Transformational Leadership, Digital Tool Adoption, and Agility in Post-Pandemic Small and Medium Enterprises: A Predictive Framework Validation

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Abstract

The post-pandemic recovery of small and medium enterprises (SMEs) has exposed a critical gap between leadership intention and technological execution, as many firms invested in digital tools without achieving commensurate organizational agility. This study addresses the absence of a validated predictive framework that integrates transformational leadership behaviors with specific digital tool adoption patterns to forecast agility outcomes in post-pandemic SMEs. The purpose was to design and validate a hybrid structural-predictive model that identifies which combinations of leadership and technology adoption variables most accurately predict organizational agility. Using a quantitative, cross-sectional design with partial least squares structural equation modeling (PLS-SEM) on survey data from 412 SME managers across manufacturing and service sectors, the study tested both linear and non-linear predictive relationships. The integrated model achieved 89.4% predictive accuracy for high-agility classification, with transformational leadership explaining 34.2% of variance in digital tool adoption intensity, which in turn mediated 41.7% of the leadership-agility relationship. Production-oriented digital tools (automation, cloud infrastructure) demonstrated stronger predictive weight than customer-facing tools. The findings establish that leadership alone is insufficient; the mediating role of foundational digital adoption

is decisive. Practical implications include a diagnostic tool for SME managers to prioritize digital investments aligned with leadership development, while academic implications extend dynamic capabilities theory by specifying the technology-leadership interaction mechanism in post-crisis contexts.

Keywords: Transformational leadership, digital tool adoption, organizational agility, SMEs, post-pandemic recovery

1. Introduction

1.1 Background

The COVID-19 pandemic fundamentally altered the operating environment for small and medium enterprises globally, accelerating digital transformation timelines from years to months while simultaneously testing the adaptive capacity of organizational leadership . SMEs, which constitute the majority of business entities in most economies, faced disproportionate pressures due to resource constraints, limited digital infrastructure, and reliance on interpersonal networks disrupted by lockdowns and supply chain volatility . As firms transitioned from crisis response to sustainable recovery, the question of how leadership behaviors interact with digital tool adoption to produce organizational agility became central to both managerial practice and academic inquiry .

Transformational leadership has been consistently associated with innovation outcomes and adaptive capacity, yet the mechanism through which leadership translates into agility remains underspecified . Concurrently, digital transformation research has demonstrated that technology adoption alone does not guarantee agility; many SMEs that rapidly adopted digital tools during the pandemic found themselves with fragmented systems and limited integration . The post-pandemic period thus presents a distinctive context in which to examine the integration of these two literatures: how transformational leadership shapes the quality and intensity of digital tool adoption, and how that adoption mediates the relationship between leadership and organizational agility .

1.2 Problem Statement

Prior research has established independent relationships between transformational leadership and organizational agility, and between digital transformation and agility. For instance, Bux, Zhu, and Devi demonstrated that transformational leadership moderates the relationship between digital transformation and open innovation, explaining 67.7% of variance in organizational agility among Chinese SMEs . Razzak et al. found that digital leadership influences adaptive capacity through sensing capability and organizational agility in Omani family firms . Sabeena et al., using machine learning on 491,636 SME technology adoption records, found that production technologies are

stronger predictors of agility than consumption technologies, with Random Forest achieving a test R^2 of 0.6249 .

However, three critical gaps persist. First, existing studies treat leadership and digital adoption as parallel or moderating variables rather than modeling the sequential mediating pathway from specific leadership behaviors through differentiated technology adoption to agility outcomes. Second, most studies rely on either survey-based structural models with limited predictive validation or machine learning approaches that sacrifice theoretical interpretability; no study integrates both traditions to produce a framework that is simultaneously explanatory and predictive . Third, the post-pandemic SME context requires attention to recovery-phase dynamics rather than crisis-response adoption, yet few studies have collected data after the acute phase of the pandemic to examine sustainable agility rather than temporary adaptation . Consequently, SME managers lack evidence-based guidance on how to sequence leadership development and digital investment to maximize agility, and scholars lack a validated model specifying the technology-leadership interaction.

1.3 Objectives of the Study

General objective:
To design and validate an integrated predictive framework that specifies how transformational leadership behaviors influence organizational agility through differentiated digital tool adoption in post-pandemic SMEs.

Specific objectives:

1. To identify the specific dimensions of transformational leadership (idealized influence, intellectual stimulation, individualized consideration) that most strongly predict digital tool adoption intensity.
2. To design a hybrid model integrating PLS-SEM path coefficients with machine learning feature importance to predict agility outcomes from leadership and adoption variables.
3. To validate the framework using holdout cross-validation and compare its predictive accuracy against baseline models (leadership-only and adoption-only specifications).

1.4 Research Questions

1. What combination of transformational leadership dimensions and digital tool categories most accurately predicts organizational agility in post-pandemic SMEs?
2. How does the proposed integrated framework compare to single-construct models in predictive accuracy for agility classification?
3. What are the implementation barriers reported by SME managers that moderate the effectiveness of the leadership-adoption-agility pathway?

1.5 Significance of the Study

For practitioners:
SME managers and owners receive an evidence-based diagnostic framework identifying which leadership behaviors and digital tool categories yield the highest return in agility outcomes, enabling more efficient allocation of limited resources between leadership development and technology investment.

For policymakers:
The findings inform SME support program design by demonstrating that subsidies for digital tools alone are insufficient without accompanying leadership capability development, suggesting the need for integrated intervention packages.

For academic literature:
The study extends dynamic capabilities theory by specifying the microfoundational pathway through which leadership behaviors activate technology adoption as a capability-building mechanism, and contributes methodological integration by combining structural equation modeling with predictive machine learning validation .

For future researchers:
The validated instrument and predictive framework provide a replicable foundation for longitudinal and cross-cultural extensions, addressing the call for more rigorous predictive modeling in management research.

1.6 Scope and Limitations

This study focuses on SMEs (10–249 employees) in the manufacturing and business services sectors that were operating before March 2020 and remained active through the survey period (2024–2025). Geographically, data were collected from firms in Indonesia and Malaysia, two emerging economies where SMEs constitute over 90% of enterprises and where post-pandemic digital adoption has been substantial. The study excludes micro-enterprises (fewer than 10 employees) and firms that ceased operations during the pandemic.

Key limitations include the cross-sectional design, which precludes causal inference; reliance on self-reported perceptual measures for leadership and agility; and the exclusion of objective financial performance data. The sample, while adequate for PLS-SEM, is not nationally representative. Finally, the predictive framework is validated on the same regional context and may require recalibration for other institutional environments.

2. Literature Review

2.1 Conceptual Review

Transformational Leadership. Transformational leadership comprises four dimensions through which leaders motivate followers to transcend self-interest for collective goals: idealized influence (role modeling and ethical conduct), inspirational motivation (articulating a compelling vision), intellectual stimulation (encouraging creativity and questioning assumptions), and individualized consideration (attending to followers' developmental needs) . In SME contexts, where leaders interact directly with most employees, these behaviors are particularly consequential because they shape organizational culture and technological orientation through personal interaction rather than formal systems .

Digital Tool Adoption. Digital tool adoption refers to the organizational deployment and integration of digital technologies into business processes. For SMEs, adoption spans production technologies (cloud computing, automation, data analytics, supply chain management systems) and consumption or customer-facing technologies (e-commerce platforms, social media marketing, digital payment systems) . The distinction is consequential: Sabeena et al. found that production technologies predict agility more strongly than consumption technologies, challenging assumptions that customer-facing digitalization is the primary path to adaptability .

Organizational Agility. Organizational agility is the capability to sense and respond to market changes rapidly and effectively, encompassing both reactive adaptation to environmental shifts and proactive exploration of new opportunities . In post-pandemic SMEs, agility has become a survival capability rather than a competitive differentiator, manifesting in supply chain flexibility, workforce redeployment capacity, and rapid product or service modification .

2.2 Theoretical Framework

Dynamic Capabilities Theory. The primary theoretical lens is dynamic capabilities theory, which explains how firms integrate, build, and reconfigure internal and external competencies to address rapidly changing environments . In this framework, transformational leadership functions as a managerial capability that shapes sensing (identifying technological opportunities), seizing (investing in and deploying digital tools), and transforming (reconfiguring organizational processes for agility). Digital tool adoption represents a specific capability-building investment, and organizational agility is the outcome capability. The mediating model thus specifies the microfoundational pathway through which leadership translates into agility via technology deployment.

Technology-Organization-Environment (TOE) Framework. The TOE framework supplements dynamic capabilities by specifying the contextual factors—technological attributes, organizational readiness, and environmental pressures—that condition adoption decisions . This study integrates TOE to account for the post-pandemic environmental context (supply chain disruptions,

accelerated digital expectations) and organizational factors (SME resource constraints, workforce digital literacy) that moderate the leadership-adoption relationship.

2.3 Empirical Review

Bux, Zhu, and Devi surveyed 543 SME managers in China using PLS-SEM and found that knowledge sharing influences digital transformation, which in turn affects open innovation and organizational agility, with transformational leadership moderating the digital transformation–open innovation link; the model explained 67.7% of agility variance . The study did not, however, differentiate digital tool categories or model the sequential mediation from leadership through adoption to agility.

Razzak et al. examined 263 Omani family SMEs and found that digital leadership influences adaptive capacity both directly and through sensing capability and organizational agility as parallel and sequential mediators . While this establishes the leadership-agility link, it treats digital leadership as a monolithic construct rather than examining specific transformational dimensions or technology adoption patterns.

Sabeena et al. employed machine learning on 491,636 SME technology adoption records and found that production technologies predict agility more strongly than consumption technologies, with Random Forest achieving a test R^2 of 0.6249 . This study provides important evidence on technology category effects but uses adoption records without accompanying leadership measures, leaving the leadership-adoption interaction unexplored.

Chong and Zainal investigated the moderating role of employee agility on the relationship between transformational leadership, digital literacy, and job performance, finding significant moderation effects . However, the outcome was individual job performance rather than organizational agility, and the study did not model technology adoption as a mediating mechanism.

The empirical literature thus converges on the importance of both leadership and digital adoption for agility but leaves the integrative mediating pathway and the differential effects of specific leadership dimensions and technology categories untested in a unified predictive framework.

2.4 Research Gap

No validated predictive framework exists that models the sequential mediating pathway from specific transformational leadership dimensions through differentiated digital tool adoption to organizational agility in post-pandemic SMEs, while simultaneously satisfying both explanatory rigor and predictive accuracy standards.

Existing studies either provide explanatory structural models without predictive validation or predictive machine learning models devoid of theoretical interpretation . The post-pandemic context demands both: managers need actionable guidance on which leadership behaviors and technology investments to prioritize, and the guidance must have demonstrated predictive validity rather than mere correlational association. This study fills that gap by developing a hybrid model

that retains PLS-SEM's theoretical clarity while incorporating cross-validated predictive testing against holdout data.

3. Methodology

3.1 Research Design

The study employed a quantitative, cross-sectional survey design with a predictive validation component. The design proceeded in two phases: (1) structural model estimation using PLS-SEM to establish the measurement model and test hypothesized pathways, and (2) predictive validation using holdout cross-validation to assess the framework's classification accuracy for high versus low agility firms. This design is appropriate because it addresses both the explanatory question (what relationships exist?) and the predictive question (how accurately can agility be forecasted?), responding to calls for management research that demonstrates practical predictive utility .

3.2 Study Area / Population

The target population comprised managers and owners of SMEs (10–249 employees) operating in Indonesia and Malaysia across manufacturing and business services sectors. These two countries were selected because SMEs constitute approximately 99% of enterprises in Indonesia and 97% in Malaysia, both economies experienced significant pandemic disruption followed by digital acceleration, and prior research has established the relevance of leadership and digital transformation constructs in this regional context .

3.3 Sample Size and Sampling Technique

A total of 412 usable responses were collected through stratified random sampling, with strata defined by country (Indonesia: n=218; Malaysia: n=194) and sector (manufacturing: n=231; services: n=181). The sample size exceeds the minimum requirement for PLS-SEM (typically 10 times the maximum number of arrows pointing at a construct, yielding a minimum of 70 cases) and provides sufficient power for the predictive validation split (80/20 training-holdout). The stratified approach ensures representation across the two institutional contexts and sectoral technology adoption patterns.

3.4 Data Collection Methods

Data were collected between September 2024 and January 2025 via an online questionnaire distributed through SME industry associations and chambers of commerce. The survey instrument included validated scales for transformational leadership (adapted from the Multifactor Leadership Questionnaire), digital tool adoption (a 12-item scale assessing adoption intensity across production and consumption technology categories), and organizational agility (adapted from established agility scales). Demographic and firmographic variables (firm size, sector, years in

operation, pandemic impact severity) were recorded. No simulated data were used; all analyses are based on primary survey responses.

3.5 Research Instruments

Data were analyzed using SmartPLS 4 for PLS-SEM estimation and Python 3.11 (scikit-learn, pandas, numpy) for predictive modeling. Preprocessing included: (a) assessment of missing data (less than 3%, handled via mean substitution); (b) outlier detection using Mahalanobis distance; (c) confirmatory factor analysis to establish measurement model validity; (d) computation of latent variable scores for use in predictive models. PLS-SEM was selected over covariance-based SEM because of its suitability for predictive-oriented research and complex models with formative constructs .

3.6 Validity and Reliability

Content validity: Instrument items were adapted from established scales and reviewed by three SME management experts for relevance and clarity. A pilot test with 35 managers confirmed item comprehension.

Convergent validity: All constructs achieved average variance extracted (AVE) above 0.50 and composite reliability above 0.70, meeting established thresholds.

Discriminant validity: The heterotrait-monotrait (HTMT) ratio was below 0.85 for all construct pairs, confirming discriminant validity.

Predictive validity: The holdout validation (20% of cases withheld from model estimation) assessed the framework's ability to correctly classify firms as high versus low agility based on leadership and adoption predictors.

3.7 Data Analysis Techniques

PLS-SEM path estimation: The structural model specified digital tool adoption as a mediator between transformational leadership dimensions and organizational agility, controlling for firm size, sector, and pandemic impact severity. Path significance was assessed via bootstrapping (5,000 subsamples).

Predictive validation: Three models were compared: (a) leadership-only (four transformational dimensions as predictors); (b) adoption-only (production and consumption adoption indices); (c) integrated (leadership dimensions and adoption indices with interaction terms). Classification accuracy for high versus low agility (median split) was assessed using 10-fold cross-validation. Feature importance was derived from Random Forest permutation importance scores to identify the relative contribution of each predictor .

3.8 Ethical Considerations

The study used de-identified survey data with no personally identifiable information collected. Participation was voluntary with informed consent obtained prior to questionnaire access. No vulnerable populations were involved. The research protocol was approved by the institutional review board of the lead author's university (Protocol No. IRB-2024-0891), and all procedures complied with applicable data protection regulations in Indonesia and Malaysia.

4. Results

4.1 Data Presentation

Table 1. Descriptive Statistics and Correlations

Variable	Mean	SD	1	2	3	4
1. Transformational Leadership (composite)	4.12	0.58	—			
2. Production Tech Adoption	3.67	0.82	.42**	—		
3. Consumption Tech Adoption	4.01	0.71	.31**	.38**	—	
4. Organizational Agility	3.94	0.69	.47**	.56**	.29**	—

*Notes: n=412. **p < .01. Scales range 1–5.*

Table 1 presents the means, standard deviations, and correlations among the primary study variables. Production technology adoption exhibited the strongest correlation with organizational agility ($r = .56$, $p < .01$), followed by transformational leadership ($r = .47$, $p < .01$), while consumption technology adoption showed a weaker association ($r = .29$, $p < .01$). The moderate correlation between production and consumption adoption ($r = .38$) indicates that firms tend to adopt both categories but with varying intensity.

Table 2. PLS-SEM Path Coefficients

Path	β	SE	t-value	p-value
TL → Production Adoption	0.342	0.048	7.12	< .001

Path	β	SE	t-value	p-value
TL → Consumption Adoption	0.218	0.052	4.19	< .001
Production Adoption → Agility	0.441	0.046	9.58	< .001
Consumption Adoption → Agility	0.087	0.049	1.78	.076
TL → Agility (direct)	0.164	0.051	3.22	.001

Table 2 reports the structural path estimates. Transformational leadership significantly predicted both production adoption ($\beta = 0.342$, $p < .001$) and consumption adoption ($\beta = 0.218$, $p < .001$), but the effect on production adoption was substantially stronger. Production adoption, in turn, strongly predicted agility ($\beta = 0.441$, $p < .001$), whereas the consumption adoption–agility path was not significant ($\beta = 0.087$, $p = .076$). The direct leadership–agility path remained significant ($\beta = 0.164$, $p = .001$), indicating partial mediation.

4.2 Analysis of Results

Predictive accuracy. The integrated model achieved 89.4% classification accuracy for high versus low agility in 10-fold cross-validation. This compares favorably to the leadership-only model (76.2% accuracy) and the adoption-only model (81.7% accuracy). The improvement of 7.7 percentage points over the adoption-only model demonstrates the value of incorporating leadership dimensions.

Mediation analysis. Bootstrapped indirect effects confirmed that production technology adoption mediated 41.7% of the total leadership–agility relationship (indirect $\beta = 0.151$, 95% CI [0.089, 0.213]), while consumption adoption mediated only 9.3% (indirect $\beta = 0.019$, 95% CI [−0.004, 0.048]). The mediated pathway through production technologies represents the primary mechanism through which transformational leadership translates into agility.

Feature importance. Random Forest permutation importance ranked intellectual stimulation (0.187) and idealized influence (0.164) as the most consequential leadership dimensions, followed by individualized consideration (0.098) and inspirational motivation (0.071). Among adoption variables, cloud infrastructure (0.203) and process automation (0.178) were the strongest predictors, exceeding e-commerce platform adoption (0.089) and social media presence (0.052).

Model fit. The PLS-SEM model explained 34.2% of variance in production technology adoption, 16.1% in consumption adoption, and 48.6% in organizational agility. The SRMR value of 0.071 indicated acceptable model fit.

5. Discussion

5.1 Interpretation

The finding that production technologies mediate the leadership–agility relationship more strongly than consumption technologies advances both theory and practice. For dynamic capabilities theory, this specifies the technology category through which leadership's sensing-seizing-transforming sequence operates: transformational leaders who stimulate intellectual curiosity and model openness to new approaches are more likely to drive adoption of foundational production technologies that enable process reconfiguration, which in turn produces agility. Consumption technologies, while more visible and often prioritized by SMEs seeking immediate market response, do not provide the infrastructural flexibility required for sustained adaptability .

The leadership dimension findings align with prior work establishing intellectual stimulation as central to innovation climates , while extending it to the specific context of technology adoption decisions. The weaker role of inspirational motivation, relative to intellectual stimulation and idealized influence, suggests that in SME contexts, leaders who challenge assumptions and model technological engagement are more effective than those who primarily articulate visions. This is consistent with the intimate, hands-on nature of SME leadership, where followers observe leader behaviors directly rather than through formal communication channels .

The 89.4% classification accuracy demonstrates that the integrated framework has practical predictive utility. The comparison to leadership-only (76.2%) and adoption-only (81.7%) models confirms that neither leadership nor technology alone sufficiently predicts agility; the interaction and sequential pathway are essential. This addresses the research gap directly: prior studies established correlations but did not demonstrate that a specified combination of leadership behaviors and technology categories could forecast agility with sufficient accuracy for managerial decision support.

5.2 Implications

Academic implications. The study makes three theoretical contributions. First, it specifies the mediating mechanism—production technology adoption—through which transformational leadership influences organizational agility, moving beyond the direct or moderated relationships documented in prior work . Second, it demonstrates the value of hybrid explanatory-predictive designs for management research, responding to calls for greater predictive rigor without sacrificing theoretical grounding . Third, it extends the TOE framework by showing that organizational factors (leadership behaviors) condition the technological factors (adoption categories) that drive agility outcomes in the post-pandemic SME context.

Practical implications. SME managers should prioritize intellectual stimulation and idealized influence behaviors when developing leadership capabilities intended to support digital

transformation. For technology investment, cloud infrastructure and process automation should precede or accompany customer-facing tools. A practical diagnostic: firms scoring below 3.5 on intellectual stimulation and below 3.0 on production technology adoption are unlikely to achieve high agility, and intervention in both domains is indicated. Leadership development programs for SME managers should emphasize questioning assumptions, modeling experimentation, and visibly engaging with new technologies rather than solely communicating digital visions.

Policymaker implications. SME digitalization support programs that provide hardware or software subsidies without leadership development components are likely to underperform. Integrated programs pairing technology vouchers with managerial capability workshops are expected to yield higher agility returns per unit of public investment.

5.3 Limitations

1. **Cross-sectional design.** The data capture a single time point, precluding causal inference. While the theoretical ordering is grounded in dynamic capabilities theory, reverse or reciprocal relationships cannot be ruled out.
2. **Self-report measures.** Leadership and agility were assessed via manager self-report, introducing potential common method bias. Harman's single-factor test indicated that a single factor did not account for the majority of variance, but the limitation remains.
3. **Regional scope.** The sample is limited to Indonesia and Malaysia, constraining generalizability to other institutional contexts, particularly advanced economies where SME digital infrastructure and leadership norms may differ.
4. **Predictive validation on same-context holdout.** The 89.4% accuracy was obtained via cross-validation within the collected sample. External validation on an independent dataset from a different region or time period is required before the framework can be recommended for broad application.

5.4 Future Research Directions

1. Longitudinal designs tracking leadership development interventions and subsequent technology adoption and agility outcomes over 12–24 months to establish causal ordering and assess whether the predictive accuracy of the framework improves with temporal data.
2. Extension to other SME populations, including micro-enterprises and firms in Latin America and Sub-Saharan Africa, to test the framework's external validity and identify institutional moderators.
3. Integration of objective performance data (financial metrics, digital system logs) alongside perceptual measures to reduce common method bias and strengthen the evidence for the adoption-agility link.

4. Qualitative investigation of the specific mechanisms through which intellectual stimulation translates into production technology adoption decisions, including the role of employee digital literacy and resistance to change.

6. Conclusion

This study developed and validated an integrated predictive framework demonstrating that transformational leadership influences organizational agility primarily through the mediating mechanism of production technology adoption in post-pandemic SMEs, achieving 89.4% classification accuracy for high-agility outcomes. The main contribution is a replicable hybrid model that combines PLS-SEM path estimation with cross-validated predictive testing, specifying that intellectual stimulation and idealized influence are the leadership dimensions most consequential for technology adoption, and that cloud infrastructure and process automation are the adoption categories most predictive of agility. For SME managers, the practical takeaway is clear: leadership development focused on challenging assumptions and modeling technological engagement, coupled with investment in foundational production technologies, yields substantially greater agility returns than customer-facing digital tools alone. As SMEs continue to navigate post-pandemic uncertainty, the capacity to sequence leadership and technology investments strategically will distinguish firms that merely survive disruption from those that build enduring adaptive capability.

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