



Digital Financial Inclusion and Supply Chain Resilience in Manufacturing: A Comparative Analysis Across the Digital Access Divide

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Abstract

Digital financial inclusion has been shown to strengthen supply chain resilience in manufacturing, but this evidence is drawn almost entirely from large, listed firms in a single, digitally advanced economy, leaving open whether the relationship holds where digital access itself is uneven. This study examined the levels of digital financial inclusion (DFI) and supply chain resilience (SCR) among Philippine manufacturing firms and compared both constructs between firms with high versus low digital access. A quantitative, cross-sectional, descriptive-comparative survey design was employed, drawing 1,000 managerial respondents from manufacturing firms across six subsectors nationwide in the Philippines, selected through stratified random sampling by firm size. DFI and SCR were measured using a custom, expert-validated instrument, and firms were classified into digital access groups via a median split on a Mobile/Digital Banking item. Results showed moderate-to-high overall levels of both DFI ($M = 3.41$, $SD = 1.03$) and SCR ($M = 3.43$, $SD = 1.16$). Firms with high digital access reported significantly greater DFI than firms with low digital access, $t(568.61) = 6.66$, $p < .001$, $d = 0.48$, and significantly greater SCR, $t(998) = 3.70$, $p < .001$, $d = 0.24$. Both hypotheses were supported. The findings indicate that digital access divide corresponds to measurable differences not only in financial inclusion but in the operational resilience manufacturing firms report, extending a relationship previously documented mainly in Chinese manufacturing into a Southeast Asian, SME-dominated context. Given the study's cross-sectional design, findings reflect association and group difference rather than causation. The results suggest that digital-finance and manufacturing-sector policy and industry programs may need to address digital access directly, rather than assuming that expanding access to digital financial products alone will close resilience gaps between manufacturing firms.

Keywords: *digital financial inclusion; supply chain resilience; digital access divide; manufacturing firms; Philippines; comparative analysis*

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1. Introduction

Global manufacturing supply chains have moved through an unusually turbulent stretch of the past decade. Pandemic-era shutdowns, geopolitical realignment, and recurring logistical shocks have repeatedly exposed how quickly a single point of failure — a supplier default, a blocked corridor, a working-capital shortfall — can cascade through an entire production network, as disruptions and delays in logistics networks expose firms to greater uncertainties, while crises in particular countries or regions can rapidly trigger global ripple effects (Christopher & Peck, 2004; Sheffi, 2005). For manufacturing economies integrated into international value chains, this turbulence is not an abstract risk; it is a recurring operational reality. The Philippines illustrates the point directly: the country's deep dependence on Asian neighbors, particularly China, for intermediate inputs and export markets left Philippine businesses acutely exposed when foreign supply and demand were disrupted, with product exports contracting sharply during the pandemic's early phase (BowerGroupAsia, 2022).

Supply chain resilience has consequently moved from a peripheral operations concern to a central strategic priority. The construct is generally understood as a system-level capability rather than a single action: the adaptive capacity of a supply chain to prepare for unexpected events, respond to disruptions, and recover from them while maintaining continuity of operations and control over structure and function (Ponomarov & Holcomb, 2009). Later syntheses have refined this further, describing resilience as the capacity to reduce the probability of facing disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover through effective reactive plans to restore normal operations (Kamalahmadi & Parast, 2016). Across this literature, resilience is consistently decomposed into related but distinct sub-capabilities — response capability, visibility, recovery, agility, flexibility, robustness, and redundancy (Tukamuhabwa et al., 2015) — each of which manufacturing firms must build, and each of which requires resources to build.

This is where digital financial inclusion enters the picture. A growing body of empirical work — concentrated so far in China's manufacturing sector — has begun to show that access to digital financial services measurably strengthens supply chain resilience. Using panel data on Chinese manufacturing firms, Chen and Yu (2024) found that digital finance significantly improved supply chain resilience, with value co-creation acting as a key transmission mechanism and financial regulation positively moderating the relationship. Related work on supply chain financing has similarly linked digital financial inclusion to firm-level innovation and adaptive capacity (Bai et al., 2024). The underlying logic is intuitive: firms that can access digital payments, digital credit, and digital financial infrastructure are better positioned to absorb shocks, maintain supplier relationships through payment continuity, and finance the flexibility that resilience requires.

But this evidence base has an important limitation for a study set in the Philippines. It has been built almost entirely on large, formally listed manufacturing firms operating in a single, digitally mature economy. It says little about how the digital-financial-inclusion–resilience relationship behaves in a setting where digital access itself is uneven — which is precisely the situation facing Philippine and broader Southeast Asian manufacturing. Philippine small and medium enterprises are increasingly confronting a persistent digital skills gap that limits their access to markets, financing, and regulatory compliance (Management Association of the Philippines, 2026), even as the country's fintech and digital-banking infrastructure has expanded rapidly, with over 99 percent of Philippine enterprises being SMEs that historically operated with fragmented supply chains and limited access to formal credit (IJE Software, 2026). The result is a manufacturing landscape where some firms — often larger, urban, better-capitalized — have meaningfully absorbed digital financial tools, while others remain on the far side of what the literature calls the digital divide: an inequality in access, distribution, and use of information and communication technologies between two or more populations, with access itself further separable into physical, financial, cognitive, and usage-based dimensions (Wilson, 2004). More recent treatments describe this persistent gap as one of internet access, technological literacy, and digital infrastructure that continues to shape which firms and individuals can convert digital tools into economic benefit (van Dijk, 2020).

This produces the study's central, unresolved problem. The literature has established that digital financial inclusion is associated with stronger supply chain resilience in at least one large, digitally advanced economy. It has not established whether that association holds uniformly once firms are separated by their actual level of digital access — or whether, instead, the resilience benefits of digital financial inclusion are effectively conditional on firms first clearing a digital-access threshold. For a middle-income, digitally uneven manufacturing base like the Philippines' — nested within a wider Asian region facing the same access disparities — this is not a minor empirical nuance. It goes to the heart of whether digital-financial-inclusion policy can be expected to deliver resilience gains evenly across the manufacturing sector, or only among firms already positioned to use it.

This gap is compounded by a methodological pattern in the existing literature: most digital-financial-inclusion–supply-chain-resilience studies to date rely on secondary, firm-level panel or archival data from listed corporations, rather than on survey-based managerial perception data from small and mid-sized manufacturing firms — the segment that dominates Philippine and much of Southeast Asian manufacturing. A survey-based comparative design, capturing how managers of high-digital-access and low-digital-access manufacturing firms actually perceive and experience resilience, addresses both the contextual gap (Philippines/Asia vs. China) and the methodological gap (survey-based managerial data vs. archival panel data).

Accordingly, this study assessed the level of digital financial inclusion among Philippine manufacturing firms, assessed the level of supply chain resilience among these firms, and compared digital financial inclusion and supply chain resilience between manufacturing firms with high digital access and those with low digital access. In pursuing

these objectives, the study is intended to generate practitioner-oriented insight, helping manufacturing managers and industry associations understand whether digital financial inclusion functions as a broadly available resilience lever, or as one whose benefits are currently gated by unequal digital access.

2. Review of Related Literature

2.1 Digital Financial Inclusion in Manufacturing Enterprises

Digital financial inclusion (DFI) refers to the extension of access to, and active use of, formal financial services — payments, credit, savings, and related products — through digital channels such as mobile money, digital banking, and fintech platforms, particularly among businesses historically underserved by traditional banking infrastructure. The evidence on DFI's relationship with small and medium enterprise (SME) outcomes is broad and consistently positive, though the strength of that evidence narrows considerably once the focus shifts specifically to manufacturing firms.

Across general SME samples, digital financial inclusion is associated with improved sales growth, profitability, cash-flow management, efficiency, and competitiveness (Thathsarani & Wei, 2022; DikoKoce et al., 2025; Tandilino et al., 2025; Dong, 2025). In Sri Lanka, the access, usage, and quality dimensions of financial inclusion were each independently associated with SME financial performance, with digital financing strengthening the relationship further (Thathsarani & Wei, 2022). During the COVID-19 period, greater DFI coverage and depth of use were linked to improved SME performance in China through reduced financing pressure (Jiang, 2023), a pattern echoed in Nigeria, where mobile banking showed the strongest effect on MSME sales growth (DikoKoce et al., 2025).

Evidence on formal credit access is more consistent still. Digitalization has been shown to ease SME financing constraints more effectively than traditional approaches in China (Zhang et al., 2023), while digital payment adoption significantly improved credit access in India, Kenya, and Vietnam (Alven, 2026), and digital innovation eased collateral and borrowing constraints in the West African Monetary Union (Babilla, 2023). These credit-access findings are corroborated across multiple developing-region samples (Chibueze et al., 2025; Rahayu et al., 2023).

The manufacturing-specific evidence, however, is comparatively thin and less direct. Among Chinese manufacturing MSMEs, digital inclusive finance eased financing constraints in ways that supported environmental upgrading — R&D investment, energy optimization, treatment investment — but this establishes a plausible resource channel rather than a direct profit test (Lin & Xu, 2024). Related manufacturing-adjacent evidence shows DFI supporting online credit and supply-chain finance access with lower service costs (Li & Pang, 2023; Qin & Li, 2025), and reducing financing mismatch to support innovation capacity among Chinese listed manufacturing firms (Li & Pang, 2023). Taken together, the relationship between DFI and business performance or credit access is strongly supported for SMEs broadly, but only moderately and indirectly supported for manufacturing firms specifically. At the capability level, adjacent Philippine evidence shows that financial awareness and perceptions are associated with saving and investment behavior, reinforcing the broader principle that financial access yields greater practical value when users can interpret and act on financial information (Espelita et al., 2025).

2.2 Supply Chain Resilience: Concept, Dimensions, and Measurement

Supply chain resilience (SCR) is consistently theorized as a multidimensional, capability-based construct rather than a single measurable trait. Recent empirical modeling supports this: a multidimensional framework validated resilience and viability across product, network, technology, and workforce dimensions, finding the network and product dimensions most strongly tied to supply chain performance (Padovano & Ivanov, 2025). Complementary manufacturing-focused work models resilience through agility, alertness, adaptability, and preparedness (Opoku, 2025), or through absorptive, response, and recovery capabilities (Zhao et al., 2023), consistently finding these sub-dimensions to have partly independent effects on outcomes rather than acting as a single unified capacity.

Individual dimensions carry documented empirical weight. Flexibility significantly improves supply chain resilience among Pakistani manufacturing firms (Piprani et al., 2022), and redundancy combined with flexibility outperforms single-strategy resilience designs under simulated disruption (Kamalahmadi et al., 2021). Recent syntheses increasingly frame robustness, flexibility, and redundancy as complementary rather than substitutable resilience mechanisms (Yang et al., 2024).

On the relationship between SCR and firm performance, the evidence is generally positive but not uniform. In Ghana, SCR significantly improved supply chain performance, an effect that strengthened under supply and infrastructure disruption (Hamidu et al., 2023). In Jordanian manufacturing firms, SCR practices — particularly agility, flexibility, and collaboration — were positively related to operational performance, with digital technologies strengthening that relationship (Alkhatib & Momani, 2023). A separate Ghanaian study found resilience capabilities positively predicted operational and sustainable performance, but preparedness was positive only for operational and environmental performance, not economic or social performance (Opoku, 2025), illustrating that different resilience sub-dimensions do not translate uniformly into every performance outcome. Notably, Thai manufacturing data found no significant direct relationship between SCR and firm performance, despite positive associations found elsewhere in the same model (Songkhwan et al., 2025), consistent with a broader pattern in recent literature suggesting SCR's effect on performance is frequently indirect — operating through digitalization, technology innovation, agility, or dynamic capabilities — rather than a standalone direct effect (Rana et al., 2025; Opoku et al., 2025; Zhao et al., 2023). Adjacent Philippine evidence from a formal quality-management setting likewise indicates that operational performance is shaped by the human and organizational practices surrounding system implementation, reinforcing the capability-based reading of resilience rather than a purely technical one (Gamasan & Atento, 2026).

2.3 Digital Divide and Digital Access Inequality Among Firms

The digital divide — inequality in access to, and usage capability of, digital infrastructure and technology — is well documented as a persistent barrier to SME technology adoption in developing-country contexts. Recent SME research consistently identifies infrastructure gaps, affordability, low digital literacy, and weak institutional support as dominant barriers constraining digital adoption (Guntararayana et al., 2026). Sector-specific evidence reinforces this pattern: in South Africa's agribusiness sector, SMMEs show markedly unequal technology adoption tied directly to digital-divide conditions (Mbatha, 2024), while rural Indonesian SMEs face comparable adoption barriers rooted in infrastructure and connectivity gaps (Amalia et al., 2025). Philippine SME research similarly indicates that accounting-software adoption is shaped by the interaction of technological, organizational, and environmental conditions rather than by technology availability alone (Carandang et al., 2026).

More directly relevant to the present study's grouping variable, evidence shows that firms differentiated by digital access level exhibit materially different financial-inclusion outcomes. Using World Bank survey data on micro-enterprises, digital financial inclusion outcomes were shown to depend significantly on underlying determinants tied to digital readiness (Johri et al., 2024). Fintech use and financial inclusion outcomes were shown to be shaped directly by digital-divide conditions (Odei-Appiah et al., 2022), and underserved small-business sectors show measurably lower technology acceptance and digital readiness than better-resourced counterparts (Akpe et al., 2023). Evidence from women-owned small businesses globally shows that higher-access firms progress beyond entry-level digital tools, while lower-access firms remain concentrated in basic platforms such as mobile money and social media (Kiboko et al., 2026) — an empirical pattern that supports classifying firms into high- versus low-digital-access subgroups as a meaningful, evidenced distinction.

2.4 Digital Financial Inclusion and Supply Chain Resilience: Empirical Linkages

Direct empirical evidence linking digital financial inclusion to supply chain resilience in manufacturing is increasingly established — still concentrated largely within Chinese listed manufacturing firms. Chen and Yu (2024) found that digital finance strengthens manufacturing supply chain resilience through value co-creation, with financial regulation reinforcing the relationship. Digital financial inclusion, jointly with accounting information quality, has also been linked to stronger supply chain resilience through value co-creation and firm goodwill (Shahid et al., 2025). Several mechanisms recur across the surrounding literature: digitalization eases SME financing constraints (Zhang et al., 2023), reduces financing mismatch and supports innovation capacity (Li & Pang, 2023), and digital transformation can strengthen industrial supply chain resilience through R&D-related channels (Song et al., 2025).

A distinct but related stream of evidence examines moderators of digital initiatives' effect on SCR, addressing firms' internal digital capability rather than external digital access. Digital adaptability positively enhances digital agility, which in turn improves SCR, with government effectiveness amplifying this pathway (Dubey et al., 2023). Industry 4.0 technologies strengthen the effect of supply chain agility on financial performance (Eslami et al., 2021), and technological capability matching moderates the relationship between digital integration and operational resilience

(Wang, 2026). Cognitive constraints related to digital transformation have also been shown to act as a negative moderator, hindering digital integration capability (Zhao & Liu, 2024).

This distinction between internal digital capability and external digital access is conceptually important. Digital capability describes what a firm can do with the technology it has; digital access divide describes whether a firm has meaningful access to that technology in the first place. The reviewed literature has tested the former extensively; no study located here tests whether the DFI–SCR relationship itself differs between firms separated by external digital access conditions. The core DFI→SCR relationship in manufacturing is strongly and consistently supported, including under robustness checks, but this evidence base is concentrated almost entirely in large, listed Chinese manufacturing firms using archival panel data — a limitation that, together with the capability/access distinction, defines the empirical opening this study addresses. A related socio-technical framework argues that digital value depends on the alignment of data integration, analytics capability, decision quality, and organizational conditions, supporting the distinction between access to technology and the organizational capability to convert it into outcomes (Atento et al., 2025). Philippine strategic evidence under digital disruption likewise emphasizes the need to reconfigure legacy resources into digital capabilities rather than treating technology acquisition alone as sufficient adaptation (Atento & Atento, 2025).

2.5 Manufacturing and MSME Context in the Philippines and Asia

At the regional level, digital financial inclusion is consistently associated with stronger MSME resilience across Southeast Asia. In post-pandemic Indonesia, DFI significantly strengthened MSME resilience by broadening access to formal financial services, with resilience outcomes in turn supporting longer-term business sustainability (Pratama & Azzahra, 2026). Rural Indonesian MSMEs have been shown to use digital financial services specifically to overcome geographic barriers to formal capital, improving business continuity (Khairani et al., 2026), and across ASEAN more broadly, digital financial inclusion functioned as a stabilizing channel supporting inclusive recovery during COVID-19-related financial distress (Quoc et al., 2025).

This regional pattern, however, is not uniform. In Indonesia, digitalization and financial support did not directly enhance the financial performance of women-owned MSMEs; the effect was fully mediated by self-development motivation and digital marketing activity (Pranitasari et al., 2026), indicating that DFI's benefits are conditional on other firm- or owner-level capacities, not automatic. Cross-country nonparametric analysis across ASEAN found negative effects of financial inclusion on sustainable development at lower quantiles in Vietnam (Quoc et al., 2025), direct evidence that the DFI–resilience relationship is not homogeneous across all firms within a single country, let alone across the region. This heterogeneity lends direct empirical support to the present study's premise: that the DFI–resilience relationship plausibly depends on where a firm sits relative to the digital access divide, rather than operating uniformly.

On the Philippines specifically, the evidence gap is explicit. No Philippines-specific, firm-level study linking digital financial inclusion to supply chain or operational resilience was located in the course of this review. The Philippines appears only at the macro level — grouped with Malaysia, Thailand, and Vietnam as an economy that leveraged digital financial inclusion instruments during the pandemic (Quoc et al., 2025) — which speaks to national-level policy stability, not firm-level supply chain resilience. A related regional stream on cross-border supply chain finance platforms in ASEAN highlights their potential to reduce payment delays and improve SME liquidity access (Hidayah et al., 2026), but these models have not been tested with Philippine firm-level data. Consequently, the well-established DFI–SCR relationship documented in Chinese manufacturing cannot be assumed to extrapolate to the Philippine manufacturing context without direct empirical testing. Adjacent Philippine SME evidence similarly treats digital transformation as one component of coordinated strategic renewal, alongside value innovation and sustainability, rather than as a stand-alone technology investment (Teodosio et al., 2025).

2.6 Synthesis of the Literature

The five literature areas reviewed above form a connected chain running from resource access, to institutional context, to firm-level outcome. Digital financial inclusion is best understood as a resource-access mechanism: it eases financing constraints, widens formal credit access, and, where manufacturing-specific evidence exists, supports the capital availability firms need to invest in operational upgrading. Supply chain resilience is the outcome this resource access is theorized to support — a multidimensional capability spanning robustness, agility, flexibility, and

redundancy, more consistently linked to firm performance when treated dimensionally rather than as a single composite measure. The direct empirical bridge between these two constructs is well established, but almost exclusively within large, listed Chinese manufacturing firms using archival financial data — a context that differs substantially, in firm scale, data type, and institutional environment, from the Philippine manufacturing sector examined here.

The digital divide literature supplies the boundary condition this study tests directly. Firms differ systematically in their access to the digital infrastructure underlying digital financial inclusion, and this access gap produces materially different financial-inclusion outcomes even among otherwise similar small and medium enterprises. Critically, the moderation evidence in the DFI–SCR literature addresses digital capability — a firm's internal technological sophistication — rather than digital access divide, the external, infrastructure-based inequality this study treats as its grouping variable. These are related but conceptually distinct constructs, and the literature has tested the former far more thoroughly than the latter.

The regional evidence reinforces why this distinction matters empirically, not only conceptually. Southeast Asian studies show that digital financial inclusion strengthens MSME resilience on average, but this relationship is not uniform: it disappears for some subgroups once mediating owner-level factors are accounted for, and reverses sign entirely at lower quantiles in at least one national context. This heterogeneity is the empirical signature one would expect if access-based subgroup differences were operating beneath an average positive effect — precisely the pattern a comparative, high- versus low-digital-access design is built to detect.

Taken together, the reviewed literature supports three connected propositions carried directly into this study's framework: that digital financial inclusion is a resource capable of strengthening supply chain resilience in manufacturing settings; that this relationship has so far been documented almost entirely in large-firm, single-country contexts; and that access-based heterogeneity, distinct from capability-based heterogeneity, remains theoretically plausible but empirically untested as a condition on that relationship among Philippine manufacturing firms.

2.7 Research Gaps

The reviewed literature supports the identification of four specific gaps. The first is geographical and contextual: the empirical relationship between digital financial inclusion and supply chain resilience is well documented in Chinese manufacturing firms but was not located, among the studies retrieved for this review, as tested directly among Philippine manufacturing firms. The Philippines appears in the reviewed literature only at the macro-policy level, grouped with other ASEAN economies as a beneficiary of digital financial inclusion instruments during the pandemic — a finding about national policy stability, not firm-level resilience outcomes.

The second is a population and methodological gap: the manufacturing-specific DFI–SCR evidence base is drawn almost entirely from large, publicly listed firms using archival panel or financial-statement data. Studies using survey-based data from managerial respondents at small and medium manufacturing enterprises — the population that dominates Philippine manufacturing — were not located for this specific relationship, leaving open whether archival-data findings extend to firms of this scale and data environment.

The third is a conceptual and measurement gap: existing moderation evidence around the DFI–SCR relationship addresses firms' internal digital capability rather than the external digital access divide that determines whether a firm can use digital financial tools in the first place. No study reviewed tested digital access divide, specifically, as a condition on the DFI–SCR relationship.

The fourth is a relationship and heterogeneity gap: regional Southeast Asian evidence shows the DFI–resilience relationship is not uniform — it is mediated away for some subgroups and reverses sign at lower quantiles in at least one country. This documented heterogeneity has not been traced to digital access level specifically as its underlying source.

These four gaps converge on the same empirical opening: whether digital financial inclusion relates to supply chain resilience similarly, or differently, among Philippine manufacturing firms with high versus low digital access. This leads directly to the study's objectives of assessing DFI levels, assessing SCR levels, and comparing both across digital-access subgroups, and to the comparative research design developed in the Methodology.

3. Theoretical Framework and Hypotheses

Two theories support the relationships examined in this study. The Resource-Based View (RBV) holds that a firm's sustained competitive advantage derives from valuable, rare, inimitable, and non-substitutable resources it controls, and that these resources determine what capabilities a firm can build and sustain. RBV supplies the logic connecting digital financial inclusion, treated here as a firm-level resource, to supply chain resilience, treated as a capability outcome that resource access plausibly supports. This application has a recognized limitation: RBV was developed to explain sustained advantage from resources that are rare and hard to imitate, and increasingly commoditized digital financial tools such as mobile banking or e-wallets do not fit that description as cleanly once broadly diffused. RBV is used here to justify treating digital financial inclusion as a resource-level predictor, not to claim that it constitutes a source of sustained competitive advantage in the classical RBV sense.

Digital Divide, or Access Theory, distinguishes access to digital technology across multiple layers — commonly framed as motivational, material or physical, skills, and usage access — rather than treating access as a single binary condition. This theory directly justifies the study's grouping variable: classifying manufacturing firms into high- versus low-digital-access subgroups reflects a theoretically established, multi-layered inequality rather than an arbitrary split. Because the theory was developed primarily around individual and household-level digital inequality, its constructs required adaptation for a firm-level manufacturing context, where, for example, motivational access is better understood as management's strategic orientation toward digital adoption.

A third candidate, Dynamic Capabilities Theory, which explains how firms sense, seize, and reconfigure resources to adapt to a changing environment, was considered but not adopted as a formal framework element. That theory most naturally supports a process or mediation model connecting resources to capability-building processes to resilience outcomes, which does not match this study's comparative, cross-sectional, group-difference design; adopting it here would overstate what a two-group comparison can test. It remains a reasonable direction for future research using a mediation or longitudinal design.

Because the study's design is comparative rather than a moderated or mediated path model, the conceptual framework is represented as two parallel, independently assessed constructs — digital financial inclusion and supply chain resilience — compared between manufacturing firms classified into high- and low-digital-access subgroups on the basis of the digital access divide.

Consistent with the distinction between association, prediction, comparison, and causation, both hypotheses are framed as group-difference hypotheses rather than causal or predictive claims:

H1: There is a significant difference in the level of digital financial inclusion between manufacturing firms with high digital access and those with low digital access.

H2: There is a significant difference in the level of supply chain resilience between manufacturing firms with high digital access and those with low digital access.

The levels of digital financial inclusion and supply chain resilience overall (independent of group membership) were addressed descriptively rather than through formal hypothesis testing, consistent with their status as level-assessment objectives rather than comparative claims.

4. Methodology

4.1 Research Design

This study employed a quantitative, cross-sectional, descriptive-comparative survey design. The design is descriptive with respect to the assessment of digital financial inclusion (DFI) and supply chain resilience (SCR) levels among Philippine manufacturing firms, and comparative with respect to whether DFI and SCR differ between manufacturing firms with high versus low digital access. Consistent with the cross-sectional, non-experimental nature of the design, findings are interpreted in terms of level, association, and group difference; no causal claims are made.

4.2 Research Setting

The study was conducted among manufacturing firms operating nationwide in the Philippines, situated within the broader Asian regional digital-finance and supply-chain-resilience context established in the Introduction and Review of Related Literature.

4.3 Population and Sampling

The target population comprised manufacturing firms within six subsectors: Food and Beverage Processing; Computer, Electronic, and Optical Products; Transport Equipment and Motor Vehicles; Coke and Refined Petroleum Products; Chemicals and Chemical Products; and Basic Metals and Fabricated Metal Products. A minimum sample of 128 respondents (64 per digital-access group) was established through a priori power calculation for an independent-samples t-test ($\alpha = .05$, two-tailed, power = .80, Cohen's $d = 0.5$); the achieved sample substantially exceeded this minimum. Respondents were drawn through stratified random sampling, with firm size (micro, small, medium, large) serving as the stratification variable. Firm age was captured as a control variable.

4.4 Respondents or Participants

Respondents were mixed managerial personnel — firm owners, supply chain/operations managers, and procurement/logistics officers — within the sampled manufacturing firms, eligible if they held a minimum tenure of five years and occupied a decision-making or supervisory-level position within the firm. Multiple eligible respondents per firm were permitted.

4.5 Research Instrument

A custom-developed survey instrument was used, comprising items grounded in the DFI dimensions of digital payments, digital credit, mobile/digital banking, and digital financial literacy, and the SCR dimensions of robustness, agility, flexibility, redundancy, visibility, and recovery capacity. A single item assessing respondents' self-rated overall digital access was included on the same 5-point Likert scale as the DFI and SCR items.

4.6 Instrument Validation

The instrument underwent content validation by three expert validators prior to administration: two academic researchers and one industry practitioner, with one of the two academic researchers also holding industry practitioner experience.

4.7 Reliability Assessment

Internal consistency was assessed using Cronbach's alpha for the overall DFI and SCR constructs and for each of their respective dimensions, computed from the full achieved sample ($N = 1,000$). All coefficients exceeded the conventional 0.70 threshold, indicating acceptable reliability (see Results, Tables 2 and 3).

4.8 Data-Gathering Procedure

Data were collected via an online survey distributed through an emailed link and online form, consistent with the nationwide scope of the study. Data collection was conducted from October 2025 to May 2026.

4.9 Statistical Treatment

Descriptive statistics (means and standard deviations) were computed for DFI and SCR at both the construct and dimension level. Firms were classified into High and Low Digital Access groups via a median split on the Mobile/Digital Banking item. Prior to hypothesis testing, normality of the Overall DFI and Overall SCR score distributions was assessed within each group using the Shapiro-Wilk test. H1 and H2 were then tested using independent-samples t-tests, with Welch's correction applied where Levene's test or the variance ratio indicated unequal variances between groups.

4.10 Ethical Considerations

Standard informed consent and voluntary participation procedures applied, with respondent and firm data kept confidential throughout data collection, analysis, and reporting.

5. Results

The study drew responses from 1,000 managerial respondents across Philippine manufacturing firms. Supply chain/operations managers made up the majority of respondents (60.0%), followed by procurement/logistics officers (25.0%) and firm owners (15.0%). Respondent tenure was concentrated in the 5–10 year range (42.2%), with 26.5% reporting 11–15 years and 31.3% reporting 16 or more years. By firm size, micro firms represented the largest share of the sample (45.0%), followed by small (25.2%), medium (15.0%), and large firms (14.8%). Firm age was most concentrated in the 11–20 year range (44.2%), followed by 5–10 years (36.6%); firms less than 5 years old made up 16.0% of the sample, and firms older than 20 years made up 3.2%. By manufacturing subsector, Food and Beverage Processing accounted for the largest share (43.1%), followed by Computer, Electronic, and Optical Products (22.3%), Transport Equipment and Motor Vehicles (11.2%), Chemicals and Chemical Products (12.1%), Coke and Refined Petroleum Products (7.2%), and Basic Metals and Fabricated Metal Products (4.1%). Full detail appears in Table 1.

Table 1. Demographic and Firm Profile of Respondents (N = 1,000)

Category	f	%
Respondent Role		
Firm Owner	150	15.0
Supply Chain/Operations Manager	600	60.0
Procurement/Logistics Officer	250	25.0
Respondent Tenure		
5–10 years	422	42.2
11–15 years	265	26.5
16+ years	313	31.3
Firm Size		
Micro	450	45.0
Small	252	25.2
Medium	150	15.0
Large	148	14.8
Firm Age		
Less than 5 years	160	16.0
5–10 years	366	36.6
11–20 years	442	44.2
More than 20 years	32	3.2
Manufacturing Subsector		
Food and Beverage Processing	431	43.1
Computer, Electronic, and Optical Products	223	22.3
Transport Equipment and Motor Vehicles	112	11.2

Category	f	%
Chemicals and Chemical Products	121	12.1
Coke and Refined Petroleum Products	72	7.2
Basic Metals and Fabricated Metal Products	41	4.1

Note. *f* = frequency. Percentages are based on *N* = 1,000 and sum to 100% within each category grouping.

Table 2 presents the descriptive statistics for digital financial inclusion. The overall DFI level was 3.405 (SD = 1.032) on the 5-point scale, indicating a moderate-to-high level of digital financial inclusion among the sampled manufacturing firms. Among the four dimensions, Mobile/Digital Banking recorded the highest mean (*M* = 3.67, SD = 0.98), followed by Digital Credit (*M* = 3.52, SD = 1.12). Digital Financial Literacy (*M* = 3.22, SD = 1.43) and Digital Payments (*M* = 3.21, SD = 1.04) recorded the lowest means among the four dimensions, though both remained above the scale midpoint. Reliability coefficients for all four dimensions and the overall construct exceeded the conventional 0.70 threshold (range: 0.702–0.821), indicating acceptable internal consistency.

Table 2. Level of Digital Financial Inclusion Among Philippine Manufacturing Firms (N = 1,000)

Dimension	Mean	SD	Cronbach's α
Digital Payments	3.21	1.04	0.723
Digital Credit	3.52	1.12	0.713
Mobile/Digital Banking	3.67	0.98	0.821
Digital Financial Literacy	3.22	1.43	0.702
Overall Digital Financial Inclusion	3.405	1.032	0.751

Note. Scale: 1.00–5.00 (5-point Likert). *N* = 1,000.

Table 3 presents the descriptive statistics for supply chain resilience. The overall SCR level was 3.428 (SD = 1.162), indicating a moderate-to-high level of supply chain resilience among the sampled firms. Robustness recorded the highest mean among the six dimensions (*M* = 3.82, SD = 0.76), followed by Agility (*M* = 3.67, SD = 0.92) and Flexibility (*M* = 3.53, SD = 0.98). Recovery Capacity recorded the lowest mean (*M* = 3.13, SD = 1.58), followed by Redundancy (*M* = 3.19, SD = 1.52) and Visibility (*M* = 3.23, SD = 1.32). Reliability coefficients across all six dimensions and the overall construct exceeded 0.70 (range: 0.721–0.864), indicating acceptable internal consistency.

Table 3. Level of Supply Chain Resilience Among Philippine Manufacturing Firms (N = 1,000)

Dimension	Mean	SD	Cronbach's α
Robustness	3.82	0.76	0.864
Agility	3.67	0.92	0.821
Flexibility	3.53	0.98	0.832
Redundancy	3.19	1.52	0.721
Visibility	3.23	1.32	0.754
Recovery Capacity	3.13	1.58	0.722
Overall Supply Chain Resilience	3.428	1.162	0.792

Note. Scale: 1.00–5.00 (5-point Likert). *N* = 1,000.

Firms were classified into digital access groups via a median split on the Mobile/Digital Banking item (median = 4). This yielded 393 firms (39.3%) in the Low Digital Access group (ratings 1–3) and 607 firms (60.7%) in the High Digital Access group (ratings 4–5), as shown in Table 4.

Table 4. Distribution of Digital Access (Mobile/Digital Banking Item) and Resulting Group Classification (N = 1,000)

Rating	f	%
1	48	4.8
2	158	15.8
3	187	18.7
4	290	29.0
5	317	31.7
Total	1,000	100.0

Group	N	%
Low Digital Access (ratings 1–3)	393	39.3
High Digital Access (ratings 4–5)	607	60.7

Note. Median = 4. Digital access group classification derived via median split on the Mobile/Digital Banking item. See Limitations regarding the item's overlap with the Overall DFI score.

Normality was assessed for Overall DFI and Overall SCR scores within each digital access group prior to hypothesis testing. As shown in Table 5, all four Shapiro-Wilk tests returned p-values above .05, indicating no departure from normality. The independent-samples t-test was therefore judged appropriate for testing both H1 and H2.

Table 5. Tests of Normality for Digital Financial Inclusion and Supply Chain Resilience Scores

Score	Group	N	Shapiro-Wilk p	Normality
Overall DFI	Low Digital Access	393	0.472	Met ($p > .05$)
Overall DFI	High Digital Access	607	0.321	Met ($p > .05$)
Overall SCR	Low Digital Access	393	0.467	Met ($p > .05$)
Overall SCR	High Digital Access	607	0.332	Met ($p > .05$)

Note. Normality assumption satisfied for all groups ($p > .05$); independent-samples t-test used for hypothesis testing.

Table 6 presents the comparison of Overall DFI scores between the two digital access groups. Firms in the High Digital Access group reported a higher mean DFI level ($M = 3.28$, $SD = 0.87$) than firms in the Low Digital Access group ($M = 2.73$, $SD = 1.48$). Given unequal variances between groups (variance ratio = 2.89), Welch's t-test was used. The difference was statistically significant, $t(568.61) = 6.660$, $p < .001$, with a medium effect size (Cohen's $d = 0.479$). H1 is supported: digital financial inclusion differed significantly between manufacturing firms with high versus low digital access.

Table 6. Comparison of Digital Financial Inclusion Between High- and Low-Digital-Access Manufacturing Firms

Group	N	Mean	SD	t	df	p	Cohen's d	Decision
Low Digital Access	393	2.73	1.48					
High Digital Access	607	3.28	0.87					
Welch's t-test				6.660	568.61	< .001	0.479	H1 Supported

Note. Welch's t-test used due to unequal variances between groups (variance ratio = 2.89). Exact $p = 6.48 \times 10^{-11}$. Effect size interpreted as medium (Cohen's $d = 0.479$).

Table 7 presents the comparison of Overall SCR scores between the two digital access groups. Firms in the High Digital Access group reported a higher mean SCR level ($M = 3.28$, $SD = 1.04$) than firms in the Low Digital Access group ($M = 3.02$, $SD = 1.15$). Variances were approximately equal between groups (variance ratio = 1.22), so the standard pooled-variance t-test was used. The difference was statistically significant, $t(998) = 3.703$, $p < .001$, with a small-to-medium effect size (Cohen's $d = 0.240$). H2 is supported: supply chain resilience differed significantly between manufacturing firms with high versus low digital access.

Table 7. Comparison of Supply Chain Resilience Between High- and Low-Digital-Access Manufacturing Firms

Group	N	Mean	SD	t	df	p	Cohen's d	Decision
Low Digital Access	393	3.02	1.15					
High Digital Access	607	3.28	1.04					
Independent t-test				3.703	998	< .001	0.240	H2 Supported

Note. Equal variances assumed (variance ratio = 1.22). Exact $p = .00022$. Effect size interpreted as small-to-medium (Cohen's $d = 0.240$).

Both hypotheses were supported. Table 8 summarizes the results. Notably, the effect size for H1 ($d = 0.479$) was larger than that for H2 ($d = 0.240$), indicating that the gap between high- and low-digital-access firms was more pronounced for digital financial inclusion than for supply chain resilience.

Table 8. Summary of Hypothesis Testing

Hypothesis	Test	Statistic	df	p	Effect size	Decision
H1: DFI differs by digital access group	Welch's t-test	6.660	568.61	< .001	$d = 0.479$ (medium)	Supported
H2: SCR differs by digital access group	Independent t-test	3.703	998	< .001	$d = 0.240$ (small-medium)	Supported

6. Discussion

The moderate-to-high overall level of digital financial inclusion observed in this study ($M = 3.405$, $SD = 1.032$) suggests that Philippine manufacturing firms, on average, have made meaningful use of digital financial channels rather than remaining at the margins of digital finance adoption. This finding is broadly consistent with the regional pattern documented in the reviewed literature, where digital financial inclusion has been shown to support SME performance and credit access across Southeast Asian and other developing-economy contexts (Thathsarani & Wei,

2022; Zhang et al., 2023; Dong, 2025). The relatively higher mean for Mobile/Digital Banking compared to Digital Payments and Digital Financial Literacy suggests Philippine manufacturing firms may have adopted transactional digital banking more readily than the literacy or payment-specific behaviors that typically underpin deeper financial inclusion, consistent with observations elsewhere that fintech and mobile banking often serve as the entry point for SME digital adoption, with more sophisticated financial literacy and payment integration following more slowly (Tay et al., 2022; Johri et al., 2024).

The moderate-to-high overall level of supply chain resilience found here ($M = 3.428$, $SD = 1.162$) indicates that sampled manufacturing firms generally perceive themselves as reasonably capable of withstanding and recovering from disruption. The dimensional pattern is informative: Robustness and Agility scored highest, while Recovery Capacity and Redundancy scored lowest, consistent with the multidimensional, non-uniform nature of resilience documented in the literature, where different capability dimensions do not move together and do not contribute equally to firm-level outcomes (Padovano & Ivanov, 2025; Opoku, 2025). The comparatively lower Recovery Capacity and Redundancy scores may reflect a structural reality of the sample: with micro and small firms together comprising 70.2% of respondents, many sampled firms likely operate with limited slack capacity that redundancy and rapid recovery typically require, though this contextual explanation was not directly tested in the present study.

The significant difference in digital financial inclusion between high- and low-digital-access firms ($t(568.61) = 6.660$, $p < .001$, $d = 0.479$) confirms that digital access divide meaningfully separates manufacturing firms in their realized digital financial inclusion, not merely in infrastructure availability but in the financial behaviors that infrastructure enables. This aligns with the broader digital-divide literature, which consistently finds that firms with stronger digital access convert that access into materially better financial-inclusion outcomes than lower-access firms (Johri et al., 2024; Odei-Appiah et al., 2022; Kiboko et al., 2026). One alternative interpretation should be acknowledged: because the Mobile/Digital Banking item served simultaneously as the digital-access grouping variable and as one of the four components comprising the Overall DFI score, part of this effect size is definitionally guaranteed rather than purely empirical. This does not invalidate the finding, since the other three DFI dimensions were not used in group construction and could in principle have shown no group difference, but the magnitude of the H1 effect size should be interpreted with this structural overlap in mind (see Limitations).

The significant difference in supply chain resilience between high- and low-digital-access firms ($t(998) = 3.703$, $p < .001$, $d = 0.240$) is the study's central empirical contribution, directly addressing the gap identified in the Review of Related Literature: no Philippines-specific, firm-level study was located that tested whether supply chain resilience differs across firms separated by digital access level. This finding indicates that it does. This result is consistent with, and extends, the established digital-financial-inclusion–supply-chain-resilience relationship documented almost exclusively in large, listed Chinese manufacturing firms (Shahid et al., 2025; Chen & Yu, 2024), suggesting the underlying pattern is not confined to that context. It is also consistent with the heterogeneity documented in regional Southeast Asian evidence, where digital financial inclusion's relationship with MSME resilience was shown to vary meaningfully by subgroup and context rather than operating uniformly (Quoc et al., 2025; Pranitasari et al., 2026). Unlike H1, the H2 finding is not subject to the item-overlap concern, since Overall SCR shares no items with the Mobile/Digital Banking grouping variable, making it the methodologically cleaner of the two findings, even though its effect size is smaller.

The larger effect size for H1 ($d = 0.479$) relative to H2 ($d = 0.240$) is worth interpreting rather than passing over. Beyond the item-overlap explanation already noted for H1, a substantively plausible explanation is that supply chain resilience is a downstream, multidimensional capability shaped by many factors beyond digital access alone — supplier relationships, inventory strategy, organizational structure — consistent with literature showing SCR's relationship with other variables is frequently partial or indirect rather than fully direct (Rana et al., 2025; Zhao et al., 2023; Songkhwan et al., 2025). Digital access divide would be expected to relate more strongly to digital financial inclusion, which is closer in kind to digital access itself, than to a broader operational capability like resilience that digital access can only partially explain. Both explanations are plausible and are not mutually exclusive; the data available here cannot adjudicate between them.

The pattern of results is consistent with the two theoretical perspectives adopted for this study. Resource-Based View logic helps explain why digital financial inclusion, treated as a firm-level resource, relates to broader resilience capability. Digital Divide/Access Theory directly explains why firms would differ by access level in both realized financial inclusion and downstream resilience: access is not binary or uniform, and firms unevenly positioned across access layers convert nominally available digital financial infrastructure into different levels of practical benefit.

Neither theory is stretched beyond what a cross-sectional, comparative design can support; both are used here to interpret group differences, not to claim that digital access divide causes resilience differences.

For manufacturing firms and the industry associations and financial-inclusion programs that serve them, the findings suggest digital access itself, not only the availability of digital financial products, is a meaningful constraint on how much resilience benefit manufacturing firms realize. Programs aimed at expanding digital financial inclusion among Philippine manufacturing SMEs may need to pair financial-product access with genuine infrastructure and digital-capability support to translate into resilience gains, particularly for the micro and small firms that dominate this sample.

Consistent with the study's cross-sectional, non-experimental design, none of the findings reported above support causal claims. Firms with higher digital access report higher DFI and SCR; this study does not establish that digital access divide causes these differences, nor does it rule out that firms with stronger underlying resources or capabilities are simply more likely to both achieve high digital access and score well on DFI and SCR independently.

7. Conclusion

This study set out to examine digital financial inclusion and supply chain resilience among Philippine manufacturing firms, and to determine whether these constructs differ meaningfully between firms with high versus low digital access, a question left open by a literature base concentrated almost entirely in large, listed manufacturing firms in a single, digitally advanced economy. The findings answer this question directly: both digital financial inclusion and supply chain resilience differed significantly between high- and low-digital-access manufacturing firms in the Philippine sample, with high-access firms reporting stronger levels of each.

Beyond confirming that a digital access divide exists among Philippine manufacturing firms, the study's central contribution is demonstrating that this divide is not merely a matter of infrastructure availability; it corresponds to real, measurable differences in the financial behaviors firms exhibit and in the resilience capabilities they report. Firms with greater digital access were not only more digitally financially included; they also reported meaningfully greater capacity to withstand and recover from supply chain disruption. This extends the digital-financial-inclusion–resilience relationship documented in Chinese manufacturing firms into a materially different setting, a Southeast Asian, SME-dominated manufacturing base using survey-based managerial data rather than archival financial records, and indicates the underlying pattern is not confined to the context in which it was first established.

Theoretically, the study's findings are consistent with treating digital financial inclusion as a firm-level resource that supports downstream operational capability, and with treating digital access as a multidimensional condition that separates firms unevenly rather than uniformly. The stronger group difference observed for digital financial inclusion relative to supply chain resilience is itself a meaningful pattern: it suggests digital access divide bears more directly on financial inclusion outcomes than on the broader, more multiply-determined capability of supply chain resilience, which digital access can only partially explain.

The study's principal contribution is intended to be practical. For manufacturing firms, industry associations, and financial-inclusion program designers operating in the Philippines and comparable Southeast Asian contexts, the findings indicate that expanding access to digital financial products alone may not be sufficient to close resilience gaps between firms. Digital access itself, the infrastructural and capability conditions that determine whether firms can meaningfully use available financial tools, appears to be a distinct and consequential factor in whether digital financial inclusion translates into operational resilience.

These conclusions are offered within the boundaries the study's design supports. The cross-sectional, comparative design establishes that digital financial inclusion and supply chain resilience differ by digital access level; it does not establish that digital access divide causes these differences, and it does not permit generalization beyond the six manufacturing subsectors and nationwide Philippine setting examined here. Within those boundaries, the study provides Philippines-specific, firm-level evidence on a relationship that the existing literature had assumed, but not directly tested, outside a single national context.

8. Recommendations and Implications

Manufacturing firm management, particularly among the micro and small firms that dominated this sample, should treat digital access, not only enrollment in digital financial products, as a distinct investment priority. Since firms with higher digital access reported meaningfully stronger digital financial inclusion and supply chain resilience, firms positioned at lower access levels may benefit from first addressing underlying connectivity, device, and platform-access constraints before or alongside adopting new digital financial tools, since access appears to condition how much benefit those tools deliver.

Within digital financial inclusion specifically, Digital Payments and Digital Financial Literacy were the two lowest-scoring dimensions in this sample, even though overall DFI levels were moderate-to-high. Firms would benefit from targeted attention to these two areas, payment-system integration and staff or owner financial literacy, since they lag behind Mobile/Digital Banking and Digital Credit adoption. Within supply chain resilience, Recovery Capacity and Redundancy were the lowest-scoring dimensions; firms, particularly smaller manufacturers with likely limited slack capacity, may benefit from developing contingency plans, backup supplier relationships, and inventory buffering practices.

Digital-finance and manufacturing-sector policy bodies and financial-inclusion program designers should consider that expanding access to digital financial products alone may not close resilience gaps between manufacturing firms. Since digital access divide corresponded to significant differences in both DFI and SCR, programs aimed at strengthening manufacturing-sector resilience through digital finance may need to pair product access with genuine infrastructure and digital-capability support, particularly given that micro and small firms, which dominate the Philippine manufacturing landscape and this sample, are those most likely to face access constraints.

Future studies examining digital access divide should develop and validate an independent, multi-item measure of digital access, distinct from any single item embedded within a digital financial inclusion or related construct; this study's H1 finding was affected by a structural overlap between the grouping variable and one DFI dimension that a dedicated access instrument would eliminate. Where feasible, future studies should also work with respondent-level raw data rather than aggregated summary statistics, enabling more precise composite-variable construction and a fuller range of assumption checks. Future research could extend this comparative design into a mediation or moderation framework, for instance testing whether digital capability or financing-constraint relief mediates the relationship between digital access and supply chain resilience. Replication across other ASEAN manufacturing contexts would help establish whether the access-based heterogeneity observed here in the Philippines reflects a broader regional pattern or a setting-specific one. Future work could also directly test firm size and subsector as predictors of resilience-dimension scores, since this study's lower Recovery Capacity and Redundancy findings suggest a plausible but untested connection to firm scale.

9. Limitations

This study's cross-sectional design permits the identification of group differences and associations but not causal inference. The finding that high-digital-access firms report higher digital financial inclusion and supply chain resilience does not establish that digital access divide causes these differences; firms with stronger underlying organizational capacity may simply be more likely to achieve both high digital access and strong DFI/SCR outcomes independently.

Both digital financial inclusion and supply chain resilience were measured through the same survey, completed by the same respondents at the same point in time, raising the possibility of common method bias that could inflate the observed relationship between the two constructs beyond their true association. This limitation should be weighed particularly when interpreting the magnitude, though not necessarily the direction, of the reported effect sizes.

A genuine construct-validity limitation specific to H1 is that the Mobile/Digital Banking item served simultaneously as the digital-access classification variable and as one of four components of the Overall DFI score. Part of the observed group difference in DFI is therefore structurally built into how the groups were formed, rather than reflecting a fully independent relationship. H2 (supply chain resilience) does not share this limitation, since SCR shares no items with the grouping variable.

The DFI and SCR instruments were custom-developed for this study rather than adapted from previously validated scales. Content validity was established through review by three expert validators, but no construct validity evidence, such as confirmatory factor analysis or convergent and discriminant validity testing, was conducted. Reliability coefficients were acceptable across all dimensions, but reliability alone does not confirm that items measure the intended constructs as theorized.

Results for this study were supplied and analyzed as pre-aggregated summary statistics rather than as raw, respondent-level data, which precluded certain analyses that respondent-level data would have allowed, most notably a genuine multi-item composite digital-access index. Because the study design permitted multiple eligible respondents per firm, some manufacturing firms may be represented by more than one respondent in the dataset; to the extent that respondents from the same firm share firm-level characteristics, the independence assumption underlying the t-tests used for H1 and H2 may be imperfectly met.

Classifying firms into High and Low Digital Access groups via a median split, while methodologically transparent and interpretable, discards information about the degree of variation within each group, a generally recognized limitation of dichotomization approaches in quantitative research. Firm age was the only control variable captured; other plausible confounding firm-level characteristics, such as ownership type, export orientation, or prior technology investment, were not measured. Finally, findings are based on six manufacturing subsectors within the Philippines; while the sample was drawn nationwide via stratified random sampling by firm size, findings should not be generalized to manufacturing subsectors outside this defined scope, nor automatically extended to other Southeast Asian or Asian manufacturing contexts without direct testing.

Declarations

Conflict of Interest: The authors declare no conflict of interest.

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