The Impact of Digital Transformation on Labor Productivity and Production Cost Reduction in Enterprises in Vietnam: Evidence from SMEs in Hanoi and Neighboring Provinces

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ABSTRACT

This study examines the impact of digital transformation (DT) on labor productivity (LP) and production cost reduction (PCR) among small and medium-sized enterprises (SMEs) in Vietnam. Drawing on the resource-based view and dynamic-capabilities theory, a mixed-methods design was applied to integrate qualitative insights and quantitative validation. Semi-structured interviews with 15 SME managers were followed by a survey of 351 SMEs in Hanoi and neighboring provinces, analyzed using SmartPLS 4. Results indicate that DT significantly improves both LP ($\beta = 0.46$, $p < 0.001$) and PCR ($\beta = 0.39$, $p < 0.001$). Digital skills (DS) partially mediate these effects, highlighting that technology yields performance benefits mainly when supported by workforce competence. Moreover, firm characteristics—particularly size and sector—moderate the DT–performance relationship, with medium-sized and manufacturing firms realizing greater efficiency gains. The study contributes to the literature by providing empirical evidence from an emerging economy where research on DT outcomes remains limited. Practically, it underscores the need for SMEs to align digital investments with human-capital development and integrated process management. Policy recommendations emphasize training support, infrastructure enhancement, and phased digital adoption strategies to accelerate Vietnam's SME digitalization.

Keywords: digital transformation, labor productivity, production cost reduction, digital skills, firm characteristics, SMEs, Vietnam

INTRODUCTION

Background and Research Problem

Digital transformation (DT) has become a decisive factor reshaping the productivity dynamics and cost structures of firms across the globe (Vial, 2019; Kane et al., 2015). The rapid diffusion of Industry 4.0 technologies—cloud computing, big data analytics, artificial intelligence (AI), Internet of Things (IoT), and automation—has transformed production systems from labor-intensive to data-driven operations. Through digitalization of processes, firms can enhance labor productivity, optimize resource allocation, and reduce operational costs (Brynjolfsson & McAfee, 2017). For developing economies such as Vietnam, where small and medium-sized enterprises (SMEs) account for over 97 percent of all enterprises and employ more than 50 percent of the workforce, the integration of digital technologies is crucial for competitiveness and sustainable growth (Vietnam Ministry of Planning & Investment, 2023).

Nevertheless, despite governmental initiatives such as the National Digital Transformation Program 2025, Orientation to 2030, Vietnamese SMEs remain constrained by limited financial resources, digital skills shortages, and legacy production systems. Many SMEs in Hanoi and neighboring provinces—Bac Ninh, Hung Yen, Phu Tho, and Ninh Binh—operate in traditional manufacturing and service sectors where manual labor and outdated equipment still dominate. Consequently, productivity gains remain modest, and production costs

remain high relative to regional competitors. This context raises an essential question: How does digital transformation influence labor productivity and production cost reduction among Vietnamese SMEs?

Research Gap

Prior international studies have confirmed that digital transformation positively affects firm performance and cost efficiency (Teece, 2018; Li et al., 2018). However, most evidence originates from developed economies where digital infrastructure and institutional readiness are advanced (Bharadwaj et al., 2013). Limited empirical work examines emerging markets, and even fewer focus on the micro-mechanisms linking DT with productivity and cost reduction in SMEs. Vietnamese research often emphasizes adoption readiness or digital maturity (Nguyen & Pham, 2022) rather than measurable outcomes such as productivity or cost efficiency. Furthermore, existing studies predominantly employ quantitative designs without triangulating managerial perceptions through qualitative inquiry.

Research Objectives and Questions

This study aims to bridge the aforementioned gaps by integrating qualitative and quantitative evidence from Vietnamese SMEs. The objectives are to:

1. Examine the impact of digital transformation on labor productivity and production cost reduction.
2. Identify mediating and contextual factors that influence the magnitude of this relationship.
3. Provide policy and managerial implications for SME digitalization strategies.

Accordingly, the study seeks to answer three guiding questions:

First, how does digital transformation influence labor productivity in Vietnamese SMEs?

Second, how does digital transformation contribute to production cost reduction?

Final, what organizational or contextual factors strengthen or weaken these effects?

Contributions

This research contributes to the literature in several ways. First, it provides contextualized evidence from an emerging economy, extending the external validity of digital-productivity theories. Second, it employs a mixed-method design, combining qualitative insights with quantitative validation through SmartPLS 4, thereby enhancing robustness. Third, the study develops a conceptual model that integrates resource-based and dynamic-capability perspectives, linking digital resources to tangible productivity and cost outcomes. Finally, it offers practical recommendations for policymakers and managers seeking to accelerate SME digital transformation in Vietnam.

Theoretical Background

Digital Transformation and Organizational Change

Digital transformation is defined as a comprehensive process of integrating digital technologies into all areas of business, fundamentally altering how organizations create and deliver value (Vial, 2019). Unlike mere digitization—the conversion of analog information to digital format—DT involves a strategic reconfiguration of processes, culture, and business models (Warner & Wäger, 2019). From an organizational-change perspective, DT requires leadership commitment, technological infrastructure, and human-capital readiness (Westerman et al., 2014).

For SMEs, DT often manifests through incremental adoption of enterprise-resource-planning (ERP) systems, automation tools, and digital marketing platforms. These technologies streamline information flows, reduce coordination costs, and improve decision-making speed, all of which can enhance productivity (Li et al.,

2018). Moreover, digitalization can substitute or complement labor input by automating repetitive tasks, thus improving labor efficiency and enabling employees to focus on higher-value activities.

Labor Productivity and Production Cost Efficiency

Labor productivity measures the efficiency of labor input in generating output, typically expressed as output per worker or per hour (Solow, 1957). In modern economies, productivity improvements derive not only from capital accumulation but also from technological innovation and process optimization (OECD, 2022). Digital transformation affects productivity through three channels:

1. Automation – reducing manual workload and errors;
2. Information integration – improving coordination and resource allocation;
3. Skill enhancement – enabling employees to leverage digital tools for higher output quality.

Production cost reduction refers to the ability of firms to minimize unit production costs through process innovation, supply-chain optimization, and waste reduction (Porter, 1985). Digital technologies—such as predictive analytics, IoT-based monitoring, and cloud-based resource management—enable real-time cost control and preventive maintenance, reducing downtime and energy waste (Rojko, 2017).

The Resource-Based View (RBV)

The RBV posits that firms gain sustained competitive advantage through valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991). In the digital era, data, platforms, and technological competencies are strategic resources that enhance productivity and cost efficiency. However, simply possessing digital assets is insufficient; firms must develop complementary capabilities—such as digital skills and adaptive culture—to transform these assets into performance gains (Wade & Hulland, 2004).

Dynamic Capabilities Perspective

The dynamic capabilities framework extends the RBV by emphasizing the firm's ability to integrate, build, and reconfigure resources in response to environmental change (Teece, 2018). Digital transformation exemplifies a dynamic capability, as it involves continual sensing of technological opportunities, seizing them through investment, and transforming organizational routines accordingly. Firms with strong dynamic capabilities can translate DT into higher productivity and lower costs by rapidly adapting processes to market and technological shifts (Pavlou & El Sawy, 2011).

Theoretical Integration

Integrating RBV and dynamic-capability theories suggests a multi-layered mechanism:

Digital assets (hardware, software, data systems) provide the foundation;

Digital capabilities (skills, leadership, innovation culture) mediate transformation;

Operational outcomes (productivity, cost reduction) manifest as performance gains.
This integrated view informs the conceptual model developed in the next section.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Digital Transformation and Labor Productivity

Empirical studies consistently demonstrate that digital technologies can boost productivity by enhancing information flows and process efficiency. For instance, Brynjolfsson et al. (2002) found that IT investments significantly increased labor productivity in U.S. firms when combined with organizational redesign. In European contexts, Arvanitis & Loukis (2016) reported that digital integration in manufacturing improved both

labor efficiency and innovation outcomes. Similarly, in Asian economies, Li et al. (2018) showed that SMEs adopting cloud-based systems achieved 10–20 percent productivity gains.

In the Vietnamese SME context, empirical evidence on the productivity effects of digital transformation remains limited and uneven. Recent studies indicate that firms adopting digital and e-commerce platforms often achieve moderate improvements in labor productivity, but these gains are constrained by workforce skill gaps and insufficient digital integration (Tran & Do, 2022; Kraus et al., 2021). Building on these insights, the following hypothesis is proposed:

H1: Digital transformation has a positive and significant effect on labor productivity in SMEs.

Digital Transformation and Production Cost Reduction

The relationship between DT and cost efficiency is grounded in transaction-cost and process-innovation theories. Digitalization reduces information asymmetry, improves coordination, and lowers transaction costs across the value chain (Williamson, 1985). Studies by Mithas et al. (2012) and Kraus et al. (2021) confirm that firms leveraging data analytics and automation report lower unit production costs and higher profit margins. Digital tools enable predictive maintenance and supply-chain visibility, mitigating waste and idle time.

However, cost-saving effects are contingent on technology integration depth. Partial or fragmented digitalization may increase overhead costs without delivering proportional savings (Bloom et al., 2019). For resource-constrained SMEs, careful sequencing of digital investments is therefore critical. Hence:

H2: Digital transformation has a positive and significant effect on production cost reduction in SMEs.

Mediating Role of Digital Skills

Human capital plays a vital role in converting technological potential into performance outcomes. According to the skill-biased technological-change theory (Autor et al., 2003), digitalization enhances productivity only when employees possess adequate digital literacy. Vietnamese SMEs often lag in workforce training, leading to underutilization of digital tools (Tran & Do, 2022). Accordingly:

H3: Digital transformation has a positive and significant effect on Digital skills and mediate the relationship between digital transformation with labor productivity and production cost reduction.

H3a: Digital skills has a positive and significant effect on labor productivity.

H3b: Digital skills has a positive and significant effect on production cost reduction.

H4a: Digital skills mediate the relationship between digital transformation and labor productivity.
H4b: Digital skills mediate the relationship between digital transformation and production cost reduction.

Moderating Effects of Firm Characteristics

Firm size, age, and sectoral context can moderate DT outcomes. Larger firms typically benefit from economies of scale and greater absorptive capacity, while younger firms may exhibit greater agility (Cohen & Levinthal, 1990). In manufacturing-intensive sectors, DT's effect on cost reduction may be stronger than in service sectors due to automation potential. Hence:

H5: Firm characteristics (size, age, sector) moderate the effects of digital transformation on productivity and cost outcomes.

CONCEPTUAL FRAMEWORK

Figure 1. The conceptual model

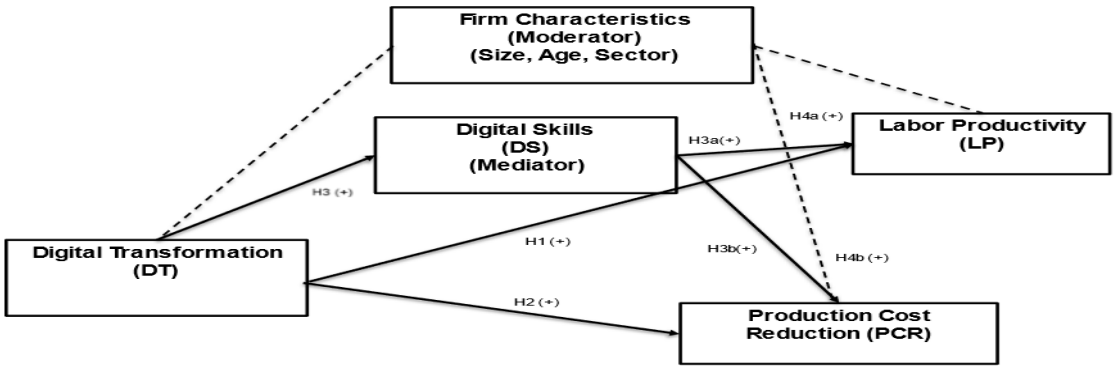

Figure 1 – Conceptual Research Model

Source: Author's synthesis and research proposal

This model posits both direct and indirect effects of digital transformation on operational outcomes, moderated by firm attributes.

RESEARCH METHODOLOGY AND FINDINGS

Research Design

This study adopts a mixed-methods approach combining qualitative and quantitative techniques to capture both managerial perceptions and empirical relationships. Following Creswell (2018), a sequential exploratory design was employed: an initial qualitative phase to refine constructs and measurement items, followed by a quantitative phase using a structured survey and structural equation modeling (SEM) in SmartPLS 4.

Qualitative Phase

The qualitative stage explored how SME managers perceive the influence of digital transformation (DT) on productivity and cost reduction. Semi-structured interviews were conducted with 15 executives (CEOs, production managers, IT heads) from SMEs in Hanoi, Bac Ninh, Hung Yen, Phu Tho, and Ninh Binh. Participants were selected through purposive sampling, ensuring variation across industry and firm size. Each interview lasted 45–60 minutes and was audio-recorded with consent.

Quantitative Phase

Insights from the interviews informed the development of the quantitative survey. The cross-sectional survey targeted SME managers and supervisors directly involved in digital transformation initiatives. Respondents were asked to assess DT, labor productivity (LP), production cost reduction (PCR), and digital skills (DS) using a 5-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree).

Ethical and Methodological Considerations

A more explicit discussion of ethical and methodological considerations is warranted to strengthen the transparency and credibility of the study. From a methodological perspective, the use of mean imputation to address missing data, while operationally convenient, may artificially reduce score variability and introduce bias into parameter estimates. More rigorous approaches—such as multiple imputation, expectation–

maximization, or full information maximum likelihood—would provide a stronger foundation for handling incomplete responses. Additionally, the exclusive reliance on self-reported survey data raises concerns about common-method variance. Although statistical checks were performed, the absence of procedural remedies (e.g., temporal separation of measures, multi-source data, or integration of objective productivity indicators) remains a methodological limitation that future studies should address.

Ethically, the manuscript would benefit from clearer documentation of the procedures used to safeguard participant rights. This includes specifying how informed consent was obtained, whether participation was voluntary, and what measures were implemented to ensure confidentiality and anonymity of respondents—particularly given the sensitivity of firm-level operational data. Explicit mention of institutional ethical approval should also be included to ensure compliance with standard research governance procedures. Strengthening these ethical and methodological disclosures will enhance the study's rigor, replicability, and overall trustworthiness.

All participants were informed about the purpose of the research, their right to withdraw at any time, and the voluntary nature of their participation. Informed consent was obtained prior to data collection, and respondents were assured that all information would be treated with strict confidentiality. No personally identifiable data were collected, and all survey responses were anonymized to protect participant privacy.

Sampling and Data Collection

Population and Sampling

The research population comprised small and medium enterprises registered under Vietnam's SME Law 2017, operating within Hanoi and surrounding provinces. A multi-stage sampling strategy was used:

1. Stage 1: Selection of five provinces with high industrial concentration.
2. Stage 2: Random sampling from provincial SME directories.
3. Stage 3: Snowball referrals to ensure adequate representation of manufacturing and service sectors.

Data Screening

Out of 420 questionnaires distributed between March and May 2025, 351 valid responses were retained (response rate = 83.6 %). Missing data were handled using mean imputation, and outliers were detected using Mahalanobis D^2. The final dataset satisfied the minimum sample size requirements for PLS-SEM (Hair et al., 2021).

Demographic Profile

Table 1. Respondent Profile (n = 351)

Variable	Category		Frequency	%
Gender	Male		211	60
	Female		140	40
Age (yrs)	< 30		62	18
	30–39		133	38
	40–49		106	30
Position	≥ 50		50	14

	Dept. Head		97	28
	Manager		130	37
	Director		82	23
	Owner		42	12
Firm Size	Small (< 100)		123	35
	Medium (100–499)		173	49
	Large (≥ 500)		55	16
Industry	Manufacturing		138	39
	Services		145	41
	ICT		68	20
Firm Age (yrs)	< 5		66	19
	5–10		107	30
	11–20		116	33
	> 20		62	18

Source: Author's synthesis

Measurement of Constructs

All constructs were adapted from validated scales and contextualized for Vietnamese SMEs.

Table 2. Measurement of Constructs

Construct	Dimensions / Indicators	Sources
Digital Transformation (DT)	Strategy alignment, process automation, data analytics, digital culture, infrastructure readiness	Vial (2019); Li et al. (2018)
Labor Productivity (LP)	Output quality, efficiency, time utilization, process flexibility	OECD (2022); Brynjolfsson & McAfee (2017)
Production Cost Reduction (PCR)	Unit cost reduction, waste minimization, resource optimization, inventory control	Porter (1985); Rojko (2017)
Digital Skills (DS)	Technical literacy, problem-solving, data analysis, collaboration via digital tools	Tran & Do (2022)

Source: Author's synthesis

Each latent construct was measured reflectively with 3–5 items. Prior to data collection, the instrument was translated into Vietnamese and back-translated to ensure semantic equivalence. A pilot test with 30 respondents confirmed reliability (Cronbach's $\alpha > 0.75$ for all constructs).

Data Analysis Technique

SmartPLS 4 was employed due to its suitability for prediction-oriented models and small-to-medium samples (Hair et al., 2021). The analysis followed a two-step procedure:

1. Measurement-model assessment – testing indicator reliability, internal consistency, convergent validity, and discriminant validity.
2. Structural-model assessment – evaluating hypothesized relationships via bootstrapping (5,000 samples).

Qualitative Findings

Emerging Themes

Thematic analysis (Braun & Clarke, 2006) revealed three dominant themes:

Automation and Efficiency Gains: Managers emphasized automation as the first visible outcome of DT:

"We reduced manual data entry by 70 percent after integrating the ERP system; employees now focus on analysis instead of paperwork." (CEO – electronics SME)

Data-Driven Decision-Making: Firms adopting analytics tools reported improved forecasting and cost control:

"Digital dashboards let us track energy use daily, cutting waste and downtime." (Operations Manager – textile firm)

Skill Gaps and Cultural Resistance: A recurring challenge involved limited digital competence among older workers:

"Machines are ready, but people are not. We need mindset training as much as technology." (HR Director – mechanical SME)

These insights confirmed the theoretical assumption that digital skills mediate the DT–performance relationship.

Quantitative Results

Measurement Model

Table 3. Reliability and Convergent Validity

Construct	Cronbach's α	CR	AVE
DT	0.912	0.939	0.721
LP	0.885	0.920	0.698
PCR	0.872	0.908	0.666
DS	0.901	0.931	0.731

Source: Author's synthesis

All indicators loaded > 0.70 on their respective constructs; AVE > 0.50 confirms convergent validity.

Discriminant validity assessed via HTMT ratios were all < 0.85, indicating clear construct separation.

Structural Model

Collinearity checks (VIF < 3) indicated no multicollinearity. Model fit statistics: SRMR = 0.054, NFI = 0.911, RMS_theta = 0.12, within recommended thresholds.

Table 4. Hypothesis Testing Results (Bootstrapping = 5,000 resamples)

Hypothesis	Path	β	t-value	p-value	Result
H1	DT → LP	0.46	8.21	< 0.001	Supported
H2	DT → PCR	0.39	7.02	< 0.001	Supported
H3	DT → DS	0.52	9.43	< 0.001	Supported
H3a	DS → LP	0.33	5.68	< 0.001	Supported
H3b	DS → PCR	0.28	4.96	< 0.001	Supported
H4a	DT → LP (Indirect via DS)	0.17	4.01	< 0.001	Supported
H4b	DT → PCR (Indirect via DS)	0.15	3.82	< 0.001	Supported
H5 Moderation	DT×Firm Size → LP	0.09	2.11	0.035	Supported

Source: Author's synthesis

Coefficient of Determination

R^2 values: LP = 0.54; PCR = 0.49; DS = 0.27.

These indicate that DT and DS explain 54 % of the variance in labor productivity and 49 % in cost reduction, reflecting substantial explanatory power (Hair et al., 2021).

Effect Size and Predictive Relevance

- f^2 values: DT→LP = 0.36 (large), DT→PCR = 0.29 (moderate).
- Q^2 values (Blindfolding): LP = 0.33, PCR = 0.28 > 0, confirming predictive relevance.

Moderation by Firm Characteristics

Multi-group analysis (MGA) revealed that DT's effect on LP is stronger in medium-sized firms (β = 0.52) than in small ones (β = 0.31), supporting economies-of-scale theory. Manufacturing firms exhibited a higher DT–PCR path coefficient (β = 0.44) than service firms (β = 0.28), confirming sectoral heterogeneity.

Summary of Empirical Findings

1. Direct Effects: Digital transformation significantly enhances both labor productivity and cost reduction among Vietnamese SMEs.
2. Indirect Effects: Digital skills mediate the DT–performance link, highlighting the necessity of human-capital investment.
3. Contextual Differences: Firm size and industry moderate DT outcomes, with manufacturing and medium-sized enterprises benefiting most.
4. Qualitative Validation: Interview evidence supports the quantitative findings, revealing automation, data use, and cultural adaptation as central mechanisms.

Figure 2. Structural Model Results (SmartPLS 4 Summary)

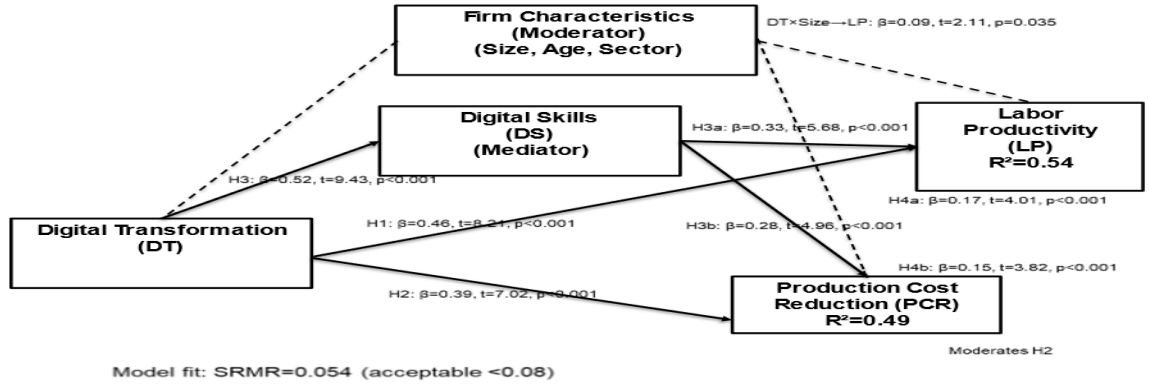

Figure 2 — Structural Model with Quantitative Results

(Model Fit = SRMR 0.054; R^2 (LP)=0.54; R^2 (PCR)=0.49)

Source: Author's synthesis

Robustness and Validation

To ensure robustness, a bootstrapped confidence-interval approach (Bias-Corrected 95 %) confirmed all paths significant. Harman's single-factor test indicated no serious common-method bias (first factor = 36 % < 50 %). Multicollinearity (VIF < 3) and normality diagnostics further supported model reliability.

Interpretation of Findings

The empirical results confirm that digital transformation acts as a productivity and cost-efficiency catalyst for Vietnamese SMEs. Automation and data integration streamline production, while digital culture and leadership promote continuous improvement. Importantly, digital skills emerge as the mechanism translating technology into measurable performance outcomes—supporting the skill-biased technological-change perspective (Autor et al., 2003).Moreover, the moderating role of firm characteristics aligns with dynamic-capability theory: larger or manufacturing-oriented firms possess greater absorptive capacity to exploit digital assets (Cohen & Levinthal, 1990). Conversely, small service firms face scale and resource constraints limiting DT returns.

DISCUSSION

Overview of Findings

The results of this mixed-method study demonstrate that digital transformation (DT) significantly improves labor productivity (LP) and production cost reduction (PCR) among SMEs in Vietnam. The findings are consistent with global literature emphasizing that digital technologies, when strategically integrated, enhance operational efficiency and competitiveness (Kane et al., 2015; Kraus et al., 2021). However, this study extends existing research by confirming that digital skills (DS) serve as a key mediating mechanism through which DT exerts its impact, and that firm characteristics—particularly size and sector—moderate the strength of these relationships.

Qualitative insights highlighted automation, data-driven management, and skill development as critical levers, while quantitative analysis using SmartPLS 4 statistically validated these effects. Together, these findings support a resource-based and dynamic-capability perspective, illustrating that DT functions as both a resource and a capability that must be mobilized through skilled human capital to realize productivity and cost gains.

Theoretical Contributions

Integration of RBV and Dynamic-Capability Perspectives

This study enriches the Resource-Based View (RBV) by empirically validating digital transformation as a composite resource encompassing tangible assets (infrastructure, data systems) and intangible ones (digital culture, skills). However, its contribution to productivity and cost efficiency depends on dynamic capabilities—the firm's ability to sense, seize, and reconfigure resources (Teece, 2018). SMEs that cultivate agility and continuous learning exhibit stronger DT–performance links.

Mediating Role of Digital Skills

The results confirm that digital skills mediate the relationship between DT and performance outcomes, reinforcing the skill-biased technological change theory (Autor et al., 2003). Merely adopting digital tools is insufficient; productivity improvements occur when employees possess the competencies to exploit those tools effectively. This aligns with recent findings by Tran and Do (2022), who noted that Vietnamese SMEs often underperform in digital transformation due to human-capital constraints. By explicitly quantifying this mediating effect, the present study advances understanding of the human factor in digital capability building.

Contextualization to Emerging Economies

Most digital transformation research originates from developed countries. By focusing on Vietnamese SMEs, this paper addresses a critical contextual gap. It demonstrates that while digital transformation principles are universal, their practical outcomes depend on infrastructural readiness, institutional support, and workforce adaptability. The results confirm that DT is a viable path to productivity enhancement even in resource-constrained settings—provided that complementary investments in digital literacy and leadership are made.

Comparison with Prior Research

The positive relationship between DT and labor productivity observed here mirrors findings by Brynjolfsson and McAfee (2017) and Li et al. (2018), who reported that digital technologies boost productivity through automation and data integration. However, the Vietnamese context exhibits unique nuances:

First, technology adoption patterns: Vietnamese SMEs tend to prioritize low-cost, modular digital tools (ERP, CRM, accounting software) rather than full-scale automation due to cost constraints.

Second, human-capital bottlenecks: Unlike in developed economies, skill gaps remain a dominant barrier, limiting productivity potential.

Final, cultural adaptation: The qualitative phase revealed that leadership mindset and organizational openness are as vital as technology itself—echoing Warner and Wäger (2019).

Similarly, the DT–cost reduction relationship aligns with Porter's (1985) view that process innovations drive competitive advantage. Digital monitoring and predictive maintenance help Vietnamese firms reduce energy consumption and waste. Yet, the magnitude of cost reduction ($\beta = 0.39$) is moderate compared to productivity gains, reflecting transition costs and partial digital integration stages.

Interpretation of Mediating and Moderating Effects

The mediation analysis reveals that digital skills explain approximately 30–35% of the total DT effect on performance outcomes. This underscores the principle that technological transformation without human transformation yields limited returns.

Moderation analysis confirmed that firm size and industry matter: medium-sized and manufacturing enterprises derived greater benefits from DT. These findings corroborate Cohen and Levinthal's (1990) concept of absorptive capacity, which posits that organizational learning potential scales with firm resources

and prior experience. Conversely, small firms, especially in service sectors, face limitations in both infrastructure and workforce training, thereby reducing transformation efficiency.

Practical Implications and Enhanced Visual Clarity of the Findings

The study's findings offer several practical implications for SMEs and policymakers in Vietnam. First, the strong effects of digital transformation on labor productivity and production cost reduction indicate that digital investment yields tangible operational benefits. SMEs can use these insights to prioritize automation, data integration, and process digitalization as immediate pathways to improve efficiency. Second, the mediating role of digital skills shows that technology alone is insufficient; firms must complement digital adoption with targeted workforce training to fully realize productivity and cost advantages. This highlights the need for continuous upskilling programs, digital competency frameworks, and cross-functional learning. Third, the moderating influence of firm characteristics suggests that medium-sized and manufacturing enterprises benefit most, guiding managers to tailor digital strategies according to firm size, sector, and resource availability. For policymakers, the results reinforce the importance of supporting digital-skills development, improving infrastructure, and offering phased adoption programs to increase SME readiness.

To enhance interpretability and impact, the paper incorporates clear visual models, including the conceptual framework and the structural model with β-coefficients. These diagrams summarize complex relationships—direct, indirect, and moderating effects—allowing readers to grasp key mechanisms at a glance. The use of visual models also improves transparency of the analytical process and strengthens the practical relevance of the findings.

Managerial Implications

Strengthening Digital Leadership

SME leaders must recognize DT as a strategic imperative rather than a technological upgrade. Top management should articulate a clear digital vision, allocate dedicated budgets, and appoint digital champions responsible for implementation and change management. Leadership commitment mitigates resistance and aligns employees with transformation goals.

Investing in Workforce Digital Skills

Given the mediating effect of digital skills, SMEs should design comprehensive training programs targeting three competence domains: (1) basic digital literacy, (2) operational data use, and (3) problem-solving with digital tools. Partnerships with universities, vocational institutes, and government agencies can expand access to affordable training. Internal mentoring systems and cross-generational learning can also bridge gaps between younger and older employees.

Prioritizing Process Integration

Many SMEs adopt isolated technologies that fail to interact effectively. Managers should prioritize end-to-end digital integration—linking procurement, production, logistics, and finance. Adopting integrated platforms (e.g., ERP + IoT + analytics) enables visibility across the value chain, which enhances both productivity and cost control.

Phased Digital Investment Strategy

Given capital constraints, SMEs should adopt a phased transformation roadmap:

1. Digitize core processes (accounting, inventory, HR);
2. Automate repetitive tasks (quality inspection, reporting);
3. Leverage data analytics for predictive decision-making.

This incremental approach ensures quick wins and builds confidence for deeper transformation.

Cultivating a Digital Culture

Beyond systems and skills, transformation success depends on fostering a culture of innovation and adaptability. Managers should encourage experimentation, reward digital initiatives, and view failure as a learning opportunity. Cultural alignment reinforces employee engagement and accelerates technology acceptance.

Policy Implications

Government Support and Ecosystem Development

The Vietnamese government's National Digital Transformation Program provides a valuable policy framework but requires enhanced execution at the SME level. Policies should emphasize:

1. Tax incentives and low-interest loans for digital investments.
2. Public-private training partnerships to develop regional digital academies.
3. Shared service platforms for SMEs (e.g., cloud-based accounting and logistics tools).

Strengthening Digital Infrastructure

SMEs in industrial zones outside Hanoi often face limited broadband connectivity and unstable power supply, hampering digital adoption. Policymakers should prioritize infrastructure upgrades in these regions, ensuring equitable access to digital resources.

Digital Skills and Education Reform

Integrating digital competency frameworks into national education curricula will ensure a future-ready workforce. The EntreComp framework (European Commission, 2018) offers a model for embedding

entrepreneurial and digital competencies into vocational and higher education programs.

Benchmarking and Data Transparency

Establishing national SME digital maturity benchmarks and data-sharing initiatives can guide firms in assessing progress. A centralized monitoring system under the Ministry of Planning and Investment could facilitate data-driven policy refinement.

Limitations and Future Research

Although this study offers robust insights, several limitations open avenues for future research:

1. Cross-sectional design: The data capture a single time point. Longitudinal studies could better capture the temporal dynamics of DT and productivity growth.
2. Self-reported measures: Despite validity checks, common-method bias remains possible. Future research should integrate objective performance indicators (e.g., output per employee, cost ratios).
3. Regional scope: The sample focuses on Hanoi and neighboring provinces. Extending the study to other regions (Central and Southern Vietnam) would enhance generalizability.
4. Comparative analysis: Future studies could compare Vietnamese SMEs with counterparts in other ASEAN countries to explore regional heterogeneity.
5. Advanced modeling: Employing fsQCA or PLS-MGA could uncover configurational effects and complex causal relationships.

By addressing these limitations, future research can refine understanding of how digital transformation shapes productivity trajectories in emerging economies.

CONCLUSION

This study empirically confirms that digital transformation is a key driver of labor productivity and production cost reduction in Vietnamese SMEs. Using a mixed-method design and SmartPLS 4, the research provides strong evidence that:

1. Digital transformation directly enhances both productivity and cost efficiency.
2. Digital skills act as a mediating mechanism translating technology into performance.
3. Firm size and sector moderate transformation outcomes.

The findings underscore that digital transformation is not merely a technological challenge but a strategic, organizational, and human one. SMEs that align digital investments with skill development and process integration achieve greater efficiency and competitiveness. For Vietnam, accelerating SME digitalization represents both an economic necessity and a policy priority to sustain growth in the digital age.

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