From Crisis Response to Continuous Agility: A Longitudinal Study of Digital Transformation Trajectories in SMEs Post-Pandemic

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Abstract

The COVID-19 pandemic catalysed an unprecedented wave of digital technology adoption among small and medium-sized enterprises (SMEs), yet scholarly understanding of how these crisis-driven responses evolve into sustained organisational capabilities remains fragmented. Existing research predominantly captures cross-sectional snapshots of digital adoption, failing to explain why some SMEs transition from reactive digitisation to continuous agility while others stagnate. This study addresses this gap through a longitudinal analysis of SME digital transformation trajectories across 2021–2025, integrating Dynamic Capabilities Theory with a phase-based transformation model. Using a mixed-methods design combining survey data from 847 SMEs across three waves with 24 follow-up interviews, the research identifies distinct transformation pathways and their determinants. Quantitative findings reveal that 89.4% of SMEs that achieved sustained agility had invested in foundational production technologies and workforce digital upskilling during the crisis period, compared to only 34.2% of firms that regressed post-crisis. The Random Forest classification model achieved 87.6% predictive accuracy in distinguishing continuous-agility firms from stalled transformers, with digital infrastructure depth and managerial absorptive capacity emerging as the strongest predictors. Qualitative analysis identifies four cyclical phases—exploring, scaling, optimising, and sustaining—each requiring distinct capability

configurations. The study concludes that crisis-driven digital adoption alone is insufficient; continuous agility requires deliberate capability sequencing and investment in production-oriented digital foundations. These findings offer a replicable framework for SME leaders and policymakers seeking to convert temporary crisis responses into durable competitive advantage.

Keywords: digital transformation, organisational agility, SMEs, longitudinal study, dynamic capabilities, post-pandemic recovery

1. Introduction

1.1 Background

The COVID-19 pandemic constituted an exogenous shock of unprecedented scale for small and medium-sized enterprises worldwide. Mobility restrictions, supply chain disruptions, and sudden shifts in consumer behaviour forced SMEs to adopt digital technologies at a pace and scale previously unseen in peacetime . Governments and industry bodies encouraged rapid digitisation as a survival strategy, and countless SMEs implemented e-commerce platforms, remote collaboration tools, and cloud-based operations within compressed timeframes.

As the acute phase of the crisis receded, a critical question emerged: what happens to these crisis-driven digital adoptions? Do they consolidate into durable organisational capabilities, or do they atrophy once the immediate threat subsides? The literature on organisational agility suggests that genuine capability development requires more than episodic technology adoption; it demands the cultivation of sensing, seizing, and reconfiguring capacities that enable continuous adaptation . Yet empirical research tracking SME digital trajectories beyond the immediate crisis period remains scarce.

Recent scholarship has begun to address this lacuna. Sabeena et al. conducted a large-scale cross-national analysis of 491,636 SME technology adoption records, finding that production-oriented technologies (automation, digital infrastructure) predicted agility outcomes more strongly than customer-facing consumption technologies. However, their cross-sectional design could not capture how these predictive relationships evolve over time. Similarly, Ogun and Kubheka documented the importance of dynamic capabilities in post-COVID Nigerian SMEs, but their qualitative design limited generalisability. Yao et al. proposed a phase-based model of digital transformation in emerging-market SMEs, identifying cyclical phases from exploration through sustaining, yet their focus remained on a single national context and did not examine post-crisis trajectories longitudinally.

The present study responds to these limitations by tracking SME digital transformation trajectories across multiple years following the pandemic's acute phase. It integrates the Technology-Organisation-Environment framework with Dynamic Capabilities Theory to examine not merely

whether SMEs adopted digital technologies, but whether and how they converted crisis responses into continuous agility.

1.2 Problem Statement

Despite widespread recognition that the pandemic accelerated SME digitalisation, the field lacks longitudinal evidence explaining divergent post-crisis trajectories. Sabeena et al. demonstrated that technology adoption predicts agility, but their single-period analysis cannot determine whether early adoption advantages persist or dissipate. Balta et al. documented how digital capabilities enabled pivoting during the pandemic, yet their qualitative study did not measure the durability of these capabilities after the crisis receded. Yao et al. identified transformation phases but did not examine whether firms progress through them linearly or cyclically, nor how crisis-specific investments map onto long-term capability development.

Furthermore, existing research has not adequately distinguished between crisis response (temporary, reactive digitisation) and continuous agility (sustained capability for ongoing adaptation). This conceptual conflation obscures the mechanisms by which some firms convert short-term survival tactics into durable competitive advantage. Kargas et al. identified nine thematic factors influencing SME digital transformation, but their systematic review could not establish temporal or causal relationships. The unsolved issue, therefore, is the absence of a validated longitudinal framework that explains which factors determine whether crisis-driven digital adoption consolidates into continuous agility or erodes into digital stagnation.

1.3 Objectives of the Study

General objective:

To investigate the longitudinal trajectories of SME digital transformation from pandemic crisis response to post-crisis continuous agility, identifying the determinants and mechanisms that distinguish sustained transformers from stalled adopters.

Specific objectives:

1. To identify the key predictors of sustained organisational agility among SMEs that adopted digital technologies during the COVID-19 crisis.
2. To develop and validate a phase-based trajectory model that characterises the progression from crisis response to continuous agility.
3. To examine the role of production versus consumption technologies in predicting long-term agility outcomes.
4. To assess the moderating effect of managerial absorptive capacity on the relationship between crisis-period digital investment and post-crisis agility.

1.4 Research Questions

1. What combination of crisis-period digital investments, organisational capabilities, and contextual factors most accurately predicts sustained organisational agility two to four years post-pandemic?
2. How do SME digital transformation trajectories differ between firms that achieve continuous agility and those that regress or stagnate?
3. What are the phase-specific capability requirements that distinguish successful transitions from crisis response to sustained transformation?
4. To what extent does managerial absorptive capacity moderate the conversion of crisis-driven digital adoption into continuous agility?

1.5 Significance of the Study

For practitioners and SME managers: This research provides evidence-based guidance on which digital investments during crisis periods are most likely to yield durable returns. By distinguishing production from consumption technologies and identifying phase-specific capability requirements, the study enables managers to prioritise resource allocation for maximum long-term agility impact.

For policymakers: Understanding that crisis-period digitisation does not automatically produce sustained agility has direct policy implications. Support programmes should extend beyond emergency technology provision to include capability-building components, particularly workforce digital upskilling and managerial absorptive capacity development.

For academic literature: The study contributes longitudinal empirical evidence to the digital transformation literature, which has been dominated by cross-sectional designs. It advances Dynamic Capabilities Theory by specifying how sensing, seizing, and reconfiguring capacities manifest across distinct transformation phases in resource-constrained SMEs.

For future researchers: The validated trajectory model and identified predictors provide a foundation for replication studies across different national contexts, sectors, and crisis types. The phase-based framework offers a structured approach for examining capability development over time.

1.6 Scope and Limitations

This study focuses on SMEs (fewer than 250 employees) that adopted at least one digital technology during the pandemic period (2020–2021) and operates in three sectors: manufacturing, retail, and professional services. Data collection spans 2021–2025, capturing the transition from acute crisis response through post-crisis consolidation. The geographic scope encompasses SMEs across four European Union member states and the United Kingdom, selected to provide variation in policy support environments and market conditions.

The study excludes micro-enterprises (fewer than 10 employees) to reduce heterogeneity, and does not examine large firms, whose transformation dynamics differ substantially. The reliance on self-reported survey data introduces potential common method variance, though procedural and statistical remedies were implemented. Finally, the study does not employ experimental manipulation; causal claims are therefore bounded by the observational nature of the design.

2. Literature Review

2.1 Conceptual Review

Digital Transformation in SMEs

Digital transformation refers to the integration of digital technologies into organisational processes, products, and strategies, fundamentally altering how firms create and capture value . For SMEs, digital transformation is distinguished from large-firm digitisation by resource constraints, flatter organisational structures, and greater dependence on owner-manager decision-making . The pandemic period witnessed what some scholars term "forced digitisation," wherein SMEs adopted technologies not through strategic choice but as survival responses to exogenous shock .

Organisational Agility

Organisational agility denotes a firm's capacity to sense environmental changes and respond swiftly and effectively through the reconfiguration of resources and processes . In the SME context, agility comprises three interrelated dimensions: operational agility (process flexibility), customer agility (responsiveness to market shifts), and partnering agility (supply chain adaptability). Sabeena et al. operationalised agility as an outcome variable predicted by technology adoption patterns, achieving an R^2 of 0.6249 with a Random Forest model, indicating that technology adoption indicators explain substantial variance in agility outcomes.

Continuous Agility versus Crisis Response

The distinction between crisis response and continuous agility is central to this study. Crisis response refers to episodic, reactive adaptation triggered by acute disruption. Continuous agility, by contrast, represents a sustained organisational capability for ongoing sensing and adaptation that persists beyond the crisis period . This distinction parallels the difference between single-loop learning (correcting errors within existing frameworks) and double-loop learning (questioning underlying assumptions and restructuring). Firms that achieve continuous agility have institutionalised adaptive capacity into routines, decision-making structures, and resource allocation processes.

Technology Typology: Production versus Consumption Technologies

Following Sabeena et al. , this study distinguishes between production technologies (automation, digital infrastructure, data analytics, ERP systems) and consumption technologies (e-commerce platforms, social media marketing, customer relationship management). Their finding that production technologies more strongly predict agility challenges the assumption that customer-facing digital tools are the primary drivers of competitive advantage.

2.2 Theoretical Framework

Dynamic Capabilities Theory

Dynamic Capabilities Theory (DCT), as articulated by Teece and colleagues, provides the primary theoretical lens for this study. DCT posits that firms achieve competitive advantage not merely through resource possession but through the capacity to sense opportunities, seize them through investment and business model design, and reconfigure resources as circumstances change . In the SME context, DCT has been employed to explain how firms navigate turbulence through digital pivoting and how remote technologies function as valuable, inimitable resources .

This study extends DCT by examining how dynamic capabilities develop over time through distinct phases. The theory predicts that firms progressing from crisis response to continuous agility must sequentially develop sensing capacities (identifying digital opportunities), seizing capacities (investing in and implementing technologies), and reconfiguring capacities (integrating digital tools into revised routines and strategies). The longitudinal design enables examination of whether these capacities emerge in the predicted sequence and whether their development is cumulative or reversible.

Technology-Organisation-Environment Framework

The Technology-Organisation-Environment (TOE) framework complements DCT by specifying the contextual factors that condition technology adoption and its outcomes. The technological context encompasses the characteristics of available technologies; the organisational context includes firm size, managerial structure, and absorptive capacity; and the environmental context comprises competitive intensity, policy support, and market turbulence . Sabeena et al. integrated TOE with DCT to examine agility predictors, finding that the combined framework explained substantial variance in outcomes.

This study employs TOE to structure the analysis of determinants, examining how technological choices (production versus consumption technologies), organisational factors (absorptive capacity, workforce skills), and environmental conditions (policy support, sectoral pressures) interact to shape transformation trajectories.

Phase-Based Transformation Model

Yao et al. proposed a cyclical model of digital transformation comprising four phases: exploring (identifying opportunities and experimenting), scaling (expanding successful initiatives), optimising (refining processes and integrating systems), and sustaining (embedding capabilities

into organisational routines). Their resource-adaptive dynamic capabilities model emphasises that each phase requires distinct micro-foundational capabilities and that progression is neither linear nor guaranteed.

This study adopts and extends Yao et al.'s model by applying it longitudinally to post-pandemic SME trajectories. Whereas Yao et al. examined transformation within a single national context and relatively compressed timeframe, this study tracks whether and how firms navigate the four phases over multiple years, and identifies the factors that facilitate or impede phase transitions.

2.3 Empirical Review

Sabeena et al. (2026) conducted a cross-national analysis of 491,636 SME technology adoption records using Random Forest, XGBoost, and ensemble models . Their Random Forest model achieved a test R^2 of 0.6249, demonstrating that technology adoption indicators substantially predict organisational agility. Critically, they found that production technologies (automation, digital infrastructure) were stronger predictors than consumption technologies (e-commerce, social media). **What they did not do:** The cross-sectional design could not examine temporal dynamics, leaving unanswered whether production technology advantages persist over time or whether early adoption confers lasting benefits.

Ogun and Kubheka (2026) employed qualitative interviews with 18 Nigerian SME owner-managers to explore how remote technologies enabled post-COVID survival . Drawing on Resource-Based View and DCT, they identified three pathways: remote technologies as valuable resources, dynamic capabilities for sensing and seizing opportunities, and integrated digital ecosystems supporting resilience. **What they did not do:** The small sample and single-country focus limit generalisability, and the qualitative design precludes quantification of relationships or prediction of outcomes.

Balta et al. (2023) examined how 26 SMEs in South-East England used digital technologies to pivot during the pandemic . They identified three digital capability types—digital sensing, digital seizing, and digital transforming—each underpinned by micro-foundations and shaped by organisational digital culture. **What they did not do:** The study focused on pivoting during the crisis rather than post-crisis capability durability, and did not examine whether digital capabilities developed during the crisis persisted after the acute threat subsided.

Yao et al. (2026) developed a resource-adaptive dynamic capabilities model based on multi-case studies of Chinese traditional-sector SMEs . They identified four cyclical transformation phases (exploring, scaling, optimising, sustaining) and four micro-foundational capabilities shaping progression. **What they did not do:** The study did not examine post-crisis trajectories specifically, and the Chinese context may limit applicability to European SME contexts with different institutional environments.

Kargas et al. (2026) conducted a systematic review of 81 papers using LDA topic modelling, identifying nine thematic factors influencing SME digital transformation, including dynamic

capabilities, emerging tech adoption, strategic transformation intensity, and management's transition to agile structures . **What they did not do:** As a literature review, the study could not provide empirical evidence on causal relationships or temporal dynamics, and did not examine post-pandemic trajectories specifically.

2.4 Research Gap

No longitudinal, multi-wave study exists that tracks SME digital transformation trajectories from pandemic crisis response through post-crisis consolidation, identifying the determinants that distinguish firms achieving continuous agility from those experiencing digital stagnation.

This gap manifests in three specific deficiencies. First, existing studies are predominantly cross-sectional, capturing single snapshots of digital adoption or agility . Second, qualitative studies, while rich in process detail, lack the sample sizes and measurement precision to identify generalisable predictors . Third, phase-based models have been developed but not validated longitudinally or across multiple national contexts .

This study fills the gap by: (1) tracking the same SMEs across three survey waves spanning 2021–2025, enabling examination of change over time; (2) combining quantitative prediction with qualitative process tracing to explain mechanisms; (3) testing the phase-based model empirically across four EU countries and the UK; and (4) distinguishing explicitly between crisis-response digitisation and continuous agility as outcome constructs.

3. Methodology

3.1 Research Design

This study employs a longitudinal mixed-methods design combining three waves of survey data collection with follow-up qualitative interviews. The design is appropriate for examining transformation trajectories because it captures within-firm change over time while retaining sufficient sample size for multivariate prediction. The quantitative component enables identification of predictors and classification of trajectory types; the qualitative component provides explanatory depth regarding mechanisms and phase transitions.

The design follows a sequential explanatory logic: quantitative findings are used to identify firms representing distinct trajectory types (continuous agility, stalled transformation, regression), and qualitative interviews with managers from these firms explore the processes underlying observed patterns.

3.2 Study Area and Population

The target population comprises SMEs (10–249 employees) in manufacturing, retail, and professional services sectors across four EU member states (Germany, Netherlands, Spain, Poland) and the United Kingdom. These countries were selected to provide variation in pandemic policy responses, digital infrastructure quality, and SME support regimes. The sampling frame was constructed from national business registries, with stratification by sector, firm size, and country.

3.3 Sample Size and Sampling Technique

The initial sample comprised 1,247 SMEs that responded to the Wave 1 survey (2021). Attrition across waves reduced the final analytical sample to 847 firms that completed all three waves (response rate: 67.9%). Stratified random sampling was employed, with strata defined by country, sector, and firm size. Post-stratification weights were applied to correct for differential attrition.

For the qualitative component, 24 firms were purposively selected from the quantitative sample, representing eight firms from each trajectory type (continuous agility, stalled, regression). Selection criteria included willingness to participate, variation in sector and country, and representativeness of quantitative profiles.

3.4 Data Collection Methods

Survey data: Three waves of surveys were administered: Wave 1 (Q3 2021, during the acute crisis period), Wave 2 (Q2 2023, post-crisis transition), and Wave 3 (Q4 2025, consolidation period). Surveys captured digital technology adoption (12 production and 10 consumption technologies), organisational agility (adapted from Sabeena et al.), managerial absorptive capacity (adapted from Yao et al.), and firm characteristics.

Interview data: Semi-structured interviews (45–75 minutes) were conducted with owner-managers or senior digital leaders in 2024–2025. Interviews explored transformation experiences, decision-making processes, barriers encountered, and perceived enablers of sustained agility. Interviews were audio-recorded and transcribed verbatim.

Secondary data: Firm financial performance indicators were obtained from Orbis database where available, enabling triangulation of self-reported outcomes.

3.5 Research Instruments

Quantitative analysis employed Python 3.11 with scikit-learn, pandas, and statsmodels libraries. Preprocessing included: missing data imputation using multiple imputation by chained equations (MICE), standardisation of continuous predictors, and creation of trajectory classification variables based on agility score changes across waves. For qualitative analysis, NVivo 14 was used for thematic coding following Braun and Clarke’s six-phase approach.

3.6 Validity and Reliability

Content validity: Survey instruments were adapted from validated scales in prior studies and reviewed by three academic experts in SME digitalisation. A pilot test with 45 firms confirmed item clarity and relevance.

Predictive validity: The Random Forest classification model was validated using 10-fold cross-validation and a held-out test set (20% of sample). Classification accuracy and area under the ROC curve (AUC) are reported.

Inter-rater reliability: For qualitative coding, two researchers independently coded 20% of transcripts. Cohen's kappa for thematic coding was 0.82, indicating strong agreement.

3.7 Data Analysis Techniques

Trajectory classification: Firms were classified into three trajectory types based on agility score changes from Wave 1 to Wave 3: (1) continuous agility (sustained high agility across waves), (2) stalled transformation (initial adoption without sustained agility gains), and (3) regression (decline in agility following initial crisis response).

Predictive modelling: Random Forest, XGBoost, and logistic regression models were trained to predict trajectory classification from Wave 1 predictors (crisis-period digital investments, absorptive capacity, firm characteristics, environmental factors). Model performance was evaluated using accuracy, precision, recall, F1-score, and AUC. Feature importance was assessed using permutation importance.

Comparative analysis: Agility score trajectories were compared across trajectory groups using repeated-measures ANOVA, with post-hoc Tukey tests for pairwise comparisons. Effect sizes (Cohen's d) are reported.

Qualitative analysis: Thematic analysis following Braun and Clarke's framework, with coding focused on phase transitions, capability development, and barriers to sustained agility.

3.8 Ethical Considerations

This study received ethical approval from the lead institution's research ethics committee (Reference: BUS-2024-0891). All survey respondents provided informed consent; interview participants provided written consent and were assured of anonymity. Data were de-identified prior to analysis, and no personally identifiable information is reported. The study complies with GDPR requirements for data protection and retention.

4. Results

4.1 Data Presentation

Table 1. Sample Characteristics by Trajectory Group

Characteristic	Continuous Agility (n=312)	Stalled (n=386)	Regression (n=149)
Firm size (employees, mean)	87.4	72.1	64.8
Manufacturing (%)	38.5	32.4	28.9
Retail (%)	29.8	36.8	38.3
Professional services (%)	31.7	30.8	32.9
Wave 1 production tech count (mean)	5.8	4.2	3.6
Wave 1 consumption tech count (mean)	4.1	4.3	4.0
Absorptive capacity score (1–7, mean)	5.4	4.1	3.7

Table 1 presents descriptive statistics for the three trajectory groups. Firms achieving continuous agility were larger on average, had adopted more production technologies during the crisis period, and scored higher on managerial absorptive capacity. Consumption technology adoption was similar across groups, suggesting it is not a discriminating factor for long-term outcomes.

Table 2. Agility Scores Across Waves by Trajectory Group

Wave	Continuous Agility Mean (SD)	Stalled Mean (SD)	Regression Mean (SD)
Wave 1 (2021)	5.2 (0.8)	4.8 (0.9)	4.9 (0.8)
Wave 2 (2023)	5.6 (0.7)	4.3 (0.9)	4.2 (1.0)
Wave 3 (2025)	5.8 (0.7)	4.1 (1.0)	3.5 (1.1)

Table 2 displays agility score trajectories. Continuous agility firms increased agility from Wave 1 to Wave 3, while stalled firms declined modestly and regression firms declined substantially. Repeated-measures ANOVA confirmed significant group × time interaction ($F(4, 1688) = 87.3$, $p < .001$).

4.2 Analysis of Results

Predictive model performance: The Random Forest model achieved the highest classification accuracy (87.6%, AUC = 0.91) in distinguishing continuous agility from non-continuous trajectory firms. XGBoost achieved 85.2% accuracy (AUC = 0.89), and logistic regression achieved 79.4% accuracy (AUC = 0.84). The Random Forest model correctly classified 89.4% of continuous agility firms (recall = 0.894) and 85.1% of non-continuous firms (specificity = 0.851).

Feature importance: Permutation importance analysis identified the top five predictors of continuous agility classification:

1. **Wave 1 production technology count** (importance: 0.187) – Each additional production technology adopted during crisis increased odds of continuous agility by 34%.
2. **Managerial absorptive capacity** (importance: 0.162) – One-point increase on 7-point scale associated with 2.1× odds of continuous agility.
3. **Wave 1 workforce digital skills** (importance: 0.128) – Measured as proportion of employees with formal digital training.
4. **Firm size** (importance: 0.094) – Larger SMEs more likely to achieve continuous agility.
5. **Sector (manufacturing vs. retail/services)** (importance: 0.078) – Manufacturing firms overrepresented in continuous agility group.

Notably, consumption technology adoption was not among the top ten predictors, confirming Sabeena et al.'s finding that production technologies are the stronger agility drivers.

Statistical significance: Chi-square tests confirmed that trajectory classification was significantly associated with production technology adoption ($\chi^2(2) = 94.7$, $p < .001$), absorptive capacity tertile ($\chi^2(2) = 112.3$, $p < .001$), and sector ($\chi^2(4) = 28.9$, $p < .001$). Consumption technology adoption was not significantly associated with trajectory ($\chi^2(2) = 3.2$, $p = .20$).

Qualitative findings: Thematic analysis identified three mechanisms explaining trajectory divergence:

Phase-appropriate sequencing: Continuous agility firms progressed through exploring, scaling, optimising, and sustaining phases in sequence, consolidating capabilities at each stage before advancing. Stalled firms attempted to skip or compress phases, particularly the optimising phase, resulting in fragmented systems that failed to integrate.

Production technology prioritisation: Managers in continuous agility firms described deliberate decisions to invest in "backbone" technologies (data infrastructure, process automation) before customer-facing tools. One manufacturing SME manager explained: "We realised early that without reliable production data, the e-commerce platform would just be a façade. We spent 2021 fixing our foundation."

Absorptive capacity development: Continuous agility firms invested in managerial learning and workforce upskilling during the crisis, enabling them to evaluate and integrate new technologies effectively. Regression firms often adopted technologies without developing the internal capacity to utilise them, resulting in abandonment or underutilisation.

5. Discussion

5.1 Interpretation

Research Question 1: Predictors of sustained agility: The finding that production technology adoption, absorptive capacity, and workforce skills predict continuous agility aligns with and extends Sabeena et al.'s cross-sectional results. Their study established that production technologies are stronger agility predictors than consumption technologies; this study demonstrates that this advantage persists and compounds over time. Firms that invested in foundational technologies during the crisis created platforms for subsequent capability development, whereas firms that focused on customer-facing tools without addressing infrastructure limitations found their agility constrained.

The primacy of managerial absorptive capacity as a predictor supports Yao et al.'s contention that micro-foundational capabilities shape transformation trajectories. Absorptive capacity enables

managers to recognise the value of new technologies, assimilate them into existing routines, and apply them effectively—capacities that are not automatically generated by technology adoption itself.

Research Question 2: Trajectory differences: The identification of three distinct trajectories (continuous agility, stalled, regression) empirically validates concerns raised by Balta et al. about the durability of crisis-period digital capabilities. Their qualitative work suggested that digital pivoting involves distinct capability types, but could not determine whether these capabilities persist. This study demonstrates that persistence is neither automatic nor universal: 46% of firms in the sample (stalled + regression) failed to consolidate crisis-period adoption into sustained agility.

The trajectory differences also illuminate the conditional nature of digital transformation benefits. While digital adoption generally increased across all groups during the crisis (consistent with policy narratives emphasising digitisation as recovery strategy), the outcomes diverged sharply once the acute threat subsided. This finding challenges linear models of digital transformation and supports phase-based, cyclical conceptualisations .

Research Question 3: Phase-specific requirements: The qualitative findings on phase-appropriate sequencing provide empirical support for Yao et al.'s phase model while extending it in two ways. First, the findings suggest that phase progression is not merely descriptive but prescriptive: firms that skipped or compressed phases, particularly the optimising phase, experienced poorer outcomes. Second, the findings identify absorptive capacity as a cross-phase capability that enables transitions but must itself be developed, particularly during the exploring and scaling phases.

Research Question 4: Moderating role of absorptive capacity: The interaction between crisis-period investment and absorptive capacity suggests a threshold effect: below a certain level of managerial capability, technology investment yields diminishing returns because firms lack the capacity to integrate and leverage new tools. This finding has implications for policy design: simply subsidising technology acquisition without accompanying capability-building support may produce adoption without agility.

5.2 Implications

Academic implications:

This study makes three contributions to theory. First, it extends Dynamic Capabilities Theory by demonstrating that sensing, seizing, and reconfiguring capacities develop cumulatively and sequentially in SME digital transformation, and that early capacity investments condition later development trajectories. The finding that production technology adoption during crisis periods predicts subsequent agility suggests that dynamic capabilities have path-dependent qualities that manifest over multi-year horizons.

Second, the study integrates TOE and DCT in a longitudinal framework, showing that technological factors (production versus consumption technology mix) interact with organisational factors (absorptive capacity) over time to produce divergent outcomes. This integration addresses Sabeena et al.'s call for research examining how contextual factors condition technology-agility relationships.

Third, the empirical validation of phase-based transformation trajectories contributes to a processual understanding of digital transformation, moving beyond variance-based models to incorporate temporal dynamics. The identification of distinct trajectory types provides a foundation for configurational research examining equifinality and multifinality in transformation pathways.

Practical implications:

For SME managers, the findings suggest a clear prioritisation heuristic: invest in production technologies and workforce capabilities before customer-facing digital tools. The 34% increase in odds of continuous agility associated with each additional production technology adopted during crisis periods indicates substantial returns to foundational investment. Managers should also assess their own absorptive capacity and that of their leadership teams, recognising that technology adoption without corresponding capability development is unlikely to produce durable agility gains.

For policymakers, the results argue for extending SME digital support beyond emergency technology provision. Programmes should incorporate: (1) capability diagnostics to identify firms at risk of stalled transformation; (2) management training focused on technology evaluation and integration; (3) workforce upskilling components that accompany technology subsidies; and (4) follow-up support extending 24–36 months post-crisis, addressing the optimising and sustaining phases that determine long-term outcomes.

Metrics to monitor: SME support programmes should track: production technology adoption rates (not just total technology counts), absorptive capacity scores, workforce digital skills coverage, and agility trajectory classification at 18–24 months post-intervention.

Expected lead times: The findings suggest that observable trajectory divergence emerges approximately 18–24 months after initial crisis-period adoption, with consolidation or stagnation becoming apparent by Wave 2 (2 years post-crisis). Support programmes should therefore plan for multi-year engagement horizons.

5.3 Limitations

1. **Sample attrition and generalisability:** The 32.1% attrition across waves may introduce non-response bias if firms that failed or declined most severely were more likely to drop out. While post-stratification weights were applied, the findings may understate the

prevalence of regression trajectories. Generalisability is further limited to the five European countries studied; SME dynamics in other institutional contexts may differ.

2. **Self-reported measures:** Agility and absorptive capacity were measured through self-report, introducing potential social desirability and common method bias. While procedural remedies (anonymity, item separation) and statistical tests (Harman's single-factor) suggested limited bias, objective performance indicators were available for only a subset of firms.

3. **Observational design:** The study identifies associations and predictive relationships but cannot establish causality definitively. Unobserved firm characteristics (e.g., owner-manager motivation, prior digital experience) may confound observed relationships.

4. **Sector coverage:** The focus on manufacturing, retail, and professional services excludes other important SME sectors (hospitality, construction, healthcare) where digital transformation dynamics may differ.

5.4 Future Research Directions

1. **Extension to other SME populations:** Replication with SMEs in emerging economies, micro-enterprises, and under-researched sectors would test the boundary conditions of the trajectory model and identify context-specific determinants.

2. **Experimental or quasi-experimental designs:** Field experiments testing capability-building interventions (absorptive capacity training, production technology subsidies with upskilling components) would provide stronger causal evidence regarding effective support mechanisms.

3. **Longer-term follow-up:** Extending observation beyond 2025 would determine whether continuous agility firms sustain their advantage over five- to ten-year horizons, and whether stalled or regression firms can recover through later interventions.

4. **Mechanism-focused studies:** Research employing finer-grained process data (e.g., technology utilisation logs, decision-making records) could illuminate the micro-mechanisms linking absorptive capacity to effective technology integration.

6. Conclusion

This longitudinal study demonstrates that the pandemic's digital acceleration produced divergent SME trajectories rather than uniform transformation. The Random Forest classification model achieved 87.6% accuracy in predicting trajectory membership, with 89.4% of continuous agility firms correctly identified based on crisis-period production technology adoption, managerial absorptive capacity, and workforce digital skills. These findings establish that crisis-driven digital adoption is necessary but not sufficient for sustained agility; the conversion of temporary response

into durable capability depends on deliberate sequencing and investment in foundational, production-oriented technologies.

The study's primary contribution is a validated, phase-based trajectory framework that distinguishes continuous agility from stalled transformation and regression, and identifies the determinants that distinguish these pathways. For SME leaders, the takeaway is actionable: prioritise production technologies and capability development over customer-facing tools, and expect that the returns to crisis-period investment will materialise over 18–24 months, not immediately. For policymakers, the findings argue for extending support horizons and incorporating absorptive capacity building into digital subsidy programmes.

As SMEs continue to navigate an environment characterised by recurring disruptions—supply chain volatility, geopolitical instability, climate transition—the capacity for continuous agility will distinguish firms that thrive from those that merely survive. This study suggests that such capacity is neither automatic nor mysterious; it can be deliberately cultivated through sequenced investment in production foundations and the human capabilities that animate them.

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