# Digital Transformation Adoption and Economic Sustainability of Pharmaceutical Manufacturing Firms in Enugu State

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***Abstract***

*The study evaluated the Digital transformation Adoption and Economic sustainability of pharmaceutical manufacturing firms in Enugu State. The specific objectives are to: examine the relationship between Digital Culture and cost Efficiency; and Evaluate the relationship between Digital Strategy and revenue generation of pharmaceutical manufacturing firms in Enugu State The study used the descriptive survey design approach. The primary source of data was the questionnaire. A total population of 280 staff was used. 250 staff returned the questionnaire and accurately filled. Data were presented and analyzed and the hypotheses were tested using Z – test. The findings indicated Digital Culture had significant relationship with the cost Efficiency of Pharmaceutical manufacturing firms in Enugu State, Z(9.370, P. < .05) and Digital Strategy had significant relationship with revenue generation of pharmaceutical manufacturing firms in Enugu State Z(360, P. < .05). The study concluded that Digital Culture and Digital Strategy had significant relationship with the cost Efficiency and revenue generation of Pharmaceutical manufacturing firms in Enugu State. The study recommended among others that Pharmaceutical manufacturing firms in Enugu State should promote a strong digital culture by encouraging technology adoption, continuous employee digital training, and data-driven practices to enhance operational efficiency and reduce production costs.*

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## 1. Introduction

Historically, industrial development has evolved from mechanization and automation to the present era of digitalization driven by the Fourth Industrial Revolution. Digital transformation refers to the strategic integration of digital technologies into organizational processes to improve efficiency, innovation, and competitive advantage (Vial, 2019). Globally, pharmaceutical manufacturing firms now adopt advanced technologies such as automation, data analytics, and digital supply chain systems to enhance operational performance and ensure long-term economic sustainability (Verhoef et al., 2021).

Digital transformation adoption refers to the intentional and systematic integration of digital technologiessuch as advanced automation, cloud computing, artificial intelligence, data analytics, and Internet of Things (IoT) systemsinto core business processes, production operations, and decision-making functions with the aim of enhancing efficiency, quality, innovation, and competitiveness. In pharmaceutical manufacturing, this involves adopting technologies that improve production precision, enable real-time monitoring of processes, strengthen supply chain visibility, ensure regulatory compliance, and support strategic business decisions (Kraus et al., 2022).

At the national level, in Nigeria, the manufacturing sector operates within a challenging economic environment characterized by infrastructural deficits, high production costs, and market instability. Consequently, digital transformation has become a strategic tool for improving productivity, reducing operational inefficiencies, and strengthening financial performance. Empirical evidence indicates that digitalization positively influences firm performance in Nigeria's manufacturing industry (Olayinka & Adebayo, 2023).

Economic sustainability refers to the ability of these firms to maintain long-term financial viability, competitive stability, and value creation while managing economic, operational, and market challenges. It involves consistently generating sufficient revenues, controlling production and distribution costs, optimizing resource utilization, and ensuring resilience against economic shocks such as currency fluctuations, supply chain disruptions, and changes in regulatory environments (Elkington, 1997; updated in contemporary studies). In essence, economically sustainable pharmaceutical firms are those that achieve ongoing profitability without compromising their capacity to innovate, meet regulatory standards, or contribute to the broader economy (Yu et al., 2021).

Locally, in Enugu State, pharmaceutical manufacturing firms contribute significantly to healthcare delivery and employment generation. However, economic volatility, rising input costs, and limited technological infrastructure threaten their sustainability. Despite increasing awareness of digital technologies, there remains limited empirical evidence on how digital transformation adoption affects the economic sustainability of pharmaceutical manufacturing firms in Enugu State, thereby necessitating further investigation.

### 1.2 Statement of the Problem

Pharmaceutical manufacturing firms are expected to operate efficiently, maintain consistent profitability, ensure high product quality, and remain competitive through continuous innovation and strategic use of modern technologies. In today's digital era, effective adoption of digital transformation initiativessuch as automated production systems, digital quality control, real-time data analytics, and integrated supply chain platformsshould enhance operational efficiency, reduce

production costs, improve regulatory compliance, and strengthen long-term economic sustainability. For pharmaceutical manufacturing firms in Enugu State, digital transformation adoption should ideally support resilience against economic volatility, exchange rate fluctuations, and infrastructural challenges while ensuring sustained growth and market relevance.

Despite the global shift toward digitalization, many pharmaceutical manufacturing firms in Enugu State face significant challenges in adopting and fully integrating digital technologies into their operations. These challenges include high implementation costs, inadequate digital infrastructure, limited technical expertise, resistance to organizational change, and inconsistent power supply. As a result, several firms continue to rely heavily on traditional production and management systems, which may limit efficiency, increase operational waste, reduce competitiveness, and constrain profitability. Moreover, there is limited empirical evidence examining how digital transformation adoption directly influences the economic sustainability of pharmaceutical manufacturing firms within the state.

If this problem remains unresolved, pharmaceutical manufacturing firms in Enugu State may experience declining productivity, rising operational costs, weakened competitive advantage, and increased vulnerability to economic shocks. Over time, this could lead to reduced profitability, business closures, job losses, and weakened contributions to regional healthcare delivery and economic development. Therefore, there is a critical need to investigate the relationship between digital transformation adoption and economic sustainability to provide evidence-based strategies for strengthening the long-term viability of pharmaceutical manufacturing firms in Enugu State.

## 1.3 Objective of the Study

i. Examine the relationship between Digital Culture and cost Efficiency of Pharmaceutical manufacturing firms in Enugu State
ii. Evaluate the relationship between Digital Strategyand revenue generation of pharmaceutical manufacturing firms in Enugu State

## 1.4 Research Question

i. What is the relationship between Digital Culture and cost Efficiency of Pharmaceutical manufacturing firms in Enugu State?
ii. What is the relationship between Digital Strategy and revenue generation of pharmaceutical manufacturing firms in Enugu State?

## 1.5 Hypotheses

i. Digital Culture has relationship with cost Efficiency of Pharmaceutical manufacturing firms in Enugu State
ii. Digital Strategy has relationship with revenue generation of pharmaceutical manufacturing firms in Enugu State

## 2. Review of Related Literature

### 2.1 Conceptual Review

#### 2.1.1 Digital

Digital technologies refer to tools and systems that automate production, enhance data management, and improve decision-making. These include automation systems, digital quality control, real-time inventory monitoring, data analytics, and Internet of Things (IoT) applications, which help firms reduce errors, ensure regulatory compliance, optimize supply chains, and increase operational efficiency (Raimo et al., 2023). By leveraging these technologies, pharmaceutical firms can improve productivity, maintain product quality, and strengthen long-term economic sustainability.

#### 2.1.2 Transformation

Transformation refers to a deliberate and strategic process of reshaping business operations, organizational structures, and production processes to improve efficiency, competitiveness, and adaptability in a rapidly changing industry. It involves reengineering workflows, integrating innovative technologies such as automation, digital quality management, and data analytics, and revising management practices to enhance decision-making, regulatory compliance, and product quality. Transformation also encompasses cultural and organizational change, requiring employees and management to adopt new ways of working and leverage digital tools effectively. For pharmaceutical firms, such transformation is critical for responding to evolving market demands, minimizing operational inefficiencies, reducing production costs, and sustaining long-term economic performance in competitive and resource-constrained environments (Kraus, Durst, Ferreira, Veiga, Kailer, & Weinmann, 2022).

#### 2.1.3 Adoption

Adoption refers to the deliberate decision and process by which a firm takes up new technologies, techniques, or systemssuch as automation, digital analytics, or continuous manufacturingand integrates them into its production operations to improve efficiency, product quality, compliance with regulatory standards, and competitive performance. Adoption is driven by internal goals (e.g., reducing production variability) and external pressures (e.g., stricter regulatory requirements and global competition), and it often involves organizational change, training, and investment in infrastructure (Schaefer, Balchunas, & Charlebois, 2023).

#### 2.1.4 Digital Transformation Adoption

Digital Transformation Adoption refers to the strategic process of integrating digital technologies into all aspects of production, management, and supply chain operations. It involves adopting tools such as automation systems, digital quality management platforms, predictive analytics, Internet of Things (IoT) sensors, and real-time inventory monitoring to streamline processes, reduce human error, and enhance decision-making. This adoption goes beyond simply using technology; it requires organizational change, including restructured workflows, staff training, and the development of a digital culture within the firm. For pharmaceutical manufacturers, digital transformation adoption enables faster production cycles, improved compliance with regulatory standards, enhanced product quality, and cost optimization. Moreover, it strengthens the firm's ability to respond to market fluctuations, ensures competitiveness, and contributes to long-term economic sustainability by maximizing operational efficiency and minimizing resource wastage (Raimo, et al 2023).

### 2.1.5 Component of Digital Transformation Adoption

Digital Strategy and Leadership, Technology Adoption and Infrastructure, Process Automation and Integration, Data Management and Analytics, Digital Culture and Change Management, Customer Experience and Digital Services, Workforce Development and Digital Skills, Innovation and Business Model Transformation (esterman, Bonnet & McAfee, 2024); (Bharadwaj, El Sawy, Pavlou & Venkatraman, 2024); (Liu et al., 2025); (Ransbotham, Kiron & Khodabandeh, 2024); (Kane, Palmer & Phillips, 2024); (Verhoef et al., 2024); (Bughin et al., 2024); (Sebastian et al., 2025).

### 2.1.6 Component of Digital Transformation Adoption Used in the Study

#### 2.1.6.1 Digital Culture

Digital culture refers to the set of shared values, beliefs, practices, and behaviours that supports and encourages the use of digital technologies, data-driven decision-making, and continuous innovation across the organization. A strong digital culture enables employees at all levels to embrace digital tools (such as analytics, automation, AI, and IoT), fosters collaboration between technical and non-technical teams, and aligns organizational mindsets with strategic digital transformation goalshelping firms better adapt to regulatory demands, improve operational efficiency, and sustain competitive advantage in dynamic markets (Salman *et al*., 2026).

#### 2.1.6.2 Digital Strategy

Digital strategy refers to a deliberate plan that guides how digital technologies are applied to achieve strategic business objectives, enhance operational efficiency, and strengthen competitiveness. It involves the identification, selection, and deployment of digital toolssuch as automation systems, digital quality management platforms, predictive analytics, cloud computing, and Internet of Things (IoT) applicationsacross production, supply chain, and management processes. A robust digital strategy ensures that technology adoption is aligned with organizational goals, facilitates regulatory compliance, improves product quality, reduces operational costs, and enables faster decision-making. For pharmaceutical firms, having a clear digital strategy not only supports day-to-day operational excellence but also promotes long-term economic sustainability by creating resilient processes, optimizing resource utilization, and maintaining competitiveness in a rapidly evolving market (Kraus, et al 2022).

### 2.1.7 Economic

Economic refers to the strategic management of financial and material resources to ensure efficiency, profitability, and long-term sustainability. It involves planning and controlling production costs, optimizing the use of raw materials, investing strategically in technology and skilled personnel, and managing supply chains to reduce waste and improve productivity. Economic considerations also include pricing strategies, revenue generation, and the ability to respond to market fluctuations, regulatory changes, and competitive pressures. For pharmaceutical firms, maintaining strong economic performance is essential not only for survival and growth but also for supporting research and development, ensuring high-quality drug production, and contributing to broader public health outcomes (Mensah & Julien, 2022).

### 2.1.8 Economic Sustainability

Economic sustainability refers to a firm’s ability to achieve long-term financial viability and resilience by balancing profitability with strategic investments in innovation, operational efficiency, risk management, and sustainable practices. It means maintaining stable revenue and

competitive advantage over time without undermining future growththrough cost-effective production, responsible management of resources, and alignment with environmental, social, and governance (ESG) frameworks that can attract investment and reduce risks. Economic sustainability also helps firms withstand market fluctuations, reduce operational costs (e.g., through efficiency and waste reduction), and foster investor confidence while contributing to broader sustainable development goals within the healthcare sector (Zhu, Liu & Chen, 2026).

### 2.1.9 Component of Economic Sustainability

The Components of Economic Sustainability in SMEs include: Financial Performance and Profitability( Revenue growth and profitability, Cost efficiency and expense management and Liquidity and solvency); Access to Finance and Capital (Working capital availability, Investment readiness and access to loans, Financial planning and credit access); Competitive Advantage and Market Position(Market share growth, Customer retention and satisfaction, Unique value propositions); Innovation and Technological Capability( New product or service development, Adoption of digital and productivity technologies, Research and development orientation); Business Management and Strategic Planning(Strategic financial planning, Quality management systems and Risk assessment and management) as noted by the following authors: Urban,& Naidoo, (2025); Ogujiuba, K.K., Eggink, M., & Olamide, E. (2023). Litvaj, I., Drbúl, M., &Bůžek, M. (2023). Miethy Zaman, G. Tanewski& G. Ekanayake (2025).

### 2.1.10 Component of Economic Sustainability Used in the Study

#### 2.1.10.1 Cost Efficiency

Cost efficiency refers to the firm's ability to minimize production and operational expenses while maintaining high-quality standards, regulatory compliance, and optimal output. It involves the strategic management of resources, such as raw materials, labor, energy, and technology, to reduce waste and optimize productivity. Implementing cost-efficient practices may include adopting automated production systems, digital inventory management, predictive maintenance, and process optimization techniques. By reducing unnecessary expenditures and improving operational workflows, pharmaceutical firms can lower production costs, enhance profit margins, and remain competitive in a challenging market. Ultimately, achieving cost efficiency contributes to the long-term economic sustainability of the firm by ensuring that it can continue to operate effectively and invest in innovation despite market pressures and economic fluctuations (Yu, Chavez, Feng, & Fynes, 2021).

#### 2.1.10.2 Revenue Generation

Revenue generation refers to the processes and activities through which firms earn income from their core operationsprimarily from the sales of manufactured drugs, licensing of products or technologies, and strategic commercialization of approved therapies. It includes income from product sales across various markets, royalties or licensing fees from the use of patented formulations, and other commercial arrangements that convert research and production outputs into financial returns. Effective revenue generation enables firms to sustain operations, finance research and development, maintain competitive market positions, and support long-term growth (Sipelyte,& Metaxa, 2025).

### 2.1.11 Conceptual Framework

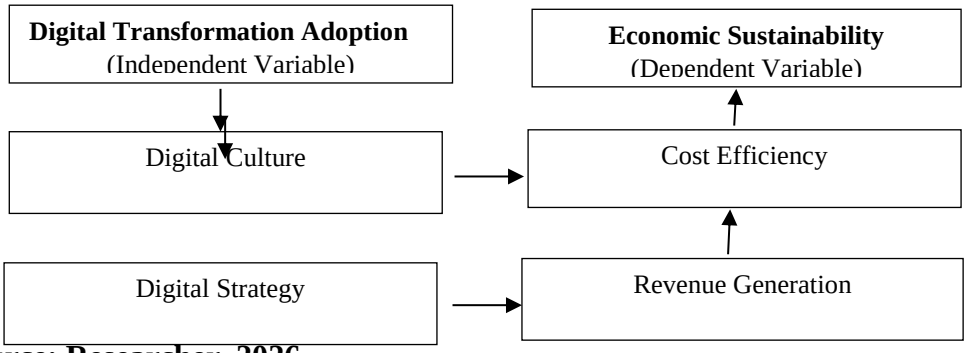



**Fig**
**Source: Researcher, 2026**

The diagram above illustrates the linkage of the Digital transformation Adoption and Economic sustainability of pharmaceutical manufacturing firms in Enugu State. The independent Variable of the study Digital transformation Adoption includes Digital Culture, Digital Strategywhile the dependents of the Economic sustainability are Cost Efficiencyand Revenue Generationof pharmaceutical manufacturing firms in Enugu State.

## 2.2 Theoretical Framework

The following theories guided the study

i **Technology–Organization–Environment (TOE) Framework** – Tornatzky and Fleischer (1990).

ii **Resource-Based View (RBV) Theory** – Jay Barney (1991).

The study is anchored on Technology–Organization–Environment (TOE) Framework because it systematically explains how technological factors (availability and suitability of digital tools), organizational factors (resources, managerial support, and skilled workforce), and environmental factors (regulations, competition, and market pressures) jointly influence technology adoption.

### 2.2.1 Technology–Organization–Environment (TOE) Framework

The **Technology–Organization–Environment (TOE) Framework**, developed by Tornatzky and Fleischer (1990), explains how technological innovation adoption is influenced by three major contexts: technological factors (availability and characteristics of technology), organizational factors (firm size, structure, resources, managerial support), and environmental factors (competition, regulation, industry pressure).

The TOE framework helps explain how internal readiness (such as financial capacity and technical expertise), technological benefits (automation, ERP systems, data analytics), and external pressures (regulatory standards, competition, government policies) influence digital transformation adoption. The framework also provides a basis for examining how such adoption enhances operational efficiency and ultimately supports economic sustainability.

### 2.2.2 Resource-Based View (RBV) Theory

The Resource-Based View (RBV) theory, advanced by Barney (1991), posits that firms achieve sustained competitive advantage and long-term performance when they possess valuable, rare, inimitable, and non-substitutable (VRIN) resources.

Digital transformation adoption, digital capabilities such as advanced technological infrastructure, skilled personnel, data management systems, and innovative processes can be viewed as strategic resources. For pharmaceutical manufacturing firms in Enugu State, the effective deployment of

digital technologies becomes a unique capability that enhances productivity, reduces costs, improves quality assurance, and strengthens financial stability. Thus, RBV explains how digital transformation adoption contributes directly to economic sustainability by creating sustained competitive advantage.

## 2.3 Empirical Review

### 2.3.1 Digital Culture and Cost Efficiency

Obodoagu, & Okechukwu, (2024). Conducted effect of digital skills strategies on the sustainability of pharmaceuticalfirms in Enugu State. The specific objectives were to: examine the effect of creativity strategy onthe regulatory compliance among investors and evaluate the effect of communication strategy onthe growing concerns of pharmaceutical firms in Enugu State. The descriptive survey design wasused. The population of study was 315 staff of pharmaceutical firms. The whole population wasused due to small number. A total of 263 staff returned the questionnaire accurately filled. Datawere presented and analyzed using mean score and standard deviation using Sprint Likert Scale.The hypotheses was analyzed using Z - test. The findings indicated that Creativity strategy hadsignificant positive effect on regulatory compliance among investors and Communication strategy had significant positive effect on the growing concerns ofpharmaceutical firms in Enugu State.

Abiloro, et al (2024). Carried out a study on Nexus between digital transformation and cost management in Nigerian Manufacturing Companies. The research method integrated both quantitative and qualitative approaches. The population of the study comprised 250 staff members,. The sample size was determined using Yamane's Sample Size statistical techniques. The findings revealed the relationship between digital transformation initiatives, technology-enabled cost management strategies, and organizational outcomes at Cadbury Plc. The regression analysis revealed that the implementation of digital transformation initiatives positively influences the effectiveness of cost management practices, as evidenced by the statistically significant coefficient while the regression result of the technology-enabled cost management strategies has significant relationship on Cadbury efficiency and decision-making.

Nnaekwe, et al (2024) Examined the impact of information and communicationtechnology (ICT) on the marketing of medical & healthcareproducts in Nigeria. The study used survey descriptive research method. Interviews were carried out onthe staff of Nemel Pharmaceutical Company Limited Enugu. The overall finding of the study shows that digitalmarketing played a significant role in the supply of healthcare products by pharmaceutical companies in Nigeriaduring and after COVID-19 pandemic. The result also shows that digitalization influences the relationshipbetween pharmaceutical companies and its customers during Post COVID – 19 Era in Nigeria.

Egbuciem, et al (2025) Conducted a study on digital transformation strategies andorganisational efficiency ofAluminium Manufacturing Firms in Enugu State. Specific Objectives were to: identify the relationship between digital transformation and generating of revenue; and ascertain the Relationship between digital reinforcement and reduced costs of Aluminum Manufacturing Firms in Enugu State. The area of the study was the Enugu metropolis, Enugu State. The study used the descriptive survey design approach. The primary source of data was the administration of questionnaire. Total populations of 265staff were used. The whole population was used due to small number. 214 staff returned the questionnaire and accurately filled. Data was presented and analyzed using Likert Scale and the hypotheses using t- test. The findings revealed that digital

transformation had significant positive relationship with generating of revenue of Aluminum Manufacturing Firms in Enugu State. Digital reinforcement had significant positive relationship with reduced costs of Aluminum Manufacturing Firms in Enugu State.

Ikwuagwu, et al (2025) Carried out a study on Assessing the Impact of Digitalization on the Performance of Manufacturing Sector in Nigeria. The study adopts an ex-post facto research design, using secondary quantitative data from the audited financial reports of five publicly listed Nigerian manufacturing firms covering the period 2020 to 2024. Panel Least Squares regression was employed to analyze the data. Findings reveal that operational efficiency (OPEF) has a statistically significant and negative coefficient ($\beta = -0.7650$, $p < 0.000$), indicating that improved operational efficiency often enabled by digital tools significantly enhances firm performance. However, revenue growth (RVGR) was statistically insignificant.

### 2.3.2 Digital Strategy and Revenue Generation

Ashafoke, &Obaretin, (2023) Carried out a study on Effect of Digital Channel and Revenue Generation in Nigeria. This research attempts to investigate the effect of imposing a digital tax on digital channels on revenue generation in Nigeria using data collected from tax experts in Lagos state, Nigeria, via Google form. An exploratory research design is used, and data is analyzed using Structural Equation Model (SEM) via the STATA software for statistical analysis.The study administered 200 questionnaires to respondents in FIRS and selected BIG4 auditing firms in Nigeria. The findings of the research show that there is a positive and insignificant relationship between revenue generation and tax e-commerce as well as between revenue generation and content providers. On the other hand, there is a positive and significant relationship between digital advertisers and revenue generation.

Weber, (2024). Conducted a study on impact of digital transformation on firm performance: a comparative study of Germany. This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.Findings: The comparative study on digital transformation's impact on firm performance in Germany reveals that embracing digitalization leads to improved productivity, efficiency, and innovation. It also emphasizes how digital technologies enhance market competitiveness, expand customer reach, and drive revenue growth and profitability.

Oti-Akenteng, et al (2025).Examined the impact of digitalization on revenue generation, public participation, and allocation efficiency. The study adopts a quantitative research approach using panel data from 2010 to 2022. Secondary data were collected from credible sources including the World Bank, Bank of Ghana, and Our World in Data. Ordinary Least Squares (OLS) regression was used to estimate the relationships among digitalization and the dependent variables, supported by diagnostic tests including multicollinearity, heteroscedasticity, and stationarity checks to validate model assumptions.Findings: The results reveal that digitalization has a statistically significant positive effect on revenue generation but a significant negative effect on public participation.

Abakpa, &Dvouletý, (2025) Carried out a study on How does digitalization shape the business financial performance: a systematic review. This systematic literature review (SLR) examines how digitalization shapes the financial performance of businesses by synthesizing research published from 2014 to 2024. The study analysed 30 articles and utilized the adaptive enterprise architecture

(EA) framework to categorize findings across various layers: interaction, human, technology, environment, and security. Key findings from prior literature indicate that digitalization significantly enhances financial performance through improved profit levels, sales growth, and market share, among others, with questionnaire surveys being the predominant method for measurement.

Moro, et al (2025) conducted a study on Digitalization intensity and its impact on financial performance: The role of scalable platforms. Utilizing a dynamic panel data methodology, the results demonstrate the temporal impacts of digital platforms on key financial indicators. Furthermore, it explores the complex interplay between digital intensity and marginal benefits, offering practical ideas for companies seeking to enhance both scalability and funding opportunities. By analyzing differing levels of digital intensity, we illustrate how scalability influences financial margins and market capitalization. The results imply that organizations adopting digital platforms are more inclined to secure long-term economic viability and financing capability through improved efficiencies in data processing and strategic decision-making. However, investing in digitalization has an optimal point from where it shows diminishing returns.

### 2.4 Gape of the Study

The studies done were carried outsideDigital transformation Adoption and Economic sustainability of pharmaceutical manufacturing firms in Enugu Stateand did not focus to best of my knowledge on theDigital Culture and cost Efficiency, Digital Strategy and revenue generation**.** Most of the studies reviewed analyzed their data through A purposeful sampling technique, Descriptive statistics and appropriate inferential statistics, Purposive Sampling technique, Pearson Moment Correlation Coefficient, Multiple sampling technique, Partial Least Square Structural Equation Modeling (PLS-SEM), Multiple Regression Analysis (MRA) method, Simple linear regression and Pearson correlation coefficient (r) while the present study made use of Z test to test Digital transformation Adoption and Economic sustainability of pharmaceutical manufacturing firms in Enugu State.

## 3. Methodology

### 3.1 Research Design

Research design serves as a road map or plan or action showing what and how the researchers will take step by-step procedure of accomplishing the research endeavour. Succinctly put, it consists of the blue print for collection, evaluation and analysis of the necessary data for a study. For the study, the descriptive sample survey was employed. Descriptive analysis entails the systematic collection and prescription of data to give a clear picture of a particular situation. This was chosen because of reduced costs.

### 3.2 Area of the study

The areas of the study was Enugu state, Nigeria. The firms used were registered under Manufacturing Association of Nigeria (MAN), they include: AC Drugs Ltd, No 4, Alor Road Edward Nnaji, Layout Abakpa- Nike, MICHELLE Laboratories Ltd, Plot 23 Block 2, thinkers Corner Industrial Layout, Emene; VADIS Industries Ltd., 8 Chukwuemeka Ikpeze Close, Off Hillview Street, Trans-Ekulu, Enugu; and JUHEL Industries Ltd. 35 Nkwubor Road Emene These organisations were chosen due good number of employees and high Ethical Standard.

### 3.3 Sources of Data

Sources of data for the empirical study were primary and secondary source.

### 3.3.1 Primary Sources

The primary sources were from the staff or employees of the organizations understudy that were given the Questionnaire

### 3.3.2 Secondary Sources of Data

Secondary data are the already existing data collected by the investigator agencies and organizations. Secondary data include government publications, websites, books, journal articles, internal records etc.

(i) Government Publications: The government publications collection consists of publications produced by the federal government and state government.

## 3.4 Population of the Study

The total population for the study was Eight hundred and eighty (880). (See table 3.1 for population distribution of the relevant firmsunder study).

**Table 3.1 Population of the firms understudy**

| S/N | Name of the firms | Staff Strength | Percent |
|---|---|---|---|
| 1 | AC Drugs | 281 | 29 |
| 2 | MICHELLE Laboratories Ltd | 160 | 21 |
| 3 | VADIS Industries Ltd. | 152 | 19 |
| 4 | JUHEL Industries Ltd | 287 | 31 |
| | **Total** | **880** | **100** |

***Source: Human Resources Department in February 2026***

### 3.5 Sample Size Determination

To determine the adequate sample size, the researcher opts for the Freund and William's statistical formula. In calculating the sample size, the researcher used the statistic formula for selecting a finite population as formulated by Freund and Williams.

$$n = \frac{Z^2 N(pq)}{N(e)^e + Z^2(pq)}$$

*Where* n = Sample Size

N = The population

p = Probability of success/proportion

q = Probability of failure/proportion

Z = Standard error of the mean

e = Limit of tolerable error (or level of significance)

N = 880

p = .5

q = (1 – .5) = .5

Z = 95percent = 1.96

e = 0.5percent

$$\frac{(1.96)^2 \; x \; 880 \; x. 5 \; x \; .5}{880(0.05)^2 + \; (1.96)^2 \; x \; .5 \; x \; .5}$$

$$\frac{3.8416 \; x \; 3067 \; x \; .25}{2.2 + \; .9604}$$

$$\frac{845.152}{3.160}$$

$$= 267.453$$

$$\sim 267$$

The study sample size was two hundred and sixty seven (267) respondents. This sample size is justified because the population is huge and such a sample would be sufficient to address the research problem.

**Table 3.2: Proportionate Allocation of Questionnaire**

*Thus*:

| S/N | Names of companies | Population | Caculations | Sample Size |
|---|---|---|---|---|
| 1 | AC Drugs | 281 | $\frac{281 \; x \; 267}{880}$ | 85 |
| 2 | MICHELLE Laboratories | 160 | $\frac{160 \; x \; 267}{880}$ | 49 |
| 3 | VADIS Industries Ltd. | 152 | $\frac{152 \; x \; 267}{880}$ | 46 |
| 4 | JUHEL Industries Ltd | 287 | $\frac{287 \; x \; 267}{880}$ | 87 |
| | **Total** | **880** | | **267** |

**Source: Field Survey, 2026**

### 3.6 Sampling Techniques

To determine the sample for the study, the random sampling technique was applied.

### 3.7 Instrument for Data Collection

The questionnaire was designed and administered on the selected respondents in the firms. The responses generated were used thereafter for data analysis. The responses from the participants were measured using 5-liket scale as follows: Strongly Agree [SA] –5 points, Agree A – 4 points, Undecided UN – 3 Points, Disagree [D] – 2 points and strongly Disagree SD – 1 point.

**Table 3.3a Cronbach Alpha Reliability Test**

| | | N | % |
|---|---|---|---|
| Cases | Valid | 10 | 100.0 |
| | Excluded | 0 | .0 |
| | Total | 10 | 100.0 |

a. Listwise deletion based on all variables in the procedure.

Table 3.3b Reliability Statistics

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N0 of Items |
|---|---|---|
| .82 | .85 | 20 |

SPSS 20.0 Output

### 3.10 Methods of Data Analyses

Data was collected, coded, grouped into frequencies, and arranged into tables for ease of reference. Data from the questionnaire was collected and analyzed using simple percentages and mean. To determine the nature and strength of relationship between the research variables, Pearson Correlations was used to test the hypotheses with aid of Special Package for Statistical Software (SPSS). For the 5-point likert scale questions, the scale and decision rule stated below was used in analysing the findings. Three hundred and fifty(350) employees returned their questionnaire and accurately filled.

**Scale**

Strongly Agree (SA) - 5
Agree (A) 4
Neutral (N) 3
Disagree (D) - 2
Strongly Disagree (SD) 1

**Decision Rule**

If Mean >3.0, the respondents agree
If mean ≤3.0, the respondents disagree

Data from the questionnaire were collected and analyzed using simple percentages, mean and standard deviation, Z- test statistic tool was used to test the hypotheses.

**Z –Test**

$$\mathbf{Z} - \frac{\overline{\chi} - \mu}{\frac{\sigma}{\sqrt{n}}}$$

Where;

$\overline{\chi}$ = Population mean
$\mu$ = Sample mean
$\sigma$ = Standard deviation
$n$ = Sample size

## 4. Data Presentation and Analysis

### Table 4.1: Distribution and Returned Questionnaire

The chapter presents and analyzes the data collected for the study. The presentation and interpretation of data were based on the questionnaire administrated to the staff of the Ministriesunderstudy in Enugu State.

### Table 4.1 Distribution and Return of the Questionnaire

| Ministries | **Distributed** | **No Returned** | **percent** | **No not Returned** | **Percent** |
|---|---|---|---|---|---|
| 1. AC Drugs | 85 | 82 | 31 | 3 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 2. MICHELLE Laboratories | 49 | 46 | 18 | 3 | 1 |
| 3. VADIS Industries Ltd. | 46 | 42 | 17 | 4 | 1 |
| 4. JUHEL Industries Ltd | 87 | 80 | 33 | 7 | 3 |
| **Total** | **267** | **250** | **94** | **17** | **6** |

***Source: From the questionnaire administration, 2026***

Two hundred and Sixty seven (267) copies of the questionnaire were distributed to the respondents and two hundred and fifty (250) copies were returned representing ninety four(94%) percent, while six (6) copies of the questionnaire were not returned representing one (1%)percent. This shows a high rate of the respondents.

### 4. 1 DataPresentation

### 4.1.1Therelationship between Digital Culture and cost Efficiency of Pharmaceutical manufacturing firms in Enugu State

**Table 1: Responses on therelationship between Digital Culture and cost Efficiency of Pharmaceutical manufacturing firms in Enugu State**

| | | 5 SA | 4 A | 3 N | 2 DA | 1 SD | ∑FX | - X | SD | Decision |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Digital culture promotes the adoption of automated systems that reduce operational waste and improve cost efficiency in pharmaceutical manufacturing firms in Enugu State. | 705<br>141<br>56.4 | 228<br>57<br>22.8 | 51<br>17<br>6.8 | 24<br>12<br>4.8 | 23<br>23<br>9.2 | 1031<br>250<br>100% | 4.12 | 1.282 | Agree |
| 2 | A strong digital culture encourages data-driven decision-making, helping firms minimize production errors and unnecessary expenses. | 685<br>137<br>54.8 | 232<br>58<br>23.2 | 51<br>17<br>6.8 | 62<br>31<br>12.4 | 7<br>7<br>2.8 | 1037<br>250<br>100% | 4.15 | 1.161 | Agree |
| 3 | Digital collaboration tools enhance coordination among departments, thereby lowering administrative and production costs. | 740<br>148<br>59.2 | 180<br>45<br>18.0 | 51<br>17<br>6.8 | 36<br>18<br>7.2 | 22<br>22<br>8.8 | 1029<br>250<br>100% | 4.12 | 1.317 | Agree |
| 4 | Firms with an established digital culture are more likely to implement innovative technologies that optimize resource utilization and reduce operating costs. | 740<br>148<br>59.2 | 184<br>46<br>18.4 | 51<br>17<br>6.8 | 54<br>27<br>10.8 | 12<br>12<br>4.8 | 1041<br>250<br>100% | 4.16 | 1.226 | Agree |
| 5 | Continuous digital learning within organizations improves employee productivity, which contributes to greater cost efficiency in pharmaceutical manufacturing operations. | 740<br>148<br>59.2 | 172<br>43<br>17.2 | 51<br>17<br>6.8 | 54<br>27<br>10.8 | 15<br>15<br>6.0 | 1032<br>250<br>100% | 4.13 | 1.274 | Agree |
| | **Total Grand mean and standard deviation** | | | | | | | **4.136** | **1. 252** | |

***Source: Field Survey, 2026***

Table 1, 198 respondents out of 250 representing 79.2 percent agreed that Digital culture promotes the adoption of automated systems that reduce operational waste and improve cost efficiency in pharmaceutical manufacturing firms in Enugu State with mean score of 4.12 and standard deviation of 1.282. A strong digital culture encourages data-driven decision-making, helping firms minimize production errors and unnecessary expenses 195 respondents representing 78.0 percent agreed with mean score of 4.15 and standard deviation of 1.161. Digital collaboration tools enhance coordination among departments, thereby lowering administrative and production costs 193 respondents representing 77.2 percent agreed with mean score of 4.12 and standard deviation

of 1.317. Firms with an established digital culture are more likely to implement innovative technologies that optimize resource utilization and reduce operating costs 194 respondents representing 77.6 percent agreed with mean score of 4.16 and 1.226. Continuous digital learning within organizations improves employee productivity, which contributes to greater cost efficiency in pharmaceutical manufacturing operations191 respondents representing 76.4 percent agreed with a mean score of 4.13 and standard deviation 1.274.

### 4.1.2 Therelationship between Digital Strategyand revenue generation of pharmaceutical manufacturing firms in Enugu State

**Table 4.1.2.1: Responses on the relationship between Digital Strategyand revenue generation of pharmaceutical manufacturing firms in Enugu State**

| | | 5 SA | 4 A | 3 N | 2 DA | 1 SD | ∑FX | - X | SD | Decision |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A well-defined digital strategy enables pharmaceutical manufacturing firms in Enugu State to expand market reach hrough online platforms, thereby increasing revenue generation. | 740<br>148<br>59.2 | 208<br>52<br>20.8 | 45<br>15<br>6.0 | 38<br>19<br>7.6 | 16<br>16<br>6.4 | 1047<br>250<br>100% | 4.19 | 1.226 | Agree |
| 2 | Digital strategy supports efficient customer engagement and targeted marketing, which enhances product sales and overall income. | 740<br>148<br>59.2 | 196<br>49<br>19.6 | 45<br>15<br>6.0 | 38<br>19<br>7.6 | 19<br>19<br>7.6 | 1038<br>250<br>100% | 4.15 | 1.274 | Agree |
| 3 | The integration of digital sales channels helps firms improve distribution efficiency and generate higher revenue streams. | 740<br>148<br>59.2 | 216<br>42<br>16.8 | 51<br>17<br>6.8 | 38<br>19<br>7.6 | 24<br>24<br>9.6 | 1069<br>250<br>100% | 4.08 | 1.352 | Agree |
| 4 | Data analytics embedded in digital strategy allows firms to understand customer demand patterns, leading to improved product offerings and increased revenue. | 740<br>148<br>59.2 | 184<br>46<br>18.4 | 51<br>17<br>6.8 | 38<br>19<br>7.6 | 20<br>20<br>8.0 | 1033<br>250<br>100% | 4.13 | 1.294 | Agree |
| 5 | Effective digital strategy encourages innovation in product promotion and service delivery, contributing positively to revenue growth in pharmaceutical manufacturing firms. | 740<br>148<br>59.2 | 228<br>57<br>22.8 | 51<br>17<br>6.8 | 6<br>3<br>1.2 | 25<br>25<br>10.0 | 1050<br>250<br>100% | 4.20 | 1.255 | Agree |
| | **Total Grand mean and standard deviation** | | | | | | | **4.15** | **1. 2802** | |

***Source: Field Survey, 2026***

Table 4.1.2.1, 200 respondents out of 250 representing 80.0 percent agreed that A well-defined digital strategy enables pharmaceutical manufacturing firms in Enugu State to expand market reach through online platforms, thereby increasing revenue generation with mean score of 4.19 and standard deviation of 1.226. Digital strategy supports efficient customer engagement and targeted marketing, which enhances product sales and overall income 197 respondents representing 78.8 percent agreed with mean score of 4.15 and standard deviation of 1.274. The integration of digital sales channels helps firms improve distribution efficiency and generate higher revenue streams 190 respondents representing 76.0 percent agreed with mean score of 4.18 and standard deviation of 1.242. Data analytics embedded in digital strategy allows firms to understand customer demand patterns, leading to improved product offerings and increased revenue 194 respondents representing 77.6 percent agreed with mean score of 4.13 and 1.294. Effective digital strategy encourages innovation in product promotion and service delivery, contributing positively to revenue growth in pharmaceutical manufacturing firms 205 respondents representing 82.0 percent agreed with a mean score of 4.20 and standard deviation 1.255.

## 4.2 Test of Hypotheses

### 4.2.1 Test of Hypotheses:Digital Culture has relationship with cost Efficiency of Pharmaceutical manufacturing firms in Enugu State

**One-Sample Kolmogorov-Smirnov Test**

| | | Digital culture promotes the adoption of automated systems that reduce operational waste and improve cost efficiency in pharmaceutical manufacturing firms in Enugu State. | A strong digital culture encourages data-driven decision-making, helping firms minimize production errors and unnecessary expenses. | Digital collaboration tools enhance coordination among departments, thereby lowering administrative and production costs. | Firms with an established digital culture are more likely to implement innovative technologies that optimize resource utilization and reduce operating costs. | Continuous digital learning within organizations improves employee productivity, which contributes to greater cost efficiency in pharmaceutical manufacturing operations. |
|---|---|---|---|---|---|---|
| N | | 250 | 250 | 250 | 250 | 250 |
| Uniform Parameters[a,b] | Minimum | 1 | 1 | 1 | 1 | 1 |
| | Maximum | 5 | 5 | 5 | 5 | 5 |
| Most Extreme Differences | Absolute | .564 | .548 | .592 | .592 | .592 |
| | Positive | .092 | .028 | .088 | .048 | .060 |
| | Negative | -.564 | -.548 | -.592 | -.592 | -.592 |
| Kolmogorov-Smirnov Z | | 8.918 | 8.665 | 9.360 | 9.370 | 9.360 |
| Asymp. Sig. (2-tailed) | | .000 | .000 | .000 | .000 | .000 |

a. Test distribution is Uniform.
b. Calculated from data.

**Decision Rule:**

Since the calculated z-value (9.370) > critical z-value (.000) at the 5% significance level, we reject the null hypothesis ($H_{01}$).

**Decision:**

Furthermore, comparing the calculated Z- value ranges from 8.665 < 9.370 against the critical Z-value of .000 (2-tailed test at 95percent level of confidence) the null hypothesis were rejected. Thus the alternative hypothesis was accepted which states thatDigital Culture had significant positive relationship with cost Efficiency of Pharmaceutical manufacturing firms in Enugu State

### 4.2.2 Test of Hypotheses Two: Digital Strategy has relationship with revenue generation of pharmaceutical manufacturing firms in Enugu State

**One-Sample Kolmogorov-Smirnov Test**

| | | A well-defined digital strategy enables pharmaceutical manufacturing firms in Enugu State to expand market reach through online platforms, thereby increasing revenue generation. | Digital strategy supports efficient customer engagement and targeted marketing, which enhances product sales and overall income. | The integration of digital sales channels helps firms improve distribution efficiency and generate higher revenue streams. | Data analytics embedded in digital strategy allows firms to understand customer demand patterns, leading to improved product offerings and increased revenue. | Effective digital strategy encourages innovation in product promotion and service delivery, contributing positively to revenue growth in pharmaceutical manufacturing firms. |
|---|---|---|---|---|---|---|
| N | | 250 | 250 | 250 | 250 | 250 |
| Uniform Parameters[a,b] | Minimum | 1 | 1 | 1 | 1 | 1 |
| | Maximum | 5 | 5 | 5 | 5 | 5 |
| Most Extreme Differences | Absolute | .592 | .592 | .592 | .592 | .592 |
| | Positive | .064 | .076 | .096 | .080 | .100 |
| | Negative | -.592 | -.592 | -.592 | -.592 | -.592 |
| Kolmogorov-Smirnov Z | | 8.110 | 9.360 | 9.360 | 9.320 | 9.360 |
| Asymp. Sig. (2-tailed) | | .000 | .000 | .000 | .000 | .000 |

a. Test distribution is Uniform.
b. Calculated from data.

**Decision Rule:**

Since the calculated z-value (9.360) > critical z-value (.000) at the 5% significance level, we reject the null hypothesis ($H_{01}$).

**Decision:**
Furthermore, comparing the calculated Z- value ranges from 8.110 < 9.360 against the critical Z-value of .000 (2-tailed test at 95percent level of confidence) the null hypothesis were rejected. Thus the alternative hypothesis was accepted which states that Digital Strategy has relationship with revenue generation of pharmaceutical manufacturing firms in Enugu State

### 4.4 Discussion of Findings

#### 4.4.1 Digital Culture has relationship with the cost Efficiency of Pharmaceutical manufacturing firms in Enugu State.

From the result of the hypotheses one, the calculated Z- value ranges from 8.665 <9.370 against the critical Z- value of .000 which implies thatDigital Culture had significant relationship with the cost Efficiency of Pharmaceuticalmanufacturing firms in Enugu State. In support of the result in the literature review,Obodoagu, & Okechukwu, (2024) Conducted effect of digital skills strategies on the sustainability of pharmaceutical firms in Enugu State. The findings indicated that Creativity strategy hadsignificant positive effect on regulatory compliance among investors and Communication strategy had significant positive effect on the growing concerns ofpharmaceutical firms in Enugu State and Abiloro, et al (2024). Carried out a study on Nexus between Digital Transformation and Cost Management in Nigerian Manufacturing Companies.. The regression analysis revealed that the implementation of digital transformation initiatives positively influences the effectiveness of cost management practices, as evidenced by the statistically significant coefficient while the regression result of the technology-enabled cost management strategies has significant relationship on Cadbury efficiency and decision-making.

#### 4.3.2 Digital Strategy has relationship with revenue generation of pharmaceutical manufacturing firms in Enugu State

From the result of the hypotheses two, the calculated Z- value ranges from 8.110 <9.360 against the critical Z- value of .000 which implies thatDigital Strategy had significant positive relationship with revenue generation of pharmaceutical manufacturing firms in Enugu State. In support of the result in the literature review,Oti-Akenteng, et al (2025).Examined the Impact of Digitalization on Revenue Generation, Public Participation, and Allocation Efficiency. The results reveal that digitalization has a statistically significant positive effect on revenue generation but a significant negative effect on public participation. Abakpa, &Dvouletý, (2025) Carried out a study on How does digitalization shape the business financial performance: a systematic review. Key findings from prior literature indicate that digitalization significantly enhances financial performance through improved profit levels, sales growth, and market share, among others, with questionnaire surveys being the predominant method for measurement.

## 5. Findings, Conclusion and Recommendations

### 5.1 Summary of Findings

i. Digital Culture had significant relationship with the cost Efficiency of Pharmaceutical manufacturing firms in Enugu State,Z(9.370, P. < .05). This implies that a strong digital culture within pharmaceutical manufacturing firms in Enugu State enhances cost efficiency by promoting effective use of digital technologies, improving operational processes, reducing waste, and supporting data-driven decision-making that minimizes production and administrative costs.

ii. Digital Strategy had significant relationship with revenue generation of pharmaceutical manufacturing firms in Enugu StateZ(360, P. < .05).This implies that effective digital strategies adopted by pharmaceutical manufacturing firms in Enugu State contribute to increased revenue generation by improving market reach, enhancing customer engagement, optimizing sales processes, and supporting innovation-driven business growth.

## 5.2 Conclusion

The study concluded that digital culture and digital strategyhad significant relationship with the cost Efficiency and revenue generation of Pharmaceuticalmanufacturing firms in Enugu State. Digital transformation adoption has become a critical driver of economic sustainability among pharmaceutical manufacturing firms in Enugu State. The integration of digital technologies such as automation, data analytics, digital supply chain systems, and enterprise management platforms enhances operational efficiency, reduces production costs, improves product quality, and strengthens regulatory compliance.

## 5.3 Recommendations

Based on the findings the following recommendations were proffered:

i. Pharmaceutical manufacturing firms in Enugu State should promote a strong digital culture by encouraging technology adoption, continuous employee digital training, and data-driven practices to enhance operational efficiency and reduce production costs.

ii. Pharmaceutical manufacturing firms in Enugu State should develop and implement clear digital strategies that leverage digital platforms and data analytics to expand market reach and improve revenue generation.

## 5.4 Contribution to Knowledge

This study contributes to knowledge by providing empirical evidence on how digital transformation adoption influences the economic sustainability of pharmaceutical manufacturing firms in Enugu State. It expands existing literature by demonstrating the role of digital technologies in improving operational efficiency, cost management, innovation, and long-term financial performance within the pharmaceutical manufacturing sector in a developing economy context. The study also offers context-specific insights that bridge the gap between digital transformation theory and practical application in Nigerian manufacturing firms, thereby serving as a reference for researchers, policymakers, and industry practitioners seeking to enhance sustainable industrial growth through digitalization.

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