Beyond Adoption: Measuring the Business Value of Industry 4.0 In SMEs - From Digital Investment to Innovation and Competitive Advantage

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***Abstract*—Many people say that Industry 4.0 tools give small and medium enterprises (SMEs) a big edge over others. We still do not know for sure if using digital technology actually brings real value to Indian SMEs. This study looks at how digital technology adoption, innovation, and business performance work together in Indian businesses, and whether innovation is the bridge that connects digital technology adoption to business performance. We used data from the World Bank Enterprise Surveys (WBES) for India: the 2025 India Enterprise Survey, covering 10,479 businesses (including a subgroup of 7,386 SMEs with 5–99 workers), and the 2026 Artificial Intelligence follow-up survey, covering 1,355 businesses. Digital technology adoption was measured in two ways. First, whether a business has a website. Second, a seven-item index covering social media, messaging apps, software for managing customers or supply chains, artificial intelligence, and big data. Innovation is defined as introducing a new or improved product, service, or process in the last three years. Business performance is measured mainly as labor productivity (output per employee) and, secondarily, as sales growth. These relationships were tested using logistic regression, least squares regression, and bootstrap mediation analysis. The results show that digital technology adoption and innovation are positively linked in the larger sample. However, digital technology adoption does not directly raise labor productivity, and innovation shows a negative link to labor productivity in both samples. This suggests that digital technology adoption for SMEs does not always translate into more efficient work, and that the link between innovation and performance is more complex than expected.**

***Index Terms*—Industry 4.0; Digital Technology Adoption; Indian SMEs; Innovation; Business Performance; World Bank Enterprise Surveys; Mediation Analysis**

I. INTRODUCTION

Industry 4.0 is a change in how things are made. It happens when physical machines connect with tools like the Internet of Things (IoT), cloud computing, big data, artificial intelligence, and smart robots [1], [2], [3]. Industry 4.0 is not about buying one new tool. It is about a web of connected tools and digital ways of working that change how a company handles information. This matters because it changes how companies work, how they organize themselves, and how they compete.

Many researchers say Industry 4.0 can make manufacturing more flexible, provide information, and help companies react to what customers want [4]. The big question now is moving from “can companies use these tools” to “can they use them enough to actually make more money.”

1.1. SMEs and the Industry 4.0 Adoption Challenge

Small and medium enterprises (SMEs) are very important for the economy. Moving toward Industry 4.0 is harder for them than for big companies. SMEs usually have less money, fewer experts, and less capacity to handle the high costs and disruption that come with new technology [5]. Buying tools, training staff, and integrating new software with old systems are all significant hurdles for SMEs [5]. This does not mean SMEs cannot win: because they are smaller, they can make decisions faster and stay closer to their customers (Hassan et al. [6]). So, the real challenge for SMEs is not just starting digital technology adoption, but having the money, people, and skills to make it work.

1.2. Adoption Does Not Automatically Create Business Value

Just using Industry 4.0 tools does not mean a company will perform better. The link between using technology and doing well depends on the costs involved and how much a company has to change to make it work [5]. Frank et al. [4] show that different tools lead to different results, and the benefits are not always immediate.

For example, Bettiol et al. [7] studied Italian manufacturers and found that Industry 4.0 adoption helped productivity, but only when the company also invested in training and upkeep. Somohano-Rodriguez et al. [8] similarly argue that how a company uses its tools matters most. This means digital technology adoption is not the same thing as generating value; value comes from how a company turns those tools into real results.

1.3. Innovation as the Link Between Digital Adoption and Performance

Digital technology adoption can help a company perform better by enabling it to create new products or better ways of working. Hassan et al. [6] found that when SMEs use tools more deeply, they tend to innovate more in their products and marketing. This link is not always a straight line: Merin-Rodriganez et al. [9] found that companies often need to change their business models before they see the benefits of these tools. This fits with the idea that different Industry 4.0 tools serve different purposes [4]. Therefore, this study treats innovation as the mechanism through which digital technology adoption leads to business performance.

1.4. Organizational Capabilities and Conditions for Value Realization

To capture value from digital tools, SMEs need more than the technology itself. They need skilled employees, a solid plan, and leaders who support the change [10].

Agostini and Nosella [11] find that leadership and the ability to learn new things are key for SMEs adopting Industry 4.0. Naeem et al. [12] similarly show that how a company manages its operations is tied to how it uses data from digital tools. This confirms that digital transformation is not simply about buying machines; it is about people, management, and how a company works.

1.5. Limitations in the Existing Literature

Even though a great deal is known about Industry 4.0, gaps remain. Most studies focus on Europe, such as Italy or Germany, and say little about SMEs in developing economies. Many studies also rely on managers' self-reported opinions, which may not be entirely accurate [8], [9]. Evidence also shows that Industry 4.0 does not affect every company in the same way [4]. Because of this, studies covering different countries and different types of businesses are needed.

1.6. The Indian Context and Research Gap

Looking at India helps reveal whether using technology actually leads to real innovation and better business results. India has a diverse SME sector, with firms varying widely in technological skill, capital, and readiness. Because of this, findings from European studies may not transfer directly to India. Most research to date has not examined how Industry 4.0, or digital technology adoption, innovation, and firm performance work together for Indian SMEs. Some Indian studies examine the challenges of Industry 4.0 or digital transformation within specific sectors, but little is known about how digital technology adoption translates into innovation and better business outcomes at the level of individual firms. This is a notable gap, especially given the availability of the World Bank Enterprise Surveys, which document how Indian businesses actually behave and innovate. The 2025 India Enterprise Survey shows that 3.9% of firms introduced a new product or service in the last three years and 2.3% introduced a process innovation; for large firms, these figures were 4.8% and 2.8%. These figures provide a basis for studying whether a firm's digital capability is linked to innovation. This study does not assume that low innovation results simply from low digital technology adoption; instead, it examines whether and how digital technology adoption is linked to innovation and business performance among SMEs.

1.7. Purpose of the Study

This study therefore examines how digital technology adoption, innovation, and business performance are connected in SMEs. Prior research suggests that Industry 4.0 and digital transformation can support innovation and firm performance, but it remains untested whether digital technology adoption delivers real business value for Indian SMEs. This study uses

Industry 4.0 as a conceptual starting point but focuses on measurable digital technology adoption and firm outcomes captured in secondary data. By focusing on India, this study aims to show how SMEs can move beyond simply acquiring technology toward generating innovation and business value.

II. RESEARCH OBJECTIVES

2.1. General Objective

To examine how digital technology adoption, innovation activity, and business performance are linked in Indian firms, especially small and medium-sized enterprises.

2.2. Specific Objectives

1. To assess the extent of digital technology adoption among firms using data from the World Bank Enterprise Surveys.
2. To assess the level of innovation activity among firms, specifically in products, services, and processes.
3. To examine whether there is a link between digital technology adoption and innovation activity among firms.
4. To examine whether innovation activity is linked to business performance using firm-level data.
5. To examine whether factors such as size, age, sector, and access to finance affect innovation and business performance.
6. To examine whether innovation is the mechanism connecting digital technology adoption to business performance.

2.3. Research Question

What is the link between digital technology adoption, innovation activity, and business performance in firms, especially small and medium-sized enterprises?

2.4. Specific Research Questions

RQ1. How much digital technology adoption is there among firms?

RQ2. What is the level of product/service and process innovation among firms?

RQ3. Is digital technology adoption clearly linked to innovation activity among firms? RQ4. Is innovation activity clearly linked to business performance among firms?

RQ5. Do traits such as size, age, industry, and access to finance affect innovation activity and business performance?

RQ6. Does innovation act as the mechanism through which digital technology adoption leads to business performance?

III. RESEARCH HYPOTHESES

H1: Digital technology adoption is positively linked to innovation activity in establishments. H2: Innovation activity is positively linked to business performance in establishments.

H3: Digital technology adoption is positively linked to business performance in establishments.

H4: Innovation activity helps explain the link between digital technology adoption and business performance in establishments.

These hypotheses describe associations rather than causal claims, because the data represent a single point in time.

IV. LITERATURE REVIEW

4.1. Industry 4.0 and Digital Transformation

Industry 4.0 is a change in how things are made. It happens when digital tools are combined with machines, including the Internet of Things (IoT), cloud computing, big data, artificial intelligence, robots, and smart systems. Industry 4.0 is not about using a single tool; it is about making everything more connected and digital. Roblek et al. [2] describe Industry 4.0 as a shift in which physical and digital tools work together to enable smarter production.

Other research argues that digital transformation is more than acquiring technology; it also changes how a company operates, how leaders make decisions, and how the business competes. This is especially important for SMEs, since the value of any tool depends on how well it is used within the company, not merely whether it is present. Recent research on SME transformation suggests that for digitalization to succeed, firms must assess their existing capabilities, goals, constraints, and capacity for continuous learning.

In manufacturing, Industry 4.0 is viewed as a way to increase flexibility, generate information, drive innovation, and sustain competitiveness. Research also shows that this transition is difficult: companies cannot realize the benefits of these technologies without the skills to use them. This is why Industry 4.0 should be viewed not simply as the acquisition of tools, but in terms of how those tools translate into business outcomes.

4.2. Industry 4.0 Adoption in SMEs

SMEs stand to gain a great deal from these technologies but often lack the capital and skills to realize their full potential. Small and medium-sized enterprises occupy a difficult position during the industry 4.0 transition: although digital technologies can support growth and innovation, SMEs typically have less capital, less technology, and fewer personnel than larger companies. Mittal et al. [5] argue that many Industries 4.0 maturity frameworks are designed for large companies and may not reflect the realities faced by SMEs.

However, being small does not preclude SMEs from benefiting from digital transformation. Because they are smaller, they can often make decisions and adapt more quickly. For digital technology adoption to succeed, new tools must align with a firm's capital, skills, and goals. Industry 4.0 adoption in SMEs is therefore about organizational capability, not merely the acquisition of new machinery.

4.3. Digital Technology Adoption and Innovation

Technology use is frequently linked to innovation in SMEs, because digital tools help firms access information, share knowledge, make data-informed decisions, and adapt their products and services. Hassan et al. [6] show that technology diffusion supports multiple types of SME innovation, including product, process, marketing, and organizational innovation. This link depends on how deeply the technology is used. Digital technology adoption should not be understood merely as owning a tool; rather, the extent to which digital technologies are embedded in daily operations determines whether they lead to innovation. This is consistent with Hassan et al. [6], who find that the connection between technology and innovation depends on how well the technology is integrated, not simply on ownership.

This provides the rationale for studying innovation as an outcome of digital technology adoption. In this study, this relationship forms the core of the analytical framework: Digital Technology Adoption→ Innovation.

4.4. Digital Technology Adoption and Business Performance

The relationship between Industry 4.0 adoption and business performance is more complex than technology use alone. Research shows that Industry 4.0 technologies can improve productivity, but the magnitude of the benefit varies across companies. For example, Bettiol et al. [7] found that Industry 4.0 adoption improved productivity among Italian manufacturers, but only when firms also managed the costs of implementation and maintenance.

Industry 4.0 technologies also serve different functions. Frank et al. [4] show that different tools play distinct roles, so digital technologies should not be treated as a homogeneous category. Other studies similarly show that different technology types are associated with different business outcomes.

This suggests that possessing technology alone may not be sufficient to sustain high business performance. Firms may also need appropriate skills, organizational structures, and processes to embed the technology into daily operations. Accordingly, this study treats business performance as an outcome rather than assuming that digital technology adoption automatically improves firm performance.

4.5. Innovation and Business Performance

Innovation is the mechanism through which companies convert their tools and capabilities into business results. Introducing new products or improved processes helps firms meet customer needs, operate more efficiently, differentiate themselves, and identify new revenue streams. For SMEs, innovation is particularly important because it allows them to compete despite limited resources.

The industry 4.0 literature identifies innovation and competitiveness as central goals when SMEs adopt digital technology. The relationship between innovation and performance provides a basis for treating innovation as a bridge connecting digital technology adoption to business performance: digital technologies provide firms with capabilities and data, and innovation is the process through which firms convert those capabilities into products, services, or improved ways of working. Accordingly, this study examines whether innovation is linked to business performance alongside the direct relationship between digital technology adoption and performance.

4.6. Organizational and Capability Factors

Research indicates that spending on technology alone does not guarantee successful transformation. Factors such as organizational structure, managerial support, employee skill levels, and how well digital tools are integrated into existing workflows all influence how much value a company derives from Industry 4.0. Agostini and Nosella [11], Naeem et al. [12], and Kans and Campos [10] each identify organizational and managerial factors as central to successful transformation.

These factors are particularly important for SMEs. Because SMEs often operate with limited capital and personnel, organizational missteps can be especially costly. Digital technologies also introduce additional data and complexity, meaning firms may require stronger performance-management systems, better-trained employees, and improved decision-making processes. Digital transformation should therefore be understood as a change in how a company operates, not merely as a technology purchase.

Although these organizational capabilities are theoretically important, this study does not attempt to measure every organizational factor identified in prior research. Instead, it focuses on variables that can be measured using the available dataset, with organizational capability factors used primarily to help interpret the relationships in the model.

4.7. Industry 4.0 in the Indian Context

One study of Indian manufacturing SMEs, covering more than 250 firms, found that these companies sought to change how they measure operations, manufacture goods, and design products, viewing real-time machine data and analytics as key steps in that transition.

Other research on India has examined barriers to Industry 4.0 adoption, finding that infrastructure limitations, lack of capital, limited government support, technological complexity, and concerns about cybersecurity and data ownership represent major obstacles.

The Indian context adds further considerations for the study of Industry 4.0 and digital transformation in SMEs. India's SME sector is highly diverse, and firms' digital trajectories depend on their technological readiness, financial resources, infrastructure, skills, and organizational capabilities. Because of this diversity, empirical evidence from Indian companies is essential to determine whether the relationships identified in the broader literature between digital technology adoption, innovation, and business performance actually hold in the Indian business environment.

4.8. Research Gap

4.8.1.Geographical Gap

Most research on Industry 4.0 and digital transformation in SMEs is conducted in Europe, including Italy, Germany, Spain, and Denmark. Studies by Bettiol et al. [7], Hassan et al. [6], and Somohano-Rodriguez et al. [8] provide valuable insight into the relationships among technology, innovation, and productivity, but these findings may not generalize to Indian firms, which operate in different markets under different financial and technological conditions.

4.8.2.Empirical Gap in the SME Context

There is limited empirical evidence examining digital technology adoption, innovation, and business performance jointly for Indian SMEs. Most Indian studies focus on specific dimensions of Industry 4.0, such as readiness, supply chains, or general digital change. A need remains to determine whether digital technology adoption actually improves business performance for SMEs and whether innovation is the mechanism through which this value is created.

4.8.3.Adoption-Value Gap

A gap also exists between using technology and realizing value from it. Prior research shows that Industry 4.0 technology can support productivity and innovation, but not uniformly across firms or technologies. Evidence indicates that factors such as capital, employee skills, managerial support, and technology integration shape how much value firms derive from digital investment [5]. However, Indian SME research has not sufficiently examined how technology use fits into a broader pathway leading to innovation and business performance.

4.8.4.Methodological Gap

Methodologically, most existing studies rely on surveys, expert opinion, or case studies. While informative, these approaches do not always capture the broader picture available through standardized firm-level data. This study uses firm-level data to examine the relationship between digital technology adoption, innovation, and business performance while controlling for other firm characteristics.

4.8.5.Gap Addressed by the Present Study

In response to these gaps, this study focuses on the relationship between digital technology adoption, innovation, and business performance among SMEs. Industry 4.0 provides the conceptual foundation for the study, but digital technology adoption is used as the primary measure because the available data do not capture every Industry 4.0 technology. This study does not claim to measure Industry 4.0 comprehensively; rather, it examines whether the available digital technology indicators are linked to innovation and business performance, and whether innovation helps explain how digital adoption leads to improved performance.

V. CONCEPTUAL FRAMEWORK

The framework used in this study connects four elements: an independent variable (digital technology adoption), a mediating variable (innovation), a dependent variable (business performance), and a set of control variables (firm size, firm age, industry, and access to finance).

Independent variable, Digital Technology Adoption. This is measured in two ways, reflecting data availability (see Section 7.6): (a) whether a company has a website, available for all SMEs in the sample; and (b) a digital adoption index comprising seven components (website or social media presence, use of messaging apps, ERP software, CRM software, digital supply-chain software, any AI use, and use of big data or analytics for customer information), available only for the smaller subgroup that completed the Artificial Intelligence follow-up survey.

Mediator Innovation. Measured as whether a company introduced a new or improved product, service, or process in the preceding three years (1 = yes, 0 = no).

Dependent variable Business Performance. Measured primarily as the natural logarithm of labor productivity (annual sales divided by full-time staff), with three-year sales growth used as a secondary measure.

Control variables. Firm size (log of full-time staff), age (survey year minus year operations began), industry (18 sectors), and access to finance (1 = active loan or credit line, 0 = otherwise).

Theoretical relationships. The framework examines three direct paths digital adoption to innovation (H1), innovation to performance (H2), and digital adoption directly to performance (H3) plus one indirect path in which innovation mediates the relationship between digital adoption and performance (H4). Consistent with the literature reviewed in Section 5, all paths are hypothesized to be positive. Because the data are cross-sectional, this study does not assume a causal ordering among these variables (see Section 13).

Figure 1. Conceptual framework linking digital technology adoption, innovation, and business performance, with size, firm age, industry, and access to finance as control variables.

VI. RESEARCH METHODOLOGY

6.1. Research Design

This study uses an explanatory, non-experimental design based on secondary survey data. The design tests the associations among digital technology adoption, innovation, and business performance. Because no variables were manipulated, the study identifies associations rather than establishing causation in a strict sense.

6.2. Nature and Type of Data

The study uses quantitative data collected through face-to-face and phone interviews with a single respondent per company typically an owner, manager, or director. The researchers did not collect any primary data through their own questionnaires or interviews.

6.3. Data Source

The data are drawn from the World Bank Enterprise Surveys (WBES) for India [13]. Two linked instruments are used:

1. The India 2025 Enterprise Survey, a sample of registered private companies in India with at least five employees and at least one percent private ownership, covering manufacturing (ISIC Rev. 4 Codes 10–33) and selected service sectors. This survey comprises 10,479 completed interviews and 339 variables [14].
2. The India ES Follow-up on Artificial Intelligence (2026), a phone-interview follow-up administered to a subgroup of companies that completed the 2025 survey. This follow-up comprises 1,355 completed interviews and 132 variables, linked to the main

survey via the unique identifier id std. This match was verified: all 1,355 follow-up companies matched a company from the 2025 survey with no duplicates [15].

A correction should be noted regarding the original research design. The proposal planned to use the 2022 WBES India round, based on a reported sample of 9,376 completed interviews from the official India 2022 Enterprise Survey implementation report [16]. On closer inspection, however, the microdata file labeled "2022" was found to correspond to a different instrument: the 2022 Enterprise Surveys of the Informal Sector in Cities in India (ESIS) [17]. The ESIS dataset covers informal businesses across nine cities (10,672 interviews) and is not the same population as the formal registered businesses described in the original proposal. Because usable microdata for the formal 2022 Enterprise Survey could not be obtained only summary tables where available no statistical modeling could be performed using that round. This paper therefore uses the 2025 Enterprise Survey and the 2026 Artificial Intelligence follow-up, the WBES India datasets for which matched establishment-level microdata could be verified and analyzed.

6.4. Sample

The population of interest is formal (registered) private-sector businesses in India with at least five employees, consistent with WBES criteria. The India 2025 Enterprise Survey completed 10,479 interviews with this population. Following World Bank Enterprise Survey guidance [18], the unit of analysis is the establishment a business operating at a single physical location that maintains its own financial records rather than the firm as a whole, which may operate multiple establishments.

6.5. Sampling Criteria / Sample Selection

Firm size was defined using standard WBES categories: Small (5–19 permanent employees) and Medium (20–99 permanent employees). Large (100–199 employees) and Very Large (200 or more employees) establishments were excluded from the analysis.

Two analytical samples were constructed:

- Sample A: 7,386 SME establishments (4,295 Small, 3,091 Medium) drawn from the full 2025 Enterprise Survey, used to examine website adoption.
- Sample B: 920 SME establishments (529 Small, 391 Medium) drawn from the subgroup of Sample A that also completed the 2026 Artificial Intelligence follow-up survey, used to examine the seven-item adoption index.

No establishments were excluded beyond the employee-count filter. Complete-case analysis was used for every regression model. The final analytical samples (7,368 for Sample A; 914 for Sample B) are slightly smaller due to missing data on specific variables, as detailed in Section
8.1 and Table 1.

6.6. Variables and Operationalization

Table 3 details every variable used in the analysis, including its construct, definition, measurement, and data source.

Table 3. Variable Operationalization

Construct	Variable code(s)	Operational definition	Measurement / coding	Data source
Digital technology adoption (Sample A)	c22b	Establishment has its own website	Binary (1 = Yes, 0 = No); –9 "Don't know" treated as missing	WBES India 2025
Digital technology adoption index (Sample B)	ai_b1a3, ai_b1a4, fatb7a5/a6, fat_b9a5/a6, fatb8a4/a5/a6, ai_adopt1, fat_b9a7	Proportion of seven technology categories adopted: website/social media; messaging apps; ERP; CRM; supply-chain software; any AI use; big-data/analytics use	Continuous index, 0 to 1 (mean of seven binary indicators, complete-case)	WBES India AI Follow-up 2026
Innovation (mediator)	h1, h5	Introduced a new/improved product or service (h1) and/or a new/improved process (h5) in the preceding three years	Binary "any innovation" (1 if h1 = Yes or h5 = Yes; 0 otherwise)	WBES India 2025

Business performance (primary)	d2, l1	Log labor productivity = ln (annual sales ÷ employment)	Natural log, Indian Rupees per employee	WBES India 2025
Business performance (secondary)	d2, n3	Annualized sales growth = (sales last FY ÷ sales 3 years ago) − 1	Continuous proportion	WBES India 2025
Firm size (control)	l1	Log of permanent full-time employment at end of last fiscal year	Continuous (natural log)	WBES India 2025
Age (control)	a14y, b5	Interview year minus year establishment began operations	Continuous (years); negative values and sentinel –9 for b5 treated as missing	WBES India 2025
Industry (control)	a4a	Sampling-frame industry sector	Categorical, 18 sectors included as fixed effects where sample size permits	WBES India 2025
Access to finance (control)	k82a, k82b	Has an active loan (k82a) or line of credit (k82b) from a financial institution	Binary (1 if either = Yes; 0 otherwise)	WBES India 2025

Source: World Bank Enterprise Surveys, India 2025 and India ES Follow-up on Artificial Intelligence 2026, as verified against the survey microdata and variable labels.

6.7. Measurement of Variables

Prior to analysis, all "–9, Don't know" codes in the raw data were recoded as missing. Product and process innovation were combined into a single "any innovation" variable because each was too infrequent on its own (3.9 percent and 2.2 percent of Sample A, respectively) to support separate models; they were, however, tested separately as a robustness check in Section 8.9. Labor productivity and sales growth were calculated only for businesses with valid sales and employment figures; businesses with zero or missing values on these items were excluded (affecting 13 observations for sales growth in Sample A; see Table 1). For the Sample B adoption index, an average of the seven indicators was used, requiring all seven items to be present; this index was checked for internal consistency prior to use in Section 8.9.

6.8. Statistical Techniques

Four techniques were used, depending on the outcome of interest:

- Logistic regression (H1): used to examine the effect of digital adoption and controls on the binary innovation indicator. Coefficients, odds ratios, and average marginal effects are reported.
- Least squares regression with heteroskedasticity-robust (HC3) standard errors (H2, H3): used to examine the effects of innovation and digital adoption on log labor productivity and sales growth.
- Bootstrap-based product-of-coefficients mediation analysis (H4): the indirect effect was estimated as the product of the effect of digital adoption on innovation and the effect of innovation on labor productivity, with 500 bootstrap resamples used to construct confidence intervals the standard approach for a binary mediator.
- Robustness checks (Section 8.9): results were tested using product- versus process-only innovation, alternative estimation weights, trimming of extreme sales-growth values, and employment growth as an alternative performance measure.

Industry fixed effects (18 categories) were included in all Sample A models. Industry fixed effects were not included for Sample B, because the smaller sample size (914 observations) combined with a low outcome rate (approximately 3 percent) prevented model convergence with 18 industry categories. The Sample B logit model therefore controls only for age, firm size, and access to finance; this deviation is noted as a limitation for Sample B in Section 13.

6.9. Model Specification

H1 (logistic regression):

$$\text{logit}\,[Pr(\text{Any Innovation} = 1)] = \beta_0 + \beta_1(\text{Digital Adoption}) + \beta_2(\text{Age}) + \beta_3(\text{log Firm Size}) + \beta_4(\text{Access to Finance}) + \text{Industry fixed effects (Sample A only)} + \varepsilon$$

H2 (OLS, robust SE):
log (Labor Productivity) = $\beta_0 + \beta_1$ (Any Innovation) + β_2(Age) + β_3 (log Firm Size) + β_4 (Access to Finance) + Industry fixed effects (Sample A only) + ε

H3 (OLS, robust SE):
log (Labor Productivity) = $\beta_0 + \beta_1$ (Digital Adoption) + β_2(Age) + β_3(log Firm Size) + β_4(Access to Finance) + Industry fixed effects (Sample A only) + ε

H4 (bootstrap mediation): Indirect effect = a × b, where a is the average marginal effect of Digital Adoption on Pr(Any Innovation = 1) from the H1 model and b is the coefficient of Any Innovation from the H2 model. The direct effect (c′) is the coefficient on Digital Adoption from the H3 model.

6.10. Ethical / Data-Use Considerations
The data used are anonymous and publicly available, provided by the World Bank as establishment-level microdata for research purposes. No respondent-identifying information was accessed, and no new data were collected from individuals. All applicable World Bank Enterprise Surveys program guidelines were followed.

VII. DATA ANALYSIS AND FINDINGS

7.1. Sample Characteristics

Table 1. Sample Selection

Stage	N
Total establishments, India Enterprise Survey 2025	10,479
Establishments in AI Follow-up 2026 (matched to 2025 baseline, via idstd)	1,355
Small establishments, 2025 ES (5–19 employees)	4,295
Medium establishments, 2025 ES (20–99 employees)	3,091
Sample A: SME sample (5–99 employees)	7,386
Large / Very Large establishments excluded (100+ employees)	3,093
Sample B: AI Follow-up SME subsample (5–99 employees)	920
Sample A complete cases used in H1/H2/H3 regression models	7,368
Sample B complete cases used in H1/H2/H3 regression models	914

Source: World Bank Enterprise Surveys, India 2025 and AI Follow-up 2026.

Table 2. Sample Characteristics

Characteristic	Sample A (2025 ES SMEs)	Sample B (AI Follow-up SMEs)
N	7,386	920
Mean establishment size (employees)	27.6	28.5
Mean establishment age (years)	17.2	17.5
Small (5–19 employees), %	58.2%	57.5%
Medium (20–99 employees), %	41.8%	42.5%
Access to finance (active loan or line of credit), %	31.0%	27.7%

Source: authors' calculations from WBES India 2025 and AI Follow-up 2026 microdata.

7.2. Digital Technology Adoption

In Sample A, 29.3 percent of SME establishments (7,382 responses) reported having their own website. In Sample B, seven measures of digital technology use were examined.

Table 4. Digital Technology Adoption

Rank	Technology	Sample	N	Adoption %
—	Website	Sample A	7,382	29.3%
1	Messaging / messenger applications	Sample B	919	94.9%
2	Website / social media presence	Sample B	919	76.3%
3	Any AI technology adoption	Sample B	920	31.6%
4	ERP software (finance/administration)	Sample B	920	18.0%
5	Digital supply-chain / SRM software	Sample B	920	15.3%
6	CRM software (customer data)	Sample B	920	12.2%
7	Big-data / ML analytics (customer data)	Sample B	918	2.6%

Source: WBES India AI Follow-up 2026; website figure from WBES India 2025.

Table 4 shows that basic digital tools, such as messaging applications and website or social media presence, are used by nearly all establishments in the AI follow-up group. Advanced tools such as ERP, CRM, supply-chain software, and big-data/analytics, however, are used by very few only 2.6 percent of businesses use big-data/analytics. This illustrates a gap between having a basic digital presence and using the more advanced digital technologies commonly associated with Industry 4.0.

Figure 2. Digital technology adoption rates in the AI Follow-up subsample (Sample B, N = 920), plus the website-presence rate from Sample A. Basic tools (messaging, website/social media) are near-universal; advanced Industry-4.0-adjacent technologies (ERP, CRM, supply-chain software, big-data/analytics) remain adopted by a minority, illustrating the adoption gap discussed in Section 8.2.

Source: Table 4.

7.3. Innovation Patterns

Table 5. Innovation Indicators

Innovation type	Sample A N	Sample A %	Sample B N	Sample B %
Product/service innovation	7,384	3.9%	920	3.0%
Process innovation	7,383	2.2%	920	0.9%
R&D spending	7,386	1.1%	—	—
Any innovation (product or process)	7,386	4.7%	920	3.2%

Source: authors' calculations from WBES India 2025 microdata.

Innovation rates are low in both samples. Fewer than one in twenty SME establishments reported any product or process innovation over the preceding three years.

These low base rates constrain the statistical power available for tests involving innovation, a limitation discussed further in Section 13.

Figure 3. The innovation challenge: share of Sample A SME establishments (N = 7,386) reporting any product or process innovation in the preceding three years. The low base rate (4.7%) illustrates the statistical-power constraint discussed in Sections 8.3 and 13.

Source: Table 5.

7.4. Descriptive Statistics

Table 6 Descriptive Statistics

Panel A: Sample A (2025 ES SMEs)

Variable	N	Mean	Median	SD	Min	Max
Employment (l1)	7,386	27.6	—	—	5	99
Establishment age (years)	7,386	17.2	14	12.7	0	124
Sales growth (3-year annualized)	7,373	0.091	0.071	0.105	−0.487	3.615
Labor productivity (INR/employee)	7,386	4,290,712	2,777,778	4,218,296	150,000	62,555,556
Log labor productivity	7,386	14.90	14.84	0.87	11.92	17.95

Panel B: Sample B (AI Follow-up SMEs)

Variable	N	Mean	Median	SD	Min	Max
Employment (l1)	920	28.5	—	—	5	99
Establishment age (years)	920	17.5	—	—	0	98
Sales growth (3-year annualized)	918	0.089	—	—	−0.341	0.667
Labor productivity (INR/employee)	920	4,621,342	—	—	160,000	28,571,429
Log labor productivity	920	15.00	—	—	11.98	17.17
Digital adoption index (0–1)	916	0.357	0.286	0.199	0.000	1.000

Source: authors' calculations from WBES India 2025 and AI Follow-up 2026 microdata.

7.5. Correlation Analysis

Correlations were calculated among the digital adoption measures, innovation, business performance, and other firm characteristics. In Sample A, having a website was positively correlated with both innovation and log labor productivity, and also with firm size, consistent with the expectation that larger SMEs are more likely to have a website. Innovation, however, was negatively correlated with log labor productivity in Sample A. In Sample B, the digital adoption index was positively correlated with both firm size and log labor productivity, but showed a small negative correlation with innovation. These correlations describe co-movement only and do not establish causation; full detail is provided in the accompanying workbook.

7.6. Regression Analysis

Table 7. Regression Results

Model	Sample	DV	Key predictor	Coef.	SE	p	95% CI	N	R²/Pseud²
H1	A	Any Innovation (logit)	Website	0.4360	0.1242	0.0004	(0.196, 0.676)	7,368	0.088
H2	A	log Labor Productivity	Any Innovation	−0.2019	0.0446	<0.0001	(−0.289, −0.115)	7,368	0.156
H3	A	log Labor Productivity	Website	−0.0286	0.0219	0.1909	(−0.072, 0.014)	7,368	0.154
H3b	A	Sales Growth	Website	0.0135	0.0027	<0.0001	—	7,368	0.046
H1	B	Any Innovation (logit, no industry FE)	Digital Index	−2.1342	1.2256	0.0816	(−4.536, 0.268)	914	0.048
H2	B	log Labor Productivity	Any Innovation	−0.5578	0.1643	0.0007	(−0.880, −0.236)	914	0.130
H3	B	log Labor Productivity	Digital Index	0.2176	0.1416	0.1243	(−0.060, 0.495)	914	0.119
H3b	B	Sales Growth	Digital Index	0.0077	0.0147	0.5982	—	914	0.052

Note: All OLS models use HC3 heteroskedasticity-robust standard errors. Sample A models include 18-category industry fixed effects; the Sample B logit model excludes industry fixed effects due to non-convergence at this sample size and outcome rate (see Section 7.8). Coefficients for control variables are omitted from this summary table and are available in the supporting workbook. Source: authors' calculations from WBES India 2025 and AI Follow-up 2026 microdata.

7.7. Hypothesis Testing

Table 8. Hypothesis Testing

Sample	Hypothesis	Coefficient	p-value	Supported?
A (Website)	H1: Digital Adoption → Innovation	0.436 (logit)	0.0004	Supported.
A (Website)	H2: Innovation → Business Performance	−0.202 (OLS)	<0.0001	Not supported in the hypothesized (positive) direction; the association is significant but negative.
A (Website)	H3: Digital Adoption → Business Performance	−0.029 (OLS)	0.191	Not supported.
A (Website)	H4: Mediation (indirect effect)	−0.0038	CI (−0.0070, −0.0015), excludes zero	Indirect effect is significant but negative; does not support the hypothesized positive mediation chain.
B (Digital Index)	H1: Digital Adoption → Innovation	−2.134 (logit)	0.0816	Not supported; the association is not significant at the 5% level and its direction is negative.
B (Digital Index)	H2: Innovation → Business Performance	−0.558 (OLS)	0.0007	Not supported in the expected direction; the link is significant but negative, matching Sample A.

B (Digital Index)	H3: Digital Adoption → Business Performance	0.218 (OLS)	0.124	Not supported at standard significance levels.
B (Digital Index)	H4: Mediation (indirect effect)	0.0360	CI (0.0009, 0.0962), excludes zero	Indirect effect is significant and positive; however, neither individual path (H1, H3) is significant on its own, so this should not be read as a clear confirmation of the hypothesized chain.

Source: authors' calculations, derived directly from Table 7.

7.8. Mediation Analysis

Table 9. Mediation Analysis

Sample	Path a (Digital Adoption → Innovation, marginal effect)	Path b (Innovation → log Labor Productivity, OLS coefficient)	Indirect effect (a × b)	Bootstrap SE	95% CI (500 resamples)	Direct effect (c′)
A (Website)	0.0189	−0.2019	−0.0038	0.0014	(−0.0070, −0.0015)	−0.0286 (H3, not significant)
B (Digital Index)	−0.0645	−0.5578	0.0360	0.0250	(0.0009, 0.0962)	0.2176 (H3, not significant)

Source: authors' calculations, 500 non-parametric bootstrap resamples per sample.

In Sample A, the indirect effect of adoption on log labor productivity through innovation is small and negative, though not zero; the direct effect is not significant. In Sample B, the indirect effect is positive and not zero, while the direct effect is also not significant. In neither sample do the results match the mediation chain hypothesized under H4. Consistent with standard practice, an indirect effect that does not match the expected direction and supporting paths is not described as confirming mediation or H4.

7.9. Robustness / Supporting Analysis

Table 10. Robustness Checks (Sample A)

Check	Specification	Coefficient	SE	p-value	N
H1, product innovation only	Logit (Product Innovation ~ Website + controls)	0.4998	0.1366	0.0003	7,379
H1, process innovation only	Logit (Process Innovation ~ Website + controls)	0.4463	0.1776	0.0119	7,378
H3, unweighted	OLS log Labor Productivity ~ Website + controls	−0.0277	0.0219	0.2046	7,381
H3, weighted (survey weight)	OLS log Labor Productivity ~ Website + controls	0.0195	0.0509	0.7018	7,381
H3, alternative performance measure	Employment Growth ~ Website + controls	−0.0052	0.0034	0.1320	7,364
H3b, sales growth with 1st/99th percentile trimming	Sales Growth (trimmed) ~ Website + controls	0.0136	0.0020	<0.0001	7,233

Source: authors' calculations from WBES India 2025 microdata.

Two findings from this check are notable. First, the H1 finding holds when examining product-only or process-only innovation, confirming that the positive link between website adoption and innovation in Sample A is robust. Second, the sign of the H3 coefficient changes depending on whether survey weights are applied: the unweighted estimate is negative and not significant, while the weighted estimate is positive and also not significant. Because neither reaches significance, the H3 finding for Sample A is treated as inconclusive.

VIII. DISCUSSION

Digital adoption and innovation (H1). This study found a positive link between website adoption and innovation activity in Sample A (odds ratio 1.55, $p < .001$), which held for both product and process innovation (Section 8.9). This is consistent with research showing that digital technology supports SME innovation. However, this pattern did not appear in Sample B: the more detailed digital adoption index was associated with lower odds of innovation, though this was not statistically significant ($p = .082$). The divergence between Sample A and Sample B may reflect the smaller size of Sample B (914 establishments versus 7,368), which produces wider confidence intervals, rather than a genuine difference in the underlying relationship.

Innovation and business performance (H2). Innovation activity was negatively linked to log labor productivity in both Sample A ($p < .001$) and Sample B ($p < .001$). This does not support H2 as hypothesized and runs counter to much of the literature suggesting that innovation improves firm performance. One possible explanation is that innovation involves costs and short-term disruption that are not yet reflected in higher productivity. It is also possible that less productive businesses innovate more in an effort to address underlying problems. Because the data represent a single point in time, it is not possible to distinguish between these explanations.

Digital adoption and business performance, direct path (H3). Neither Sample A nor Sample B showed a significant direct link between digital adoption and log labor productivity. The robustness check in Section 8.9 showed that the direction of this relationship changes depending on the weighting used, so this result is treated as inconclusive. Notably, when sales growth was used as the outcome (Table 7, H3b), the link between website adoption and Sample A was positive and highly significant. This suggests that digital adoption may be more closely associated with sales growth or market reach than with labor productivity.

Mediation (H4). The mediation analysis produced effects in both samples, but neither matched the positive chain hypothesized. In Sample A, the indirect effect is small and negative. In Sample B, the indirect effect is positive, but the two paths that compose it are not individually significant. These results are not described as "mediation," since doing so would overstate the strength of the evidence.

Interpretation. Overall, these findings suggest that using technology is not equivalent to capturing value from it. Businesses in this dataset that use digital tools do not automatically become more productive, and those that innovate do not show higher productivity in this snapshot either. This does not indicate that digital technology is detrimental for SMEs; rather, the positive pathway hypothesized was not clearly observed in this data.

IX. KEY FINDINGS

1. Website adoption is present in 29.3 percent of SME establishments in the 2025 Enterprise Survey; in the AI follow-up group, more than three-quarters use basic tools such as messaging or websites, while advanced tools such as ERP or big data are used by far fewer establishments, ranging from 18.0 percent down to 2.6 percent.
2. Innovation is rare in both groups: fewer than five percent of SME establishments reported introducing a new product or process in the last three years.
3. Digital technology adoption (website presence) is linked to innovation in the larger 2025 Enterprise Survey (H1 supported), but this was not confirmed in the smaller AI follow-up group.
4. Innovation activity is negatively linked to log labor productivity in both samples (H2 not supported in the hypothesized direction).
5. Digital technology adoption shows no significant direct link to log labor productivity in either sample (H3 not supported).
6. Digital technology adoption (website presence) is linked to sales growth in Sample A, even though it is not linked to labor productivity.
7. The role of innovation in connecting adoption to business performance (H4) was not confirmed in the positive direction hypothesized in either sample.

X. CONCLUSION

This study examined how digital technology use and innovation affect the performance of Indian SMEs, and whether innovation is the pathway through which digital technology adoption leads to better business results. Data from the World Bank Enterprise Surveys for India the 2025 Enterprise Survey and the 2026 Artificial Intelligence follow-up were used for this purpose. The study shows that larger, website-adopting Indian SMEs tend to be more innovative.

However, no evidence was found that being innovative leads to higher business performance, nor that using technology directly increases worker productivity. Instead, the link between technology and business performance depends on what is measured: digital technology appears to support sales growth but not labor productivity.

Firm size, age, and access to finance were retained as controls because they are established determinants of performance. Innovation was not found to act as a bridge between technology and performance; even where a link exists, it does not operate in the direction expected. Overall, these findings suggest that using technology does not always translate into better business results for Indian SMEs in the short term, and caution should be exercised before assuming that digital technology adoption automatically drives success.

XI. RECOMMENDATIONS

For SMEs. Businesses considering technology investments should not assume that basic adoption such as having a website will immediately make workers more productive. The data suggest that digital technology is more likely to support sales growth than productivity. Firms evaluating the returns on digital investment should therefore look at sales growth as well as productivity.

For Managers. Because innovation was linked to lower productivity in this data, managers introducing new products or processes should not expect an immediate productivity boost and should anticipate a temporary dip while employees adjust to new ways of working.

For Policymakers. Many businesses, even within the more tech-savvy group, are still not using digital tools such as ERP, CRM, or big-data analytics. Rather than focusing solely on basic digital-skills training, policy support should help SMEs gain access to these specific advanced technologies.

For Industry/Support Institutions. Organizations that support SME digitalization should recognize that digital technology affects different parts of a business in different ways. Beyond providing technology, support programs should also help employees build the skills needed to use it effectively, which may help businesses convert technology into performance gains.

XII. LIMITATIONS

Cross-sectional design and causality. The data represent a single point in time, so the relationships identified are associations rather than proof of causation.

Temporal-order limitation. Technology use was measured at the time of the interview, while innovation was measured over the preceding three years. It is possible that some innovation occurred before the business adopted the technology measured, which limits the ability to establish that digital technology adoption precedes innovation.

Measurement limitations: Industry 4.0 versus digital-adoption proxy. The World Bank Enterprise Survey does not ask about Industry 4.0 technologies such as the Internet of Things, cloud computing, or robotics. The digital technology measures used here, such as website presence or AI use, serve as an empirical proxy for selected Industry 4.0-related technologies rather than a comprehensive measure of Industry 4.0 itself.

Dataset substitution. This study originally planned to use the 2022 WBES India round; however, usable microdata for that round could not be obtained. The 2025 Enterprise Survey and 2026 Artificial Intelligence follow-up were used instead, which differs from the original proposal, as explained in Section 7.3.

Sample-size and representativeness limitations, Sample B. The AI follow-up group was smaller and was not designed to be nationally representative. It included only businesses that completed the initial survey and agreed to a second phone interview.

Low innovation base rates. Fewer than five percent of SMEs reported introducing new products or processes, which limits the statistical power of analyses involving innovation.

Weighting sensitivity. In one robustness check, results for one part of the analysis changed depending on whether weighted or unweighted estimation was used, indicating that this particular finding is not strongly robust.

Missing data. Some respondents did not answer all survey questions, slightly reducing the sample size. For example, data on capacity utilization were missing for approximately half of the businesses and could not be used.

Method and single-informant bias. In these surveys, one respondent typically a manager or owner answers on behalf of the business, raising the possibility of recall error or socially desirable responding.

Generalizability. These findings apply to registered SMEs and may not extend to unregistered businesses in India, which would need to be studied separately.

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APPENDIX

Appendix A: Variable Operationalization Table

See Table 3 (Section 7.6) for the complete list of study variables, including how each was constructed, defined, measured or coded, and its data source.

Appendix B: Conceptual Framework Diagram
See Figure 1 (Section 6).

Appendix C: Sample-Selection Detail
See Table 1 (Section 8.1) for the step-by-step sample-construction process, from the 2025 Enterprise Survey population down to the final samples used in each regression model.

Appendix D: Supporting Output
Full regression output is provided in the accompanying supporting workbook, WBES India Empirical Analysis.xlsx, submitted alongside this paper. This workbook includes the control-variable coefficients omitted from Table 7, as well as the correlation matrices and raw data underlying Tables 1–10.
No questionnaire or interview appendix is included, as this study uses a secondary-data research design.