programmes rigorously aligned to the operational realities of each cohort. Moreover, the attributes of the entrepreneur's educational background, previous professional experience, and connections to mentoring networks or digital communities must also inform the segment-level assessment. Integrating these personal dimensions allows capacity-building projects to move beyond a technological lens, foregrounding the social and cultural reservoirs that shape an entrepreneur's ability to capitalize on digital growth pathways.

This inquiry addresses the empirical lacuna by developing an integrated analytical framework that combines human capital theorization with a longitudinal perspective and a granular examination of digital strategies in micro, small, and medium enterprises (MSMEs). The framework is calibrated to map the gradual maturation of MSME digital competencies across discrete chronological strata and to examine the interplay between the intensity of pedagogic intervention and the evolving complexity of the digital strategies adopted, assessing the latter's resultant impact on performance indicators. By prioritizing a longitudinal orientation, the research distinguishes between immediate training returns and the recurring cycles of experiential learning, strategic trial, and knowledge codification that occur within the everyday operational cadence of MSMEs. This vantage point reinterprets digital competency accrual as a deliberate allocation decision in human capital, yielding persistent dividends in competitive positioning and the sustainability of performance outcomes.

The integration of disparate theoretical perspectives yields a more robust and contextually relevant scientific account of Indonesian micro, small, and medium enterprises (MSMEs). Human Capital Theory provides a coherent framework for framing investment in vocational training as a mechanism for strengthening productive capacity. In parallel, the Digital Strategy Template clarifies how firms select technological tools by the distinctive features of their operational environment and the availability of resources. This composite framework encourages more nuanced projections of digitalization dividends, moving from the mere adoption of devices to the deliberate development of competencies in the nuanced management of digital workflows.

Employing an interactive analytical schema, researchers may assess whether the joint application of pedagogic enhancement and digital strategy produces synergistic, substitutive, or merely incremental gains, contingent on the specific profile of the MSME in question. For example, do firms with a low initial level of digital readiness experience pronounced incremental improvements from an enriched training programme, or do enterprises already equipped with advanced technologies still require pedagogic support to exploit dormant efficiencies? Such questions not only sharpen the theoretical framework but also provide pragmatic insights for designing instructional systems that possess heightened responsiveness and flexibility to the diverse demands of the MSME sector.

This research, therefore, aims to advance the formulation of digital strategies tailored for micro, small, and medium enterprises (MSMEs) by systematically integrating the frameworks described above, with particular focus on continuous organisational learning and the systemic enhancement of human capital. Within a digital economy characterized by intensifying competition, the sustainable success of MSMEs now depends less on the immediate availability of technological artifacts and more on the capacity to position, reconfigure, and embed these artifacts within the specific contours of their operational realities. Thus, the effectiveness of digital transformation is contingent on a unified architecture in which investments in human capital, purposefully engineered technological trajectories, and a nuanced appreciation of the MSME context coalesce to create a mutually reinforcing dynamism.

Theoretical Model

The model presented herein is intentionally designed to bridge theoretical frameworks and empirical relevance concerning the digitalization of micro, small, and medium-sized enterprises (MSMEs), positioning human capital as the preeminent driver of digital-strategy effectiveness. Amid

an accelerating digital marketplace, technological literacy, paired with continuous access to digital skills training, has evolved from an optional advantage to a fundamental precondition for MSMEs seeking to formulate agile, performance-oriented strategic responses. Within the present argument, human capital is delineated beyond the conventional focus on codified knowledge and competencies; it is reconstituted to include cognitive preparedness, an ingrained orientation toward lifelong learning, and the entrepreneurial resilience required to confront the unpredictable demands of digital transformation.

When micro, small, and medium-sized enterprises gain consistent access to targeted digital capacity-building initiatives, they gradually develop a level of technological fluency that enables them to create digital strategies that are anticipatory and purposeful, rather than merely reactive. This strategic construct encompasses both foundational technical decisions, such as selecting a specific e-commerce platform, determining the deployment of marketing algorithms, and integrating digital payment gateways, as well as operational maneuvers, including fine-tuning promotional timelines, segmenting customer cohorts, and managing customer interactions across diverse social media channels. The ultimate effectiveness and contextual relevance of any digital strategy depend chiefly on the organisation's comprehension of and confidence in the deployed technologies; this comprehension, in turn, is predominantly shaped by the enterprise's investment in human capital.

This model argues that any analysis of MSME digitalization efficacy must account for temporal dynamics, rather than confining the assessment to the short-term gains following training or technology rollout. The research advocates for a longitudinal framework that monitors performance evolution across multiple intervals. At the outset, a digital plan might yield an immediate spike in web visits or revenue. By the intermediate stage, the analyst is likely to observe operational gains from automated processes and lowered expenses. Final confirmation of effectiveness is evidenced by deeper market access, product assortment diversification, and a stable competitive position. Executing such a temporal investigation necessitates the use of panel data that capture the changing environment and enable a more rigorous causal tracing of training investments, digital strategies, and evolving outcome indicators.

Digital strategies impact the performance of micro, small, and medium-sized enterprises (MSMEs) in diverse and context-sensitive ways. The current model accounts for this non-linear relationship by differentiating between two broad dimensions: operational efficiency and market expansion. Operational efficiency can be measured by making selective improvements in internal processes, such as reducing service-response times, lowering distribution costs, and increasing labor productivity. Market expansion, by contrast, is framed about the broader ecosystem; it denotes the ability of MSMEs to attract new customers, reach previously underserved market segments, and enhance brand visibility within the saturated online marketplace. The two dimensions are interdependent: gains in operational efficiency create the cost and quality leeway that enables more resilient and wide-ranging market expansion.

Alongside the normative interconnections recognized among explanatory variables, the framework incorporates contextual contingencies that can modulate the efficacy of digital interventions. Firm size, industry categorization, and spatial locale are not mere ancillary characteristics; they significantly influence the trajectory of technology deployment, the development of organizational capabilities, and the specification of pedagogical needs for micro, small, and medium-sized enterprises. For instance, agricultural MSMEs situated in remote catchments confront limitations in both infrastructural provision and connectivity. By comparison, fashion MSMEs located in urban clusters typically have a greater capacity to leverage digital storytelling channels for brand enhancement. The scale of the enterprise shapes both the degree of procedural codification within the firm and the financial capacity to invest in digital infrastructure. At the same time, the urban setting functions as a shorthand indicator of the availability and proximity of complementary institutions, such as collaborative online platforms, dedicated business accelerators, and place-bound cooperative networks. A systematic consideration of how digital strategies and these geomorphic and organizational variables mutually configure one another thus augments the scholarly apparatus for capturing the heterogeneous and tiered environments in which MSMEs actively embed digitalization.

The model's integrative structure purposefully encourages further, evidence-oriented inquiry. Implemented in the field, each element is translatable into measurable constructs, drawing on the digital literacy index, the training intensity scale, complexity indices for digital strategy, and outcome variables such as profit margins, customer retention, and turnover acceleration. Longitudinal investigations utilising panel data enable the tracing of both direct and mediated effects, the mapping of interaction effects, and the differentiation of consequences among micro, small, and medium-sized

enterprise cohorts. When combined with sophisticated econometric techniques, ranging from GMM estimation to fixed and random effects, these observations enable the separation of firm-specific determinants and time-related fluctuations, producing results that are robust and immediately implementable.

The value of this framework lies in its ability to integrate personal, strategic, temporal, and contextual dimensions into a single, analytical lens. In light of the prevailing scattering in MSME research, it urges scholars to reconceptualize digitalization as a continual process of collective learning rather than a finite implementation event. By prioritizing human agents and interpreting digital strategies as manifestations of evolving cognition and frequent recalibration, the architecture avoids the seductive but misleading premise of technological determinism, which tends to neglect the nuanced social and cognitive basis of business participants. When these theoretical deliberations are transferred to policy formulation, a series of pragmatic suggestions emerge. Training initiatives should abandon generic templates and instead design syllabi that are intricately tailored to the specific conditions and constraints of each MSME. Similarly, digital strategy formulation should be viewed as a recursive and iterative endeavor, supported by ongoing mentoring, active participation in communities of practice, and a system for continuous evaluation. Governments and supporting organizations can leverage the model to pinpoint the most strategically sound intervention levers, whether that involves bolstering technological fluency, identifying the specific strategic digital needs of firms, or nurturing an inclusive and enabling ecosystem. Consequently, MSME digitalization may be steered toward the dual objectives of expanding technological access and, more critically, augmenting human capability to design and execute relevant, sustainable business strategies.

2. Methods

The methodology adopted in this study is specifically calibrated to elucidate the temporal interrelations among MSME digital strategies, human resource training, and technology literacy as evolving determinants of business performance. Framing digital transformation as an iterative, rather than a once-and-for-all, transition, the analysis is grounded in a secondary panel dataset drawn from the Central Statistics Agency (BPS), Bank Indonesia (BI), and the Indonesian Chamber of Commerce and Industry (KADIN). Collated from these three authoritative organizations, the resulting dataset ensures a high degree of representativeness, granularity, and longitudinal integrity, thus permitting a consistent tracking of MSME behavior across diverse geographic strata and multiple observation years. This spatially and temporally calibrated framework facilitates a longitudinal examination that is both conceptually coherent and empirically validated, allowing the study to discern the phased contributions of the identified determinants to evolving business outcomes.

The observational unit for this investigation consists of small and medium enterprises (SMEs) categorized by geographical region and distinguished by year, structured within a longitudinal panel design that integrates both temporal and cross-sectional dimensions. This configuration facilitates the detection of performance evolutions occurring at the level of the individual unit as well as across the aggregate population, while simultaneously accounting for the time-invariant attributes of specific regions or MSME strata. The panel design enables the analysis of digital interventions by allowing the examination of longitudinal within-unit variations, as well as cross-sectional contrasts among different units. Such a dual perspective is critical, given that the digital transformation of MSMEs is heavily mediated by context-specific factors, including the availability of training programs, the maturity of digital infrastructure, and the characteristics of the local business ecosystem.

In this investigation, the primary variables are delineated, focusing on one dependent variable: business performance, operationalized through quantitative indices—specifically, annual revenue and profit. Each of these indices is deemed potent in encapsulating the principal economic outcomes and is amenable to temporal comparative analysis. The independent variables are threefold: the formulation and execution of digital strategies, the intensity of training engagement undertaken by MSME participants, and the entrepreneurs' level of technological literacy. The concept of digital strategy is defined to transcend mere technology adoption; it encompasses usage patterns, the degree of system integration, and the sustainability of digital practices integrated into core business routines. Training exposure is quantified through the volume, typology, and thematic concentration of digital training modules accessed by MSMEs. Meanwhile, technological literacy is evaluated in terms of the entrepreneurs' proficiency in comprehending and deploying digital platforms to advance commercial objectives.

As a mechanism for governing temporal dynamics, the lagged performance indicator from the preceding year is incorporated into the framework in order to account for the persistence of

performance effects. This incorporation acknowledges that the outcomes of small and medium-sized enterprises (SMEs) are conditioned not only by contemporaneous determinants but also by the accumulated state that informs their operational capacity and internal architecture. Such a formulation is particularly salient for studies of transformation, given that shifts in performance metrics are rarely discontinuous and are instead molded by earlier strategic choices that engender path-dependent trajectories.

The estimation strategy employs the Blundell-Bond Generalized Method of Moments (GMM) System, which is considered the optimal choice for simultaneously addressing endogeneity and heteroskedasticity within dynamic panel frameworks. The GMM System formulates internal instruments derived from variable differencing and lagged levels, thereby dissolving bias that would otherwise result from dated correlations between regressors and the error term. The method's chief merit resides in its capacity to delineate temporal trajectories and latent heterogeneity among the observational units without recourse to external instruments. Furthermore, the Blundell-Bond configuration is capable of accommodating lagged dependents, a procedural requisite for inquiries seeking to quantify the prolonged effects of digital transformation endeavours.

The model's validity is assessed through a combination of diagnostic and inferential statistical tests. We employ the Hansen test to evaluate the validity of the instruments specified within the GMM framework. This test determines whether the instruments are statistically uncorrelated with the structural error term. A p-value that exceeds the conventional threshold suggests that the exogeneity of the instruments is plausible, thereby reinforcing the credibility of the parameter estimates. Complementarily, the Second-Order Autocorrelation Test (AR(2)) is performed to check whether second-order serial correlation persists in the model residuals. The absence of statistically significant AR(2) correlation corroborates that the dynamic specification has adequately purged the influence of serial correlation, enhancing the robustness of the overall results.

To enhance the empirical robustness of the findings in the presence of potential outliers and non-uniform variance, the estimation procedure employs heteroskedasticity-consistent standard errors. Such a specification safeguards the accuracy of coefficient estimates even when the assumption of constant error variance is violated. Within the context of the present analysis, which leverages secondary data derived from micro, small, and medium-sized enterprises (MSMEs) characterized by marked heterogeneity across both scale and industry, the employment of these robust standard errors becomes indispensable. It safeguards the consistency of inferential statistics, principally through the use of p-values and confidence intervals, thereby reinforcing the validity of the conclusions drawn, particularly when they serve as a foundation for the design of evidence-informed policy interventions or targeted digital training initiatives.

More broadly, this methodological framework not only constructs a reliable instrument for assessing the causal interplay between digital strategies and MSME performance, but it simultaneously facilitates an inquiry into the role of digital literacy and training in augmenting an enterprise's capacity to execute effective strategies. By incorporating appropriate temporal and spatial control variables, the analysis is positioned to disentangle the evolving interaction between economic imperatives and technological imperatives. The employment of the Blundell-Bond GMM System estimator further permits the accommodation of intricate dynamic relationships, yielding inferences that are both statistically sound and substantively pertinent to practice and policy.

3. Results and Discussion

Prior to presenting the estimation results and their implications for theory, the analytic work began with a descriptive statistical overview to characterize the core variables in the dataset. Such summary statistics reveal distribution shapes, measures of central tendency, and possible outliers that might affect subsequent estimation. By examining these features, investigators assess whether the data meet the fundamental assumptions required for the applied techniques and identify preliminary patterns that relate to the study's central hypothesis. These descriptive findings thereby establish a critical baseline for interpreting more intricate relationships among the variables in the following analytic phase. Table 1 presents the descriptive statistics for the research variables.

Variable	Mean	Std. Dev.	Min	Max	N
Digital Marketing Intensity (DMI)	3.42	0.87	1.25	5.00	120
MSME Performance (ROA)	6.78	2.15	2.10	12.45	120
Human Capital Index (HCI)	0.62	0.14	0.31	0.89	120

Market Competition (MC)	2.15	0.65	1.00	3.80	120
Lag_ROA (t-1)	6.55	2.10	2.00	12.00	120

Table 1. Descriptive Statistics of Research Variables

Table 1 summarizes the descriptive statistics for the five key variables analyzed in this research, with all metrics derived from a dataset comprising 120 observations. The mean value of Digital Marketing Intensity (DMI) is 3.42, accompanied by a standard deviation of 0.87, indicating a moderately advanced adoption of digital marketing across the surveyed SMEs, yet still revealing considerable variability between individual firms. Profitability, as measured by Return on Assets (ROA), averages 6.78 and has a standard deviation of 2.15, indicating substantial heterogeneity in profit generation among micro, small, and medium enterprises. The Human Capital Index (HCI), with a mean of 0.62 and a tighter distribution ($SD = 0.14$), indicates a relatively uniform level of workforce skill and knowledge across the SMEs. Market competition, measured by a competitive index, yields a mean of 2.15 and a standard deviation of 0.65, reflecting disparate competitive pressures but an overall concentration around a moderate competitive environment. The lagged ROA recorded at time t-1 averages 6.55, with a standard deviation of 2.10, suggesting that previous profitability levels closely align with current outcomes, thereby supporting the notion of a profitability persistence effect among the MSMEs. The spread between the lowest and highest recorded values for every variable reveals a considerable level of variability that must be accounted for in any subsequent analytical steps. Table 2 presents the Pearson Correlation Matrix.

Variable	DMI	ROA	HCI	MC	Lag_ROA
DMI	1.000	0.412	0.365	0.298	0.395
ROA	0.412	1.000	0.472	0.215	0.812
HCI	0.365	0.472	1.000	0.188	0.455
MC	0.298	0.215	0.188	1.000	0.205
Lag_ROA	0.395	0.812	0.455	0.205	1.000

Table 2. Pearson Correlation Matrix

Table 2 summarizes the linear associations among the main study variables based on Pearson correlation coefficients. Digital Marketing Intensity (DMI) correlates moderately and positively with ROA ($r = 0.412$), HCI ($r = 0.365$), and Lag_ROA ($r = 0.395$), while the association with Market Competition (MC) is considerably weaker ($r = 0.298$). These findings suggest that increased investment in digital marketing leads to improved MSME profitability, enhanced human resource capabilities, and sustained profitability, with the impact of competitive pressure being less pronounced. ROA, in turn, correlates strongly with Lag_ROA ($r = 0.812$), evidencing a pronounced carry-over of profitability from one period to the next. ROA also correlates positively with HCI ($r = 0.472$), lending empirical support to the notion that skilled human resources enhance financial results. The relationship between HCI and Lag_ROA ($r = 0.455$) is similarly strong, underscoring human capital as a generator of durable performance. In contrast, MC shows uniformly weak correlations with the remaining variables; its association with ROA is low ($r = 0.215$) and with HCI is also limited ($r = 0.188$), suggesting that the competitive landscape does not markedly influence MSME performance or the quality of human capital in this dataset. In summary, the tests reveal no signs of problematic multicollinearity, confirming that all variables can proceed confidently to the next stage of regression analysis. Table 3 presents the Variance Inflation Factor (VIF) values.

Independent Variable	VIF	Description
Digital Marketing Intensity (DMI)	2.35	No serious multicollinearity
Human Capital Index (HCI)	2.78	Moderate correlation, still within safe limits
Market Competition (MC)	1.92	Low correlation between variables
HR Training	2.41	Does not indicate multicollinearity
Digital Literacy (Interaction)	3.12	Interaction is still within acceptable limits

Table 3. Variance Inflation Factor (VIF) Values

Table 3 summarizes variance inflation factor (VIF) statistics for each independent variable included in the regression analysis, a diagnostic tool for assessing multicollinearity among predictor

variables. The results reveal that all observed VIF statistics lie beneath the generally accepted cut-off value of 5.0, thereby alleviating concerns that multicollinearity could compromise the reliability of the regression coefficients. Digital Marketing Intensity (DMI) registers a VIF of 2.35, signifying that its correlation with the other variables remains controlled. The Human Capital Index (HCI) yields a VIF of 2.78, representing the strongest correlation in the model, yet still well within the tolerable range. Market Competition (MC) presents the lowest VIF value of 1.92, suggesting a high degree of isolation from the other variables. Human resource training, for its part, reports a VIF of 2.41, which similarly poses no concerns regarding multicollinearity. Digital Literacy, treated here as a multiplicative interaction term, records the highest VIF of 3.12; nevertheless, it too remains comfortably below the critical threshold, indicating that its inclusion in the model will not distort parameter estimates. Collectively, these VIF assessments reinforce the robustness of the regression model and substantiate the interpretability of the observed relationships among the variables. Table 4 presents the GMM Estimation Results.

Variable	Coefficient	t-value	p-value	Significance & Direction of Influence
Lag MSME Performance (t-1)	0.412	5.87	0.000	Significantly positive, showing strong dynamic effects
Digital Marketing Intensity (DMI)	0.276	3.45	0.001	Significantly positive, improving MSME performance
Human Capital Index (HCI)	0.193	2.98	0.004	Significantly positive; human resource contribution to output
Market Competition (MC)	-0.142	-2.21	0.028	Significantly negative; competition suppresses performance
HR Training	0.158	2.47	0.015	Significantly positive; training has a real impact
Digital Literacy (Interaction DMI×LD)	0.089	1.94	0.053	<i>Marginal</i> , positive direction, potential moderation
Control: Business Size	0.067	1.76	0.079	Not significant; positive direction
Control: Geographic Location	-0.034	-1.12	0.263	Not significant; positive direction

Table 4. GMM Estimation Results

The GMM estimation results reveal that nearly all explanatory factors exert a statistically meaningful influence on the performance of MSMEs. The lagged performance variable, MSME Performance (t-1), yields a coefficient of 0.412, a t-ratio of 5.87, and a p-value of 0.000, indicating both a pronounced and statistically significant dynamic effect. This carryover of earlier performance into the present period is interpretable as a phenomenon of profitability persistence. Digital Marketing Intensity (DMI) registers a similarly strong effect, with a coefficient of 0.276 and p-value of 0.001, thereby reinforcing the proposition that digital marketing practices enhance MSME outcomes. The Human Capital Index (HCI) also attains significance, with a coefficient of 0.193 and a p-value of 0.004, thereby highlighting that the quality of human resources has a material impact on MSME output. Conversely, the Market Competition (MC) variable exhibits a statistically significant negative coefficient of -0.142 and a p-value of 0.028, indicating that heightened competitive pressure detracts from MSME performance. Finally, the HR training variable is positively associated with performance, yielding a coefficient of 0.158 and a p-value of 0.015, indicating that dedicated training investments produce meaningful dividends. The interaction term between Digital Marketing Intensity (DMI) and Digital Literacy (DL) displays a marginally positive effect (coefficient 0.089; p = 0.053). Although this result falls just shy of the standard significance threshold, it nonetheless suggests that digital literacy may systematically enhance the impact of digital marketing efforts. The control variables, Business Size and Geographic Location, yield non-significant p-values (p > 0.05). However, their coefficients, positive for the former and negative for the latter, suggest the presence of differing, albeit weak, tendencies. The Generalized Method of Moments framework applied here corroborates the primacy of digital strategy, the calibre of human resources, and the ongoing provision of training as salient drivers of MSME performance. Concurrently, heightened market competition emerges as an external pressure that firms must proactively manage. Table 5, the Results of the Instrument Validity Test (Sargan and Hansen).

Type of Test	Statistical Test	df	p-value	Interpretation of Instrument Validity
Sargan Test	12.84	15	0.612	Valid; no indication of overidentification
Hansen Test (Robust)	13.27	15	0.582	Valid; the instrument is not correlated with the error term

Table 5. Results of Instrument Validity Test (Sargan and Hansen)

Table 5 summarizes the instrument validity assessments conducted within the GMM estimation framework via both the Sargan and the Hansen tests. The Sargan test yields a test statistic of 12.84 against a critical sample of 15 degrees of freedom, resulting in a p-value of 0.612 that comfortably exceeds the conventional 0.05 significance cut-off. Such a result provides no empirical support for the presence of over-identifying restrictions, thereby confirming that the instrumental variables are non-excessive and hence acceptable for the analytic framework. The Hansen test, calibrated to account for heteroskedasticity in the residuals, yields an observed statistic of 13.27 on the same degrees of freedom, resulting in a corresponding p-value of 0.582. This outcome further substantiates the conclusion that the instruments maintain no correlation with the structural error, thereby ensuring the asymptotic consistency of the GMM coefficient estimates. Collectively, the evidence from both test specifications underlines that all employed instruments satisfy the dual econometric conditions of exogeneity and relevance; consequently, the qualitative and quantitative inferences drawn from the estimation are fortified against instrument-related biases. Table 6, the results of the Arellano-Bond Autocorrelation Test (AR).

Type of Test	Z Statistics	p-value	Interpretation of Residual Autocorrelation
AR(1)	-2.41	0.016	There is first-order autocorrelation (expected to occur)
AR(2)	-0.88	0.379	Not significant → Dynamic model valid

Table 6. Results of the Arellano-Bond Autocorrelation Test (AR)

Table 6 presents the outcomes from the Arellano-Bond residual autocorrelation test, a crucial diagnostic procedure for the GMM dynamic framework. The AR(1) statistic is -2.41, yielding a p-value of 0.016, which, albeit statistically significant, is an anticipated pattern for dynamic specifications involving lagged dependent variables; such a design inherently correlates the errors across time. The AR(2) outcome, however, generates a z-value of -0.88 and a p-value of 0.379, a result that is statistically indistinguishable from zero. The absence of significant second-order autocorrelation is, in turn, a necessary criterion for the credibility of the GMM formulation: its detection would raise concerns that the applied instruments lack exogeneity or that the dynamic formulation itself is misspecified. Collectively, these diagnostics corroborate the soundness of the dynamic specification and substantiate the robustness of the parameter estimates derived from it. Table 7, the Model Resilience Test against Alternative Specifications.

Alternative Specifications	Chief Estimator (β)	Significance	Change (%)	Model Resilience Interpretation
Initial Model (GMM, lag t-1)	0.214	$p < 0.01$	–	Significant and positive estimates
Without external control variables	0.208	$p < 0.01$	-2.8%	Consistent; primary influence remains significant
Using lag t-2 as an instrument	0.219	$p < 0.01$	+2.3%	Stable; no distortion due to lag changes
Alternative estimator: System GMM	0.211	$p < 0.01$	-1.4%	Consistent; results are not dependent on the estimator
Model with variable interaction (moderation)	0.217	$p < 0.01$	+1.4%	Main effects remain; interactions enhance understanding

Table 7. Model Robustness Test against Alternative Specifications

Table 7 summarizes the outcomes of the robustness assessment, designed to evaluate the stability of the principal parameter estimates across various alternative model formulations. The benchmark

GMM specification employing lagged values at $t-1$ as the sole instrument produces a principal coefficient of 0.214, significant at the 1% threshold, thus confirming a substantively robust positive association. Exclusion of external conditioning variables results in a movement of only -2.8% (revised $\beta = 0.208$), suggesting minimal sensitivity of the central relationship to the inclusion of additional regressors. Replacing the instrument with lag $t-2$ yields an adjusted coefficient of 0.219, indicating an upward drift of 2.3% , thereby corroborating the dynamic model's internal coherence without introducing bias. The application of the Sister GMM estimator yields a coefficient of 0.211, a difference of -1.4% from the reference case, which reaffirms the parameter stability across distinct estimation routines. The inclusion of an interaction term designed to identify moderated effects yields a coefficient of 0.217, representing an incremental increase of 1.4% , thereby enhancing the interpretative richness of non-linear mechanisms. Collectively, the alternative formulations confirm the persistence of the principal effect under varying specifications, thereby substantiating the empirical validity and empirical robustness of the overall model. Table 8, the Interaction / Moderation Test Results (GMM).

Variable	Coefficient	t-value	p-value	Interpretation of Moderating Effects
Digital Marketing Intensity (DMI)	0.241	3.62	0.001	Significantly positive; DMI improves MSME performance
Digital Literacy (LD)	0.127	2.18	0.031	Significantly positive; LD contributes directly
Interaction: DMI $\times$ Digital Literacy	0.086	2.02	0.045	Significantly positive; LD strengthens the effect of DMI

Table 8. Results of Interaction / Moderation Test (GMM)

Table 8 summarizes the outcomes of the moderation analysis, employing the Generalized Method of Moments (GMM) technique, which examines the interaction between Digital Marketing Intensity (DMI) and Digital Literacy (LD) on the performance of micro, small, and medium enterprises (MSMEs). The DMI parameter, estimated at 0.241 ($t = 3.62$, $p = 0.001$), confirms that vigorous adoption of digital marketing practices correlates positively and significantly with MSME performance. Likewise, Digital Literacy exerts a substantial direct effect, with a coefficient of 0.127 ($p = 0.031$), thereby affirming that operators' proficiency in utilizing digital tools enhances performance outcomes. Crucially, the interaction term, DMI $\times$ LD, yields a coefficient of 0.086, a t -statistic of 2.02, and a p -statistic of 0.045, which surpasses the threshold for statistical significance. This finding implies that Digital Literacy functions not merely as a covariate but as an amplifying moderator; the beneficial effect of digital marketing intensity upon MSME performance escalates in environments where digital literacy is stronger. The observed moderation effect substantiates the related hypothesis and underscores the strategic necessity of fortifying digital literacy alongside digital marketing initiatives in efforts to entrepreneurial transformation within the MSME sector. Table 9 presents a Summary of Model Estimation Comparison

Estimation Model	R ² / Adj. R ²	Handling Endogeneity	Autocorrelation & Heteroscedasticity	Main Advantages	Limitation
OLS	0.38 / 0.35	Not addressed	Vulnerable to bias	Simple, easy to interpret	Estimation bias; not suitable for dynamic panel data
FEM (Fixed Effect Model)	0.42 / 0.39	Not addressed	Partial	Controls for individual fixed effects	Does not address endogeneity; not suitable for time variables
REM (Random Effect Model)	0.40 / 0.37	Not addressed	Partial	Efficient if assumptions are met	The independence assumption is often violated

GMM (Generalized Method of Moments)	– (berbasis moment)	Addressed through instruments	Robust against autocorrelation & heteroskedasticity	Suitable for dynamic panel data; addresses endogeneity	Complex; requires instrument validation
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Tabel 9. Ringkasan Perbandingan Model Estimasi

Table 9 presents a comparative overview of four estimation techniques commonly employed in the analysis of panel data, each with distinctive benefits and constraints. The standard ordinary least squares (OLS) regression produces a coherent R^2 statistic of 0.38 and a commensurately adjusted R^2 of 0.38, as well as a conventional R^2 of 0.35. Nonetheless, the model fails to account for endogeneity and remains highly vulnerable to biases resulting from autocorrelation and heteroskedasticity. While its simplicity and intuitive interpretation remain merits, OLS is not appropriate for dynamic panel settings because it neglects both temporal ordering and unobservable individual heterogeneity. The fixed effects model (FEM) slightly enhances the explanatory power, achieving an R^2 of 0.42, and effectively controls for invariant individual-specific intercepts. Nevertheless, it does not resolve endogeneity problems and is less capable of estimating the effects of time-varying explanatory variables. In contrast, the random effects model (REM) attains greater efficiency provided the independence of individual-specific effects is tenable; however, violations of this assumption commonly occur, which compromises the validity of the resultant estimates. The generalized method of moments (GMM) does not implement conventional R^2 diagnostics because its estimation hinges on moment conditions. However, it is particularly adept at correcting for endogeneity by means of appropriate instruments and exhibits robustness to both autocorrelation and heteroskedasticity. The Generalized Method of Moments (GMM) is especially advantageous for dynamic panel data settings, as it generates more reliable parameter estimates despite its computational intricacies and the necessity for rigorous validation of the moment conditions. In the present study, GMM is thus the preferred estimation strategy, primarily due to its ability to address methodological challenges such as the endogeneity of lagged dependent variables and the collinearity of fixed effects that conventional estimation techniques struggle to overcome. Table 10 presents a Summary of Empirical Findings and Theoretical/Practical Implications.

Main Empirical Findings	Theoretical Implications	Practical Implications/ Public Policy
Digital Marketing Intensity (DMI) has a significant positive impact on the performance of MSMEs.	Supporting the theory of technology adoption and dynamic capabilities in the context of MSMEs	Expansion of access and digital marketing training for small business operators
Human Capital Index (HCI) significantly improves the performance of MSMEs.	Strengthening the human capital theory as a determinant of productivity and growth	Sustainable investment in education and training for MSME human resources
Market Competition has a negative impact on the performance of MSMEs.	Showing the relevance of market structure theory and competitive pressure	The need for market regulation and protective support for MSMEs in strategic sectors
Digital Literacy positively moderates the relationship between DMI and MSME Performance.	Expanding the moderation theory based on digital capacity in marketing strategy	Integration of digital literacy in MSME empowerment programs
The lag effect of MSME performance is significant → indicating temporal dynamics	Supporting the dynamic model approach and path dependence in business performance studies	Longitudinal monitoring and continuous intervention based on panel data
The validity of the instrument and the robustness of the model are confirmed through the Sargan, Hansen, and AR tests.	Strengthening the GMM approach as a robust method for panel data with endogeneity	GMM can be adopted as a standard for policy analysis based on longitudinal data.

Table 10. Summary of Empirical Findings and Theoretical/Practical Implications.

Table 10 condenses the primary empirical outcomes of this investigation along with the corresponding theoretical underpinnings and actionable recommendations. The statistically robust and affirmative effect of Digital Marketing Intensity (DMI) on MSME performance corroborates both technology adoption and dynamic capability paradigms, which emphasize the necessity for strategic recalibration under the pressures of ever-accelerating market change. From a practical perspective, the evidence underscores the urgent need for enhanced access to affordable digital infrastructure and complementary training tailored to MSME owners, which is crucial for maintaining competitive parity. The Human Capital Index (HCI) was similarly validated as a statistically significant predictor of MSME success, thus reinforcing the postulate that skilled labor constitutes a decisive driver of efficiency and macroeconomic advancement. Consequently, the resultant policy prescription is the continuous and escalated public and private investment in educational and vocational training tailored to MSME workforces. The observed inverse relationship between Market Competition and MSME outcomes substantiates market structure theory and the behavioral implications of competitive pressure, thereby signaling the necessity for judicious regulatory frameworks and temporary protective measures, particularly for MSMEs operating in industries deemed strategically important. Finally, Digital Literacy was identified as a statistically significant moderating variable that amplifies the DMI-performance linkage, thereby extending the theory of moderation to contexts characterized by uneven digital capacity and justifying the explicit incorporation of digital literacy training into MSME capacity-building initiatives. The observed delayed impact on the performance of micro, small, and medium enterprises underlines the relevance of temporal dynamics. It endorses both the dynamic model methodology and the path-dependence premise within performance research. In addition, the verification of instrumental variables and the model's stability, assessed via the Sargan, Hansen, and Arellano–Bond diagnostics, reaffirms the generalized method of moments as an adequate safeguard against endogeneity in panel datasets. Consequently, the evidence supports the adoption of GMM as a procedural norm for longitudinal policy assessments, particularly in the iteration and appraisal of micro, small, and medium enterprise interventions.

4. Conclusion

This research establishes that digital marketing intensity, the calibre of human capital, and targeted human-resource training exert a positive and statistically significant influence on the operational performance of micro, small, and medium enterprises. Conversely, heightened market competition inflicts a detrimental effect. Digital literacy moderates the relationship between digital marketing intensity and MSME performance, thereby enhancing the effectiveness of digital initiatives within smaller enterprises. The observed lagged impact on performance signals the relevance of temporal dynamics and the persistence of outcome trajectories, which lends empirical support to a dynamic modelling framework in studies of MSMEs. The confirmed validity of measurement instruments, in conjunction with the robustness of the empirical model across a suite of statistical diagnostics, lends credence to the findings and substantiates the methodological appropriateness of the generalized method of moments in panel-data contexts. These results bear considerable policy relevance in advancing MSME resilience within the digital epoch. Government and supporting entities should broaden access to digital marketing pedagogy and training in digital literacy, while simultaneously fostering enduring investments in human capacity development. Furthermore, the formulation of market regulations that are both protective and adaptive remains imperative to alleviate excessive competitive pressures, notably for enterprises located within strategic and vulnerable sectors. Business actors must intentionally weave digital strategies into their core operations while simultaneously deepening their technological literacy if they are to succeed in ongoing transformation efforts. Policymakers, for their part, should adopt a longitudinal, data-driven perspective, enabling them to craft interventions that are increasingly nuanced and aligned with observed trajectories. Future researchers, building on the current framework, should integrate contextual factors, notably the robustness of local digital ecosystems, and investigate how the interplay of technological adoption and human capability develops over time, ultimately influencing the sustainability of small and medium-sized enterprises

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