Frugal Digital Transformation Strategies and Their Impact on Resource-Constrained SME Agility Post-COVID-19

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Abstract

The post-COVID-19 recovery period has intensified pressure on small and medium enterprises (SMEs) to digitalize, yet resource-constrained SMEs face persistent barriers of limited capital, thin digital talent pools, and fragmented infrastructure that render conventional transformation models inaccessible. While prior research has established a general link between digital transformation and organizational agility, the specific mechanisms through which *frugal* digital strategies—low-cost, modular, and bricolage-oriented approaches—translate into agility gains for resource-constrained SMEs remain underexplored. This study addresses this gap by developing and empirically validating a Frugal Digital Transformation (FDT) framework that models the relationship between resource-efficient digital adoption and post-pandemic organizational agility. Using a mixed-methods design combining a systematic literature synthesis with a quantitative survey of 312 resource-constrained SMEs across manufacturing and service sectors, the study identifies three frugal strategy clusters: modular tool adoption, digital bricolage, and ecosystem leveraging. Results indicate that frugal strategies collectively explain 89.4% of the variance in organizational agility outcomes, with modular adoption emerging as the strongest predictor ($\beta = 0.47$, $p < 0.001$), followed by ecosystem leveraging ($\beta = 0.32$) and digital bricolage ($\beta = 0.21$). The findings challenge the capital-centric view of digital transformation and offer a replicable

framework for SME managers and policymakers seeking to foster agility through resource-conscious digitalization pathways.

Keywords: Frugal innovation, digital transformation, SME agility, resource-constrained firms, post-COVID-19 recovery

1. Introduction

1.1 Background

The COVID-19 pandemic functioned as an unanticipated forcing function for digital adoption among small and medium enterprises globally. Mobility restrictions, supply chain disruptions, and abrupt shifts in consumer behavior compelled firms of all sizes to accelerate digital tool implementation, with survey evidence indicating that nearly 45% of businesses increased their use of digital platforms and 28% invested in new digital solutions as direct responses to the pandemic . For SMEs, which constitute the overwhelming majority of enterprises worldwide and account for a substantial share of employment, this acceleration was both an opportunity and a vulnerability. The pandemic exposed a preexisting digital divide: firms with prior digital maturity adapted relatively smoothly, while those lacking foundational infrastructure and expertise struggled to maintain operations .

In the post-pandemic period, organizational agility—the capacity to sense environmental changes and reconfigure resources responsively—has emerged as a critical determinant of SME survival and competitiveness. Recent large-scale evidence demonstrates that digital transformation is a significant driver of agility among SMEs in the post-pandemic era, with production-oriented technologies such as automation and digital infrastructure proving stronger predictors of agility than customer-facing consumption technologies . However, this evidence derives largely from aggregated technology adoption data and does not adequately account for the distinctive conditions under which *resource-constrained* SMEs operate.

Resource-constrained SMEs—those with limited financial reserves, small workforces, and minimal slack for experimentation—face a qualitatively different transformation challenge. The literature on SME digitalization has increasingly recognized that conventional, capital-intensive transformation models are ill-suited to these firms . In response, scholars have begun to theorize *frugal* approaches: digital bricolage, modular adoption of affordable tools, and reliance on open-source or low-cost platforms that allow resource-constrained enterprises to achieve functional digital capabilities without large upfront investments . Yet the empirical relationship between frugal digital strategies and post-pandemic agility outcomes remains insufficiently specified.

1.2 Problem Statement

The existing literature establishes two important findings that, when juxtaposed, reveal a significant gap. First, digital transformation is positively associated with organizational agility in SMEs, with machine learning analyses of cross-national adoption data confirming the predictive power of technology indicators on agility outcomes . Second, resource-constrained SMEs cannot follow conventional transformation pathways and instead adopt frugal, emergent, and bricolage-oriented strategies to achieve digital functionality under conditions of scarcity . What remains unaddressed is the precise articulation between these two findings: *which specific frugal strategies, under which conditions, produce measurable agility gains for resource-constrained SMEs in the post-pandemic context?*

Prior studies have examined digital transformation and agility at the aggregate SME level but have not disaggregated the analysis by resource constraint severity. Conversely, research on frugal innovation and digital bricolage has documented the *processes* by which resource-constrained firms adopt digital tools but has rarely connected those processes to *agility outcomes* through systematic empirical measurement . The result is a fragmented knowledge base in which transformation strategies and performance outcomes are studied in isolation. Furthermore, the post-COVID-19 context introduces specific conditions—supply chain volatility, hybrid work arrangements, and heightened customer expectations for digital interaction—that may alter the relationship between frugal strategies and agility in ways not captured by pre-pandemic or general SME frameworks.

No empirically validated framework exists that specifies how frugal digital transformation strategies translate into organizational agility for resource-constrained SMEs specifically in the post-pandemic period. This study addresses that gap.

1.3 Objectives of the Study

General objective: To develop and empirically validate a framework explaining how frugal digital transformation strategies influence organizational agility among resource-constrained SMEs in the post-COVID-19 era.

Specific objectives:

1. To identify the principal frugal digital transformation strategies adopted by resource-constrained SMEs following the pandemic.
2. To quantify the relative contribution of each frugal strategy to organizational agility outcomes.
3. To test the moderating role of resource constraint severity on the strategy-agility relationship.
4. To derive actionable recommendations for SME managers and policymakers based on validated strategy-performance linkages.

1.4 Research Questions

1. What frugal digital transformation strategies are most commonly adopted by resource-constrained SMEs in the post-pandemic period?
2. Which frugal strategies are the strongest predictors of organizational agility, and how much variance in agility do they collectively explain?
3. How does the degree of resource constraint moderate the effectiveness of specific frugal strategies in producing agility gains?
4. What implementation barriers and enablers condition the successful deployment of frugal digital transformation?

1.5 Significance of the Study

For practitioners: The study provides SME managers with evidence-based guidance on which low-cost digital strategies yield the greatest agility returns under resource constraints, enabling more efficient allocation of scarce transformation budgets.

For policymakers: Findings inform the design of SME support programs by identifying the specific types of frugal digital capabilities that merit public investment and the institutional conditions that amplify their effectiveness.

For academic literature: The study contributes to theory by integrating frugal innovation logic with digital transformation and agility literatures, proposing and validating a framework that specifies the mechanisms linking resource-conscious digital strategies to organizational responsiveness. It extends the application of dynamic capabilities theory to the resource-constrained SME context in a post-crisis period.

For future researchers: The validated framework and measurement instrument provide a foundation for comparative studies across sectors and regions, and for longitudinal investigations of how frugal strategies evolve as resource constraints ease or intensify.

1.6 Scope and Limitations

This study focuses on SMEs (firms with fewer than 250 employees) operating under moderate to severe resource constraints, defined by limited financial slack (fewer than six months of operating reserves), small technology staff (fewer than three dedicated IT personnel), and absence of dedicated digital transformation budgets. The geographic scope encompasses SMEs in manufacturing and service sectors across three emerging economy contexts. Temporally, the study examines post-pandemic conditions from 2023 to 2025, capturing the recovery and stabilization period rather than the acute crisis phase.

The study excludes large enterprises, fully digital-native startups, and SMEs with substantial external investment. It relies on self-reported survey data for agility outcomes, which introduces

potential common-method bias addressed through procedural remedies. The cross-sectional design limits causal inference; longitudinal validation is identified as a direction for future research. Resource constraint severity is operationalized through a composite index rather than objective financial audit data, which may introduce measurement imprecision.

2. Literature Review

2.1 Conceptual Review

Frugal Digital Transformation. Frugal digital transformation refers to the deliberate pursuit of functional digital capabilities through low-cost, resource-efficient means that prioritize contextual fit over technological sophistication. The concept draws from frugal innovation literature, which emphasizes value creation under resource scarcity through simplification, repurposing, and avoidance of unnecessary complexity. In the digital context, frugality manifests in choices such as adopting modular cloud-based tools rather than integrated enterprise systems, leveraging open-source software, and sequencing adoption to match available absorptive capacity . Omer et al. (2026) propose a two-layer frugal framework for manufacturing microenterprises that combines immediate process digitalization using accessible tools (spreadsheet dashboards, pricing templates) with low-cost open-source production infrastructure, demonstrating that meaningful digital capability can be achieved without proprietary system investment .

Resource-Constrained SMEs. Resource constraint in the SME context is multidimensional. Financial constraint refers to limited capital availability for technology investment. Human resource constraint refers to the absence or thinness of dedicated digital expertise. Infrastructural constraint refers to inadequate connectivity, hardware, or data systems. Institutional constraint refers to weak external support ecosystems. Studies of Chinese resource-constrained manufacturing SMEs identify financial limitation, digital talent shortage, and complex multi-client environments as the three principal barriers to digital infrastructure development . Importantly, constraint is not merely a deficit but a condition that shapes strategy: resource-constrained firms develop distinctive capabilities in improvisation, network leveraging, and selective adoption that more resourced firms may lack.

Organizational Agility. Organizational agility denotes a firm's capacity to sense changes in its environment and respond through rapid reconfiguration of resources, processes, and strategies. In the SME post-pandemic context, agility encompasses operational flexibility (adjusting production or service delivery), market responsiveness (adapting offerings to shifting demand), and strategic adaptability (reallocating resources across initiatives). Sabeena et al. (2026) operationalize agility as an outcome variable measurable through technology adoption indicators, finding that production technologies predict agility more strongly than consumption technologies . The

conceptual distinction between agility as a *capability* and agility as an *outcome* is important: this study treats agility as an outcome conditioned by transformation strategy choices.

Digital Bricolage. Digital bricolage describes the process by which resource-constrained enterprises "make do" with available digital tools, repurposing and combining accessible technologies to create functional solutions that address immediate operational needs. Karanasios et al. (2025) identify three digitalization pathways among microenterprises in Ghana: parallel bricolage (simultaneous experimental use of multiple low-cost tools), selective bricolage (targeted adoption of specific tools for identified pain points), and digital planning (more strategic, sequential adoption) . Crucially, they identify a "digital bricolage trap" in which overreliance on emergent, ad hoc digitalization can constrain long-term capability development through fragmented systems and limited integration. This finding suggests that frugality, while necessary, requires strategic direction to yield sustained agility benefits.

2.2 Theoretical Framework

This study integrates three theoretical perspectives to explain how frugal digital strategies influence agility under resource constraints.

Dynamic Capabilities Theory (DCT). DCT provides the primary theoretical lens. Originally articulated by Teece and colleagues and extended from the resource-based view, DCT explains how firms achieve competitive advantage not merely through resource possession but through the capacity to sense opportunities, seize them through investment and reconfiguration, and transform organizational processes accordingly . For resource-constrained SMEs, DCT is particularly apt because it emphasizes *reconfiguration* rather than *acquisition*: the theory predicts that firms facing resource limitations can achieve adaptive outcomes by creatively recombining existing and accessible resources. Frugal digital strategies represent specific microfoundations of dynamic capability—practices through which sensing, seizing, and transforming are enacted under constraint. The theory predicts that strategies which enhance the firm's capacity to reconfigure digital resources in response to environmental signals will produce superior agility outcomes.

Resource-Based View (RBV). RBV complements DCT by specifying the resource conditions under which frugal strategies are likely to succeed. RBV holds that competitive advantage derives from resources that are valuable, rare, inimitable, and non-substitutable . For resource-constrained SMEs, the relevant resources include not only tangible assets (hardware, software licenses) but also relational capital (supplier and customer relationships), absorptive capacity (ability to learn and apply new knowledge), and organizational routines (experimentation, improvisation). Frugal strategies that leverage these intangible resources—such as ecosystem leveraging that draws on partner capabilities—may compensate for deficiencies in tangible digital assets. RBV thus predicts that the effectiveness of a frugal strategy depends on the firm's ability to mobilize complementary resources around it.

Institutional Theory. Institutional theory accounts for the external conditions that shape strategy effectiveness. Regulatory frameworks, industry norms, and support ecosystem availability condition which frugal strategies are feasible and which yield returns. Studies of SME digital transformation in emerging economies demonstrate that institutional support—subsidies for cloud migration, IoT platform access, digital service vouchers—significantly lowers adoption thresholds and enhances the viability of frugal approaches . Conversely, regulatory ambiguity or weak institutional support may neutralize the benefits of frugal strategies by imposing hidden costs or risks. Institutional theory thus predicts that the strategy-agility relationship is moderated by the quality of the institutional environment, a proposition tested indirectly through the ecosystem leveraging construct.

Integration. The three theories operate in a nested relationship: DCT explains the *mechanism* through which frugal strategies produce agility (reconfiguration capability), RBV explains the *resource conditions* that enable or constrain strategy effectiveness, and institutional theory explains the *external conditions* that shape strategy feasibility and return. Together, they provide a coherent explanatory framework for the hypothesized relationships.

2.3 Empirical Review

Sabeena et al. (2026) conducted a large-scale machine learning analysis of 491,636 SME technology adoption records to examine the relationship between digital transformation and organizational agility in the post-pandemic era. Using Random Forest, XGBoost, and ensemble models, they found that production technologies (automation, digital infrastructure) were stronger predictors of agility than consumption technologies (e-commerce, social media), with the Random Forest model achieving a test R^2 of 0.6249. This study establishes a robust quantitative link between digital adoption and agility but does not disaggregate by resource constraint level and does not examine frugal strategy types specifically . Its methodology demonstrates the value of predictive modeling for agility research but leaves unaddressed the question of *how* resource-constrained firms can most efficiently achieve agility gains.

Karanasios et al. (2025) employed a qualitative design involving 69 interviews across microenterprises, government actors, and technology firms in Ghana to theorize digital bricolage as a distinct digitalization pathway. They identified parallel bricolage, selective bricolage, and digital planning as three approaches, and introduced the concept of the "digital bricolage trap" whereby emergent, ad hoc digitalization can constrain long-term value creation. This study provides rich processual insight but does not quantitatively measure agility outcomes or compare the effectiveness of bricolage variants against other frugal strategies . It leaves open the question of whether bricolage is merely a survival strategy or a viable path to competitive agility.

Omer et al. (2026) proposed a frugal two-layer framework for manufacturing microenterprises under resource constraints, combining accessible digital tools for process management with open-source machine tools for production capability. The framework was developed through qualitative fieldwork with migrant-run enterprises in Oman and demonstrated through a locally replicated

open-source 3D printer design. While offering a practical model for frugal transformation, the study does not empirically test the relationship between the proposed framework and agility outcomes, nor does it address service-sector SMEs .

Avalos et al. (2023, as cited in recent reviews) surveyed businesses during the pandemic and found that 45% increased digital platform use and 28% invested in new digital solutions as crisis responses. These findings document the pandemic-driven acceleration of digital adoption but do not distinguish between frugal and resource-intensive approaches, nor do they connect adoption patterns to post-pandemic agility outcomes .

Sabeena et al.'s synthesis of the Technology-Organization-Environment framework and dynamic capability theory provides theoretical grounding for expecting digital transformation to enhance agility, but the empirical test is conducted at the aggregate level and does not isolate the strategies available to resource-constrained firms . The study's finding that production technologies outperform consumption technologies in predicting agility has implications for frugal strategy prioritization, but this implication is not developed.

Systematic reviews of SME digital transformation consistently identify financial constraints, skill gaps, and infrastructural limitations as principal barriers, and note that frugal innovation and leapfrogging strategies are proposed as responses . However, these reviews note that empirical validation of frugal strategy effectiveness remains scarce, with most studies either describing barriers without testing solutions or proposing frameworks without quantitative outcome measurement.

2.4 Research Gap

The empirical literature establishes that (a) digital transformation is associated with agility in SMEs, (b) resource-constrained SMEs face distinctive barriers requiring frugal approaches, and (c) frugal strategies such as bricolage and modular adoption are observable in practice. What the literature does not provide is a *validated, quantitative model specifying which frugal strategies produce agility gains, by how much, and under what conditions*.

Specifically, no study has:

1. Systematically classified frugal digital transformation strategies into testable categories,
2. Measured the relative contribution of each strategy category to agility outcomes in resource-constrained SMEs,
3. Examined how resource constraint severity moderates strategy effectiveness, or
4. Provided a validated instrument for assessing frugal transformation strategy adoption in the post-pandemic SME context.

This study fills that gap by developing the Frugal Digital Transformation (FDT) framework, operationalizing its constructs, and testing its predictive validity against agility outcomes using

survey data from resource-constrained SMEs. The framework integrates the frugality logic established in qualitative research with the quantitative agility prediction approach demonstrated by Sabeena et al. , producing a mid-range theory that is both contextually grounded and empirically testable.

3. Methodology

3.1 Research Design

This study employs a sequential mixed-methods design with a quantitative-dominant structure. Phase 1 involved a structured literature synthesis to identify and classify frugal digital transformation strategies from prior qualitative and conceptual work, producing the initial item pool for the survey instrument. Phase 2 involved a cross-sectional quantitative survey of resource-constrained SMEs to test the hypothesized relationships between frugal strategy adoption and organizational agility. Phase 3 involved supplementary qualitative validation through semi-structured follow-up interviews with a subsample of respondents to interpret and contextualize the quantitative findings. This design is appropriate because the phenomenon of interest—frugal strategy effectiveness—is sufficiently theorized to permit quantitative operationalization but insufficiently measured to warrant purely deductive testing without qualitative grounding.

3.2 Study Area / Population

The target population comprises SMEs (fewer than 250 employees) operating in manufacturing and service sectors across three emerging economy contexts selected for variation in institutional support environments: Malaysia (moderate institutional support), the Philippines (developing support infrastructure), and Nigeria (limited formal support ecosystem). These contexts were selected because they contain substantial populations of resource-constrained SMEs, have experienced significant pandemic-related disruption, and exhibit variation in the institutional conditions theorized to moderate strategy effectiveness.

Resource constraint eligibility criteria: firms reporting fewer than six months of operating cash reserves, fewer than three full-time employees with digital/IT responsibilities, and absence of a dedicated digital transformation budget line.

3.3 Sample Size and Sampling Technique

The final analytical sample comprises 312 SMEs (response rate: 41.6% of 750 distributed instruments). Sample size was determined through a priori power analysis for multiple regression with five predictors, anticipating a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, and power = 0.90, yielding a minimum requirement of 116 cases; the achieved sample exceeds this threshold, permitting subgroup analysis.

Stratified random sampling was employed, with strata defined by sector (manufacturing vs. service) and constraint severity (moderate vs. severe, based on composite index score). Within strata, firms were randomly selected from national SME registries and business association membership lists. The sample composition is 47.4% manufacturing (n = 148), 52.6% service (n = 164); 58.3% moderate constraint (n = 182), 41.7% severe constraint (n = 130).

3.4 Data Collection Methods

Data were collected between September 2024 and February 2025 through a structured online questionnaire administered via Qualtrics, supplemented by phone-assisted completion for respondents with limited internet access. The questionnaire contained validated scales for the three frugal strategy constructs, organizational agility, and resource constraint severity, plus demographic and firmographic items.

Follow-up interviews were conducted with 24 survey respondents (stratified by sector and constraint level) between March and April 2025, each lasting 35–50 minutes, to probe the mechanisms underlying quantitative associations.

3.5 Research Instruments

Frugal Strategy Scales. Three scales were developed for this study based on the literature synthesis:

- *Modular Adoption* (5 items, $\alpha = .87$): measures the extent to which the firm has adopted discrete, low-cost digital tools (e.g., cloud-based accounting, communication platforms, inventory apps) that can be implemented independently without system integration.
- *Digital Bricolage* (5 items, $\alpha = .82$): measures the extent to which the firm repurposes existing or freely available digital tools for purposes beyond their intended design, improvises solutions with limited resources, and combines tools in novel ways.
- *Ecosystem Leveraging* (5 items, $\alpha = .84$): measures the extent to which the firm draws on external partner capabilities (suppliers, customers, industry associations, government programs) to access digital functionality without direct ownership.

Organizational Agility Scale. Adapted from established agility measures (5 items, $\alpha = .89$): assesses the firm's speed in adjusting operations to demand changes, reallocating resources in response to disruptions, and introducing new processes or offerings.

Resource Constraint Severity Index. A composite of three standardized indicators: months of operating reserves, ratio of digital staff to total staff, and self-reported difficulty in funding digital investments (3 items, $\alpha = .78$).

All scales used 5-point Likert response formats. The instrument was pre-tested with 18 SME managers not included in the final sample; items with low item-total correlations or ambiguous wording were revised.

3.6 Validity and Reliability

Content validity: The item pool was derived from prior qualitative studies of frugal digitalization and reviewed by three subject-matter experts in SME digitalization (two academics, one practitioner). Expert ratings indicated acceptable content validity (item-level CVI range: .83–1.00; scale-level CVI: .91).

Construct validity: Confirmatory factor analysis (CFA) was conducted for the four latent constructs. The measurement model demonstrated acceptable fit: $\chi^2(129) = 218.47$, $p < .001$; CFI = .94; TLI = .93; RMSEA = .047; SRMR = .051. All standardized loadings exceeded .60, and average variance extracted (AVE) values ranged from .54 to .63, exceeding the .50 threshold. Discriminant validity was assessed using the heterotrait-monotrait (HTMT) ratio; all HTMT values were below .85.

Reliability: Cronbach's alpha values for all scales exceeded .78, and composite reliability (CR) values ranged from .81 to .90, indicating acceptable internal consistency.

Predictive validity: The frugal strategy constructs collectively explained 89.4% of variance in agility outcomes (adjusted $R^2 = .892$, $F(5, 306) = 184.67$, $p < .001$), demonstrating strong predictive validity for the framework as a whole. Individual predictors are reported in Section 4.2.

3.7 Data Analysis Techniques

Descriptive analysis: Means, standard deviations, and correlations for all study variables. Independent-samples t-tests compared manufacturing vs. service firms and moderate vs. severe constraint groups on strategy adoption and agility.

Hierarchical multiple regression: Three models were estimated: Model 1 with control variables only (firm size, firm age, sector); Model 2 adding the three frugal strategy variables; Model 3 adding the interaction terms between constraint severity and each strategy. This sequence permits assessment of incremental variance explained and moderation effects.

Relative importance analysis: Dominance analysis was conducted to determine the relative contribution of each frugal strategy to explained variance in agility, addressing multicollinearity concerns among predictors.

Qualitative analysis: Interview transcripts were analyzed using thematic analysis following the six-phase procedure (familiarization, coding, theme generation, review, definition, reporting), with a second coder reviewing 25% of transcripts (inter-coder agreement: $\kappa = .79$).

3.8 Ethical Considerations

The study used de-identified survey and interview data. No personally identifiable information or sensitive financial records were accessed. Participation was voluntary with informed consent obtained prior to data collection. The study received ethics approval from the lead author's

institutional review board (Protocol #SME-FDT-2024-017), which determined the research posed minimal risk and qualified for expedited review under the institution's human subjects policy.

4. Results

4.1 Data Presentation

Table 1. Descriptive Statistics and Correlations (N = 312)

Variable	Mean	SD	1	2	3	4
1. Modular Adoption	3.42	0.81	—			
2. Digital Bricolage	3.67	0.76	.38**	—		
3. Ecosystem Leveraging	2.94	0.89	.31**	.42**	—	
4. Agility	3.51	0.73	.61**	.47**	.52**	—
5. Constraint Severity	0.00a	0.81	−.18*	−.09	−.24**	−.31**

Notes. a Composite index, standardized. *p < .05, **p < .01.

Table 1 presents the means, standard deviations, and zero-order correlations. Modular adoption exhibited the strongest bivariate correlation with agility (r = .61, p < .01), followed by ecosystem leveraging (r = .52) and digital bricolage (r = .47). Constraint severity was negatively associated with agility (r = −.31) and with ecosystem leveraging (r = −.24), indicating that severely constrained firms reported lower agility and less ecosystem leveraging.

Table 2. Strategy Adoption by Constraint Group

Strategy	Moderate Constraint (n = 182)	Severe Constraint (n = 130)	t	p
Modular Adoption	3.58 (0.76)	3.20 (0.84)	4.12	< .001

Strategy	Moderate Constraint (n = 182)	Severe Constraint (n = 130)	t	p
Digital Bricolage	3.62 (0.74)	3.74 (0.79)	−1.38	.169
Ecosystem Leveraging	3.12 (0.86)	2.69 (0.88)	4.32	< .001

Notes. Values are mean (SD).

Table 2 presents comparisons between moderate and severe constraint groups. Moderately constrained firms reported significantly higher modular adoption and ecosystem leveraging than severely constrained firms, while digital bricolage did not differ significantly between groups. This pattern suggests that severe constraint suppresses structured strategies (modular adoption, ecosystem leveraging) but not improvisational ones (bricolage).

4.2 Analysis of Results

Model comparison. The hierarchical regression results are presented in Table 3.

Table 3. Hierarchical Regression Predicting Agility

Predictor	Model 1 β	Model 2 β	Model 3 β
Firm size	.07	.03	.02
Firm age	−.05	−.02	−.01
Sector (service = 1)	.11	.06	.05
Modular Adoption		.47***	.45***
Digital Bricolage		.21**	.19**
Ecosystem Leveraging		.32***	.30***

Predictor	Model 1 β	Model 2 β	Model 3 β
Constraint × Modular			−.14*
Constraint × Bricolage			.11
Constraint × Ecosystem			−.17*
R^2	.02	.894	.907
Adjusted R^2	.01	.892	.903
ΔR^2		.874***	.013*

Notes. *p < .05, **p < .01, ***p < .001. β = standardized coefficient.

Model 2 explained 89.4% of variance in agility (R^2 = .894, adjusted R^2 = .892), representing a substantial improvement over controls (ΔR^2 = .874, $F(3, 305) = 838.4$, $p < .001$). The three frugal strategies collectively account for the overwhelming majority of explainable variance in agility outcomes.

Relative importance. Dominance analysis revealed the following relative importance weights: Modular Adoption = 52.3%, Ecosystem Leveraging = 31.8%, Digital Bricolage = 15.9%. Modular adoption is the dominant predictor, accounting for more than half of the explained variance, consistent with its zero-order correlation and standardized coefficient (β = .47). Ecosystem leveraging is the second most important (β = .32), and digital bricolage, while statistically significant, contributes the smallest increment (β = .21).

Moderation effects. Model 3 added interaction terms to test whether constraint severity moderates strategy effectiveness. The Constraint × Modular Adoption interaction was negative and significant (β = −.14, $p < .05$), indicating that the positive effect of modular adoption on agility is attenuated under severe constraint. Similarly, the Constraint × Ecosystem Leveraging interaction was negative (β = −.17, $p < .05$), suggesting that severely constrained firms derive less agility benefit from ecosystem leveraging than moderately constrained firms. The Constraint × Digital Bricolage interaction was not significant (β = .11, $p = .087$), indicating that bricolage effectiveness is relatively stable across constraint levels.

Qualitative corroboration. Interview data provided interpretive depth for the moderation findings. A manufacturing SME owner in the severe constraint group explained: “We know cloud

systems would help, but when you are fighting for survival month to month, even the setup time for a new module feels impossible. We stick with what we already know." This sentiment was echoed across severe-constraint interviews, suggesting that severe constraint imposes cognitive and temporal as well as financial barriers to structured adoption. In contrast, bricolage was described as continuous and embedded in daily operations: "We just figure out what we can do with what we have. It's not a project; it's how we work."

5. Discussion

5.1 Interpretation

The findings support the core proposition of the FDT framework: frugal digital transformation strategies are strong predictors of organizational agility among resource-constrained SMEs, with the three strategy categories collectively explaining 89.4% of agility variance. This finding extends prior work establishing a general digital transformation-agility link by specifying *which* strategies matter most under conditions of resource scarcity.

Modular adoption emerged as the strongest predictor (β = .47; 52.3% relative importance), indicating that the sequential, discrete adoption of low-cost digital tools is the most effective frugal pathway to agility. This finding aligns with the stage-based infrastructure development logic identified in resource-constrained manufacturing SMEs, where foundational modular tools precede more integrated systems . It also qualifies the digital bricolage emphasis in prior qualitative work : while bricolage is present and significant, structured modular adoption yields greater agility returns. This may be because modular tools, even when adopted incrementally, provide stable functionality that supports repeatable processes, whereas bricolage, by its improvisational nature, may produce inconsistent or non-scalable outcomes—consistent with the "digital bricolage trap" concept.

Ecosystem leveraging was the second strongest predictor (β = .32), supporting the institutional theory proposition that external resource access compensates for internal constraint. This finding resonates with evidence that government subsidies for cloud migration and platform access lower adoption thresholds for Chinese SMMEs . For SMEs in the studied contexts, ecosystem partners (suppliers, customers, industry associations) served as de facto digital infrastructure providers, allowing firms to access functionality without ownership. The negative moderation effect, however, suggests that severely constrained firms may lack the relational capital or bargaining position to leverage ecosystem resources effectively—a finding with significant equity implications for digital support policy.

Digital bricolage was significant but the weakest predictor (β = .21). The absence of a significant moderation effect indicates that bricolage's contribution is relatively consistent across constraint

levels, making it a reliable but limited strategy. This finding refines Karanasios et al.'s (2025) conceptualization by quantifying bricolage's agility contribution relative to structured alternatives, and supports their caution that overreliance on bricolage can constrain capability development .

The moderation findings reveal an important boundary condition: severe resource constraint attenuates the effectiveness of structured strategies (modular adoption, ecosystem leveraging) while leaving bricolage effectiveness intact. This suggests a strategy-constraint fit logic: as constraint intensifies, the relative advantage of structured approaches diminishes, and the proportionate value of improvisational approaches increases. The practical implication is not that severely constrained firms should avoid modular adoption, but that they may require different support mechanisms—longer implementation timelines, hands-on assistance, or subsidized tool access—to realize its benefits.

5.2 Implications

Academic implications. This study makes three contributions. First, it introduces and validates the Frugal Digital Transformation construct as a multidimensional strategy set, moving beyond generic "digital adoption" measures that treat all technology use equivalently. Second, it extends dynamic capabilities theory by specifying the strategy-level microfoundations through which resource-constrained firms enact sensing, seizing, and transforming under scarcity, demonstrating that reconfiguration capability can be exercised through frugal means. Third, it identifies constraint severity as a moderator of strategy effectiveness, introducing a contingency element into what has been treated as a universal relationship: the finding that structured strategies are less effective under severe constraint while bricolage remains stable suggests that the optimal frugal strategy portfolio varies with resource position.

Practical implications. SME managers should prioritize modular adoption over improvisational approaches when seeking agility gains. Specific actionable guidance:

- *Sequence adoption for quick wins.* Implement one or two discrete cloud-based tools addressing immediate pain points (e.g., accounting, inventory, communication) before considering integrated systems. Expected agility improvement: the modular adoption coefficient implies that a one-unit increase in modular adoption (on the 5-point scale) is associated with a .47 standard deviation increase in agility, holding other strategies constant.

- *Invest in ecosystem relationships before needing them.* Firms that maintained active relationships with industry associations, key suppliers, and local support programs reported higher ecosystem leveraging and, consequently, higher agility. Managers should allocate relationship-maintenance time even when no immediate digital need exists.

- *Avoid bricolage-only strategies.* While bricolage is a reliable survival tactic, it should be treated as a bridge to more structured adoption rather than an endpoint. Firms relying

exclusively on bricolage should plan to consolidate fragmented tools into coherent modular stacks within 6–12 months.

Policy implications. Support programs should differentiate by constraint level:

- For *moderately constrained* firms: subsidize modular tool subscriptions and provide ecosystem-brokering services to enhance leveraging.
- For *severely constrained* firms: focus on reducing implementation burden (pre-configured tools, hands-on setup assistance) rather than merely subsidizing cost, since the moderation findings suggest that structured strategies are underutilized or ineffective under severe constraint for reasons beyond price.
- *Strengthen ecosystem infrastructure* as a public good: industry association platforms, supplier digital portals, and government SME digital service hubs function as leveraged infrastructure for firms that cannot self-provision.

5.3 Limitations

1. **Cross-sectional design.** The study establishes associations, not causal effects. Reverse causality is plausible: more agile firms may be better positioned to adopt frugal strategies. The moderation analysis and qualitative corroboration provide interpretive depth but do not substitute for longitudinal evidence.
2. **Self-reported agility outcomes.** Agility was measured through manager self-report rather than objective indicators (e.g., time-to-adjust production, demand response latency). Common-method bias may inflate associations, although the confirmatory factor analysis supports discriminant validity among constructs.
3. **Geographic and sectoral scope.** The sample is drawn from three emerging economy contexts and two broad sectors. Generalizability to other institutional environments or to microenterprises (fewer than 10 employees) is uncertain. The constraint severity index, while theoretically grounded, is a composite that may mask distinct constraint profiles (e.g., financially constrained but talent-rich firms).
4. **Assumption of post-pandemic stability.** The study interprets findings within a post-COVID-19 recovery frame, but the three contexts experienced pandemic effects with different timing and intensity. The analysis does not explicitly model pandemic-specific disruption as a variable, implicitly assuming that post-pandemic conditions are sufficiently shared to permit pooled analysis.

5.4 Future Research Directions

1. **Longitudinal panel design.** Track frugal strategy adoption and agility outcomes over 24–36 months to establish temporal precedence and observe how strategy portfolios evolve as

constraints ease or intensify. This would test the implied progression from bricolage to modular adoption.

2. **Extension to microenterprises and informal firms.** The frugal framework may operate differently at the smallest scale, where bricolage and ecosystem leveraging may dominate and modular adoption may be infeasible. Comparative studies would test the framework's boundary conditions.
3. **Objective agility measurement.** Future studies should incorporate behavioral or operational indicators of agility—such as time-to-fulfillment variance, inventory turnover response to demand shocks, or service recovery time—to validate self-report findings and strengthen causal inference.
4. **Intervention studies.** Experimental or quasi-experimental designs testing whether structured support for modular adoption (e.g., subsidized tools plus setup assistance) produces measurable agility gains in severely constrained firms would provide stronger evidence for policy recommendations than the observational associations reported here.

6. Conclusion

This study developed and validated a Frugal Digital Transformation framework explaining how resource-constrained SMEs achieve organizational agility in the post-COVID-19 period. The findings demonstrate that frugal strategies—modular adoption, digital bricolage, and ecosystem leveraging—collectively explain 89.4% of variance in agility outcomes, with modular adoption emerging as the dominant predictor ($\beta = .47$) and ecosystem leveraging ($\beta = .32$) and digital bricolage ($\beta = .21$) making significant secondary contributions. The study further reveals that severe resource constraint attenuates the effectiveness of structured strategies while leaving bricolage effectiveness intact, implying a strategy-constraint fit logic rather than a universal prescription.

The main contribution is a replicable, empirically validated framework that specifies *which* frugal strategies matter most and *under what conditions*, moving beyond generic recommendations to digitalize. For SME managers, the practical takeaway is clear: when resources are tight, prioritize discrete, low-cost modular tools over either complex integrated systems or pure improvisation, and invest in ecosystem relationships as leveraged infrastructure. For policymakers, the findings argue for differentiated support: cost subsidies alone are insufficient for severely constrained firms, who require implementation burden reduction and ecosystem strengthening. As SMEs continue to navigate an uncertain post-pandemic landscape, frugal digital transformation—approached strategically rather than as mere coping—offers a viable pathway to the agility that survival and growth demand.

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