

Technological Change and Performance of Pharmaceutical Manufacturing Firms in Ebonyi State

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Abstract

The study examined technological change and performance of pharmaceutical manufacturing firms in Ebonyi State. The specific objectives are to: Examine the relationship between innovation and new products and ascertain the relationship between Technology Adoption and operational cost of pharmaceutical manufacturing firms in Ebonyi State. The area of the study was Ebonyi State, Nigeria. The study used the descriptive survey design approach. The primary source of data was the administration of questionnaire. The population of the study consisted of three hundred and twelve four (312) employees of selected pharmaceutical firms in Ebonyi State. The whole population was used due to small number. Two hundred and eighty-four (284) respondents returned the questionnaire and accurately filled. Data was presented and analyzed by mean score and standard deviation. The hypotheses were analyzed using Z - test statistic tool. The findings indicated i. Innovation had a significant positive relationship with new products of pharmaceutical manufacturing firms in Ebonyi State, $Z = 11.274$ $p. < .05$ and Technology Adoption had a significant positive relationship with operational cost of pharmaceutical manufacturing firms in Ebonyi State, $Z = 10.542$ $p. < .05$. The study concluded that technological change plays an important role in improving the performance of pharmaceutical manufacturing firms in Ebonyi State. The study recommended among others that Pharmaceutical firms should strengthen their research and development activities by investing in innovative product development and encouraging employees to generate and implement new product ideas.

Keywords: Innovation, new products, Performance, Technological Change, Technology Adoption, operational cost

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Introduction

Technological change has become a central driver of competitiveness and performance in manufacturing industries worldwide, reshaping how firms operate, innovate, and create value. Within the pharmaceutical manufacturing sector which is inherently complex, highly regulated, and capital-intensive the adoption of modern technologies is increasingly recognized as essential for improving operational efficiency, ensuring product quality, reducing costs, and enhancing overall firm performance. Over the past decade, Industry 4.0 technologies such as automation, digital systems, real-time data monitoring, and advanced analytics have transformed traditional manufacturing paradigms, forming a “Pharma 4.0” framework where smart technologies drive process optimization and strategic decision-making (Kyeremeh, Yamoah & Yamoah, 2025).

The importance of technological change in pharmaceutical manufacturing is underscored by its potential impact on performance metrics such as production efficiency, supply chain responsiveness, compliance with regulatory standards, and operational cost reduction. Empirical evidence suggests that digital transformation and advanced technological integration positively influence sustainable supply chain performance, as demonstrated by structural equation modeling studies linking digital transformation to improved performance outcomes in the pharmaceutical sector (Ma, Shi & Kang, 2023). Furthermore, emerging digital innovations like AI-based process monitoring, IoT-enabled manufacturing systems, and predictive quality control have been identified as valuable contributors to improved operational performance and process reliability in pharmaceutical production (Fitzgerald et al., 2026). These technological advancements not only streamline production processes but also offer cost advantages by reducing waste, improving batch consistency, and enhancing quality control mechanisms.

In developing countries, the adoption of such technologies and their associated performance outcomes remains uneven and under-researched, especially at sub-national levels such as Ebonyi State in Nigeria. The pharmaceutical manufacturing sub-sector in Ebonyi State, like many other regions in Africa, is characterized by a mix of small and medium enterprises that often operate with outdated equipment and limited access to modern production technologies. This technological gap poses challenges for operational efficiency, product competitiveness, cost management, and market expansion. A recent empirical survey in Nigerian pharmaceutical manufacturing noted that awareness and adoption of Industry 4.0 technologies such as the Internet of Things (IoT) and mobile digital technologies is still at an early stage, with significant barriers related to finance and technical expertise hindering wider adoption (Adeshina & Abu-Saeed, 2024).

The relationship between technological change and organizational performance is supported by theoretical frameworks such as the Resource-Based View (RBV) and Organizational Information Processing Theory (OIPT), which posit that firms that effectively adopt and integrate advanced technologies gain competitive advantages through better resource utilization, improved knowledge flows, and enhanced process capabilities. Studies examining the interplay of emerging technologies on pharmaceutical supply chain performance have demonstrated that digital technologies play a crucial role in strengthening manufacturing, distribution, and operational processes, thereby enhancing performance outcomes (Authors, 2022). In addition, management research has shown that technological capability correlates positively with measures of competitiveness such as market share, cost leadership, and innovation in pharmaceutical firms within Nigeria, reflecting the broader implications of technology for cost and performance dimensions (Ude, 2025).

Statement of the Problem

Ideally, pharmaceutical manufacturing firms are expected to operate at high levels of efficiency, producing quality medicines at optimal costs, while ensuring compliance with regulatory standards and maintaining competitiveness in both local and global markets. In such a scenario, the integration of advanced technological systems, automation, and digital innovations enables firms to streamline production processes, minimize waste, reduce operational costs, and respond quickly to market demands. This ideal situation ensures that pharmaceutical firms contribute effectively to public health needs, while achieving sustainable growth and profitability.

However, the reality in Ebonyi State's pharmaceutical manufacturing sector falls short of this ideal. Many firms continue to rely on outdated production methods, manual processes, and limited digital tools, which hinder operational efficiency and increase the cost of production. The slow adoption of modern technologies such as computerized production management, automated quality control, and real-time data monitoring limits these firms' capacity to optimize resource utilization and respond effectively to market pressures.

If these problems are not addressed, the consequences are significant. Pharmaceutical firms in Ebonyi State risk declining operational performance, increased production costs, lower product quality, and inability to meet regulatory requirements. This can lead to reduced competitiveness, market share losses, and diminished contribution to local healthcare delivery. Moreover, inefficiencies in production may translate into higher medicine prices for consumers, reduced accessibility of essential drugs, and potential public health risks.

Objective of the Study

The main objective of the study was to examine technological change and performance of pharmaceutical manufacturing firms in Ebonyi State.

The specific objectives are to:

- i. Examine the relationship between innovation and new products of pharmaceutical manufacturing firms in Ebonyi State.
- ii. Ascertain the relationship between Technology Adoption and operational cost of pharmaceutical manufacturing firms in Ebonyi State.

Research Questions

The following research questions guide the study:

- i. What is the relationship between innovation and new products of pharmaceutical manufacturing firms in Ebonyi State?
- ii. What is the relationship between Technology Adoption and operational cost of pharmaceutical manufacturing firms in Ebonyi State?

Research Hypothesis

The following research hypothesis guide the study:

- i. Innovation has no relationship with new products of pharmaceutical manufacturing firms in Ebonyi State.
- ii. Technology Adoption has no relationship with operational cost of pharmaceutical manufacturing firms in Ebonyi State.

Review of Related Literature

Conceptual Review

Technological

Technological change in pharmaceutical manufacturing firms refers to the process of adopting, integrating, and applying new or improved technologies, methods, systems, and tools to enhance production processes, improve operational efficiency, and increase overall firm performance. These technologies can include automation of production lines, digital monitoring systems, computerized quality control, enterprise resource planning (ERP) software, advanced analytics, and Industry 4.0 solutions such as the Internet of Things (IoT) and artificial intelligence (AI) (Kyeremeh, Yamoah & Yamoah, 2025; Ma, Shi & Kang, 2023).

In pharmaceutical manufacturing, technological change is not limited to the replacement of old machinery with modern equipment. It encompasses process innovation, digitalization of production workflows, and adoption of smart systems that enable real-time monitoring, predictive maintenance, efficient resource allocation, and compliance with stringent regulatory standards. By doing so, firms can reduce production errors, optimize costs, increase product quality, and respond quickly to market and public health demands.

Change

Change in pharmaceutical firms refers to the process of transformation or modification in the structure, operations, strategies, technologies, or organizational practices of pharmaceutical manufacturing companies with the aim of improving performance, efficiency, and competitiveness. It involves the continuous adaptation of firms to internal and external pressures such as regulatory requirements, technological advancements, market dynamics, and evolving healthcare needs.

In the context of pharmaceutical manufacturing, change can take several forms. These include technological change (adoption of new production equipment and digital systems), process change (improvement in manufacturing procedures and quality control systems), organizational change (restructuring of management and workforce practices), and strategic change (adjustments in business models, product lines, or market focus). Such changes are often driven by the need to comply with stringent regulatory standards, enhance product quality, reduce operational costs, and respond to increasing global competition (Weaver, O'Hagan, & Lamprou, 2022).

Technological Change

Technological change refers to the process of developing, adopting, and applying new or improved technologies, tools, systems, and methods to enhance production processes, efficiency, and overall organizational performance. It involves the transformation of existing ways of doing things through innovation, modernization, and the integration of advanced technical knowledge into operations. In a general sense, technological change encompasses both incremental improvements (such as upgrading existing machinery or software) and radical innovations (such as the introduction of automation, artificial intelligence, or entirely new production systems). It is a continuous process that enables organizations to remain competitive, improve productivity, reduce costs, and respond effectively to changes in the business environment.

In the context of manufacturing industries, including pharmaceutical firms, technological change includes the adoption of modern equipment, digital systems, process automation, data analytics, and other Industry 4.0

technologies that improve operational efficiency and product quality. According to Ma, Shi, and Kang (2023), technological change particularly through digital transformation plays a critical role in enhancing operational performance and supply chain efficiency. Similarly, Weaver, O'Hagan, and Lamprou (2022) emphasize that emerging technologies in manufacturing contribute significantly to process optimization, sustainability, and innovation.

Components of Technological Change

Below are components of technological changes according to the following authors; Innovation, Product Innovation, Digital Transformation, Automation and Mechanization, Technology Adoption, Research and Development (R&D), Human Capital and Technical Skills, Information and Communication Technology (ICT), Organizational and Managerial Innovation, Infrastructure and Equipment Upgrade (Ma, Shi, & Kang, 2023; Mancilla-de-la-Cruz, Rodriguez-Salvador, & Ruiz-Cantu, 2020; Kyeremeh, Yamoah, & Yamoah, 2025; Weaver, O'Hagan, & Lamprou, 2022; Fitzgerald et al., 2024; Adeshina & Abu-Saeed, 2024).

Components of Technological Change that formed part of the objectives

Innovation

Innovation in pharmaceutical firms refers to the process of developing, adopting, and implementing new or significantly improved products, processes, technologies, or organizational methods to enhance performance, improve healthcare outcomes, and achieve competitive advantage. It involves the application of new ideas, scientific knowledge, and technological advancements to create value in drug development, manufacturing, and distribution.

In the pharmaceutical industry, innovation is most commonly associated with product innovation, such as the discovery and development of new drugs, vaccines, and improved formulations. However, it also includes process innovation, which focuses on improving manufacturing techniques, enhancing quality control systems, and increasing production efficiency. Additionally, technological innovation such as the use of automation, artificial intelligence, and digital monitoring systems plays a crucial role in optimizing operations and reducing costs (Fitzgerald et al., 2024). Innovation in pharmaceutical firms is largely driven by research and development (R&D) activities, which enable firms to discover new compounds, improve existing medications, and respond to emerging health challenges. According to Mancilla-de-la-Cruz, Rodriguez-Salvador, and Ruiz-Cantu (2020), innovation in pharmaceutical manufacturing also extends to advanced production technologies such as additive manufacturing and novel drug delivery systems, which enhance product effectiveness and patient outcomes.

Technology Adoption

Technology adoption refers to the process by which an organization identifies, acquires, implements, and utilizes new technologies to improve its operations, efficiency, and overall performance. It involves the acceptance and integration of technological innovations into existing systems, workflows, and organizational practices.

In the context of pharmaceutical firms, technology adoption includes the introduction and use of modern production equipment, digital systems, automation tools, and advanced technologies such as enterprise resource planning (ERP), data analytics, and quality control systems. This process enables firms to enhance manufacturing efficiency, ensure regulatory compliance, reduce operational costs, and improve product quality.

Technology adoption is not a one-time event but a gradual and systematic process that includes stages such as awareness, evaluation, acquisition, implementation, and continuous use. Successful adoption depends on several factors, including financial capacity, availability of skilled personnel, organizational readiness, and external support such as government policies and regulatory frameworks (Adeshina & Abu-Saeed, 2024).

Performance

Performance refers to the extent to which an organization achieves its set goals and objectives through the efficient and effective utilization of resources. It reflects how well a firm carries out its activities to produce desired outcomes such as profitability, productivity, quality, and competitiveness. In the context of pharmaceutical manufacturing firms, performance encompasses multiple dimensions, including operational efficiency, product quality, cost effectiveness, regulatory compliance, innovation capability, and market performance. It measures how effectively a firm transforms inputs (such as raw materials, labor, and technology) into outputs (such as finished pharmaceutical products) while maintaining high standards of safety and quality.

Performance can be assessed using both financial indicators such as profit margins, return on investment, and cost reduction and non-financial indicators, including production efficiency, product reliability, customer satisfaction, and compliance with regulatory standards. According to Ma, Shi, and Kang (2023), improvements in technological capability and digital transformation significantly enhance operational performance and supply chain efficiency in pharmaceutical firms.

Component of Performance

These are components of performance according to the following authors; Operational Efficiency, Cost Efficiency, Product Quality, Productivity, Profitability, Innovation Performance, New products, Operational cost, Market Performance, Regulatory Compliance, Flexibility and Responsiveness (Ma, Shi, & Kang, 2023; Kyeremeh, Yamoah, & Yamoah, 2025; Weaver, O'Hagan, & Lamprou, 2022; Ma et al., 2023; Ude, 2025; Fitzgerald et al., 2024).

Component of Performance that formed part of objectives

New products

New products in pharmaceutical firms refer to medicinal formulations, drugs, or therapies that are recently developed or significantly improved to meet healthcare needs, comply with regulatory standards, and provide competitive advantage in the market. These products can be entirely novel drugs, modified formulations of existing drugs, innovative delivery systems (such as sustained-release tablets or targeted therapies), or biologics that offer enhanced efficacy, safety, or patient compliance.

In pharmaceutical manufacturing, new products are typically the result of research and development (R&D) activities, clinical trials, technological innovation, and regulatory approval processes. They represent the firm's ability to innovate, respond to emerging health challenges, and remain competitive in the fast-evolving healthcare sector (Mancilla-de-la-Cruz, Rodriguez-Salvador, & Ruiz-Cantu, 2020). New products are not only limited to chemical composition but also include innovations in production processes, packaging, dosage forms, and drug delivery systems, which improve therapeutic effectiveness, reduce side effects, or enhance convenience for patients (Fitzgerald et al., 2024). The introduction of new products is a critical indicator of a pharmaceutical firm's innovation capability and market performance, as it reflects the firm's ability to generate revenue, increase market share, and maintain relevance in a highly regulated and competitive industry.

Operational cost

Operational cost, often referred to as operating expense (OpEx), represents the **recurring expenditures that a business incurs as part of its normal activities to produce goods and deliver services**. In general business practice, operating costs are defined as the day-to-day expenses necessary to maintain, run, and administer a company's activities, including costs such as wages, materials, utilities, and administrative expenses. These costs are distinct from capital expenditures, which are one-time investments in long-term assets (e.g., equipment or buildings). Operational costs are fundamental to sustaining business operations and are reflected on a firm's income statement as ongoing expenses required to generate revenue. (Investopedia 2025; Wikipedia 2025).

In the pharmaceutical industry, operational costs are particularly significant due to the complexity and regulatory rigor inherent in drug development and manufacturing. Pharmaceutical firms are responsible not only for producing safe and effective medications but also for adhering to strict quality control processes and regulatory standards before products reach the market. As such, the operational costs incurred by pharmaceutical companies encompass a broad range of activities that support both production and non-production functions. These costs are critical to understanding the economics of pharmaceutical operations and influence strategic decisions regarding pricing, investment, and profitability.

Theoretical Framework

Diffusion of Innovation Theory (Everett Rogers, 1962)

The **Diffusion of Innovation Theory** was developed by **Everett M. Rogers** in **1962**. Rogers' work explains how, why, and at what rate new ideas and technologies spread through cultures, organizations, and societies. According to this theory, technological change in organizations (like pharmaceutical firms) does not occur instantly; rather, it spreads through stages — *knowledge, persuasion, decision, implementation, and confirmation*. The theory identifies key factors that affect adoption, such as:

Relevance to the Study:

In the context of pharmaceutical manufacturing firms, Diffusion of Innovation Theory helps explain *how technological innovations (e.g., automation, digital systems, quality monitoring tech) are adopted and integrated*, and how this affects firm performance. Firms that more effectively diffuse new technologies typically realize better productivity, efficiency, and competitive advantage.

Resource-Based View (RBV) Theory (Birger Wernerfelt, 1984 / Jay Barney, 1991)

The **Resource-Based View (RBV)** is a theoretical framework used in strategic management, initially popularized by **Birger Wernerfelt in 1984**, and later elaborated by **Jay Barney in 1991**. RBV proposes that a firm's performance is determined by its ability to acquire, develop, and leverage valuable, rare, inimitable, and non-substitutable (VRIN) internal resources and capabilities. In the pharmaceutical context, *technological capabilities* (e.g., specialized manufacturing technologies, R&D systems, IT infrastructure) are treated as strategic resources. Firms that use these technologies effectively can build sustainable competitive advantage, leading to superior performance outcomes such as higher productivity, better product quality, and stronger financial results.

Relevance to the Study:

RBV provides a lens through which *technological change becomes a strategic resource*. The framework helps explain why some pharmaceutical firms outperform others not just because they adopt technology, but because they successfully integrate it into valuable capabilities that competitors cannot easily replicate.

Empirical Review

Innovation and new products

Omede et al (2020) conducted study on Competitive Intelligence and Product Development/Innovations in Pharmaceutical Firms in Lagos State, Nigeria. This study examined competitive intelligence and product development and innovation in pharmaceutical firms in Lagos State, Nigeria. Three hypotheses were formulated to determine whether or not a relationship exist between competitive intelligence and product development and innovation in pharmaceutical firms in Lagos State, Nigeria. The study adopted a survey research design to obtain data, using a structured questionnaire which was analyzed using Pearson's product moment coefficient of correlation. The result indicated that there exists a significant relationship between competitive intelligence and product development and innovation in pharmaceutical firms in Lagos State, Nigeria. Based on the finding it was concluded that the process of product development and innovation cannot be successful except there is information about customer's needs, wants and expectations of which the innovation products or services intends to serve.

Ogu (2020) conducted a study on Enhancing Energy Efficiency by Reducing Power Consumption in Cell Sites Using a Neuro-Fuzzy Controller. The high power consumption in modules of a cell site has led to high bit error rate, congestion and high cost of power consumed. This has equally led to low network performance in base station. This is overcome by improving energy efficiency through reduction of power consumption in base station or a cell site using neuro-fuzzy controller. This is overcome in this manner, characterizing and determine the power consumption of the modules of the cell site under study, developing a simulink model for the cell site under study, designing a rule base that would monitor the power consumed by the cell site and reduced it if raised, training ANN in this rule base for effective monitoring of the power consumed by the cell site and reduced it if raised. Finally, design a SIMULINK model for improving energy efficiency through reduction of power consumption in base station or a cell site using neuro-fuzzy controller and validating and justifying the percentage of power consumption reduction of the modules of the cell site with and without incorporation of neuro-fuzzy. The results obtained are 532KW power consumed in the base station when neuro –fuzzy is not incorporated in the system and 514.9KW when neuro-fuzzy is incorporated in the system. With these results obtained, it shows that the percentage reduction of power consumed at the base station when neuro-fuzzy is imbibed in the system is 3.21%.

Oluwajimade & Olanrewaju (2023) carried out study on Green Innovation Tools and Performance of Selected Pharmaceutical Firms in Ilorin Metropolis: Quantitative Approach. This paper investigated the effect of green innovation tools on the performance of selected pharmaceutical firms in Ilorin Metropolis, Nigeria. A descriptive survey research design was used in the study. The target population comprised 284 managerial staff, regular staff and factory workers of the selected pharmaceutical firms Taro Yamane formula was used to determine sample size. Stratified random sampling and proportionate sampling techniques were used to group the sample into definite categories of managerial staff, regular staff and factory workers and for adequate representation. A validated questionnaire was administered and a total of 257 were retrieved for analysis. The data collected were analyzed using PLS-CEM. The findings revealed that green innovation tools had a positive and significant effect on organizational performance.

Akpa et al (2023) conducted a study on Entrepreneurial Orientation and Competitive Advantage of Quoted Pharmaceutical Companies in Nigeria. Pharmaceutical companies play a significant role in ensuring that people have access to high-quality and affordable medical services. They provide a wide range of medical services, from preventative care to emergency services. Despite the contribution of pharmaceutical companies to the social and economic growth of citizens in both developed and developing countries, their performance may not have been as expected. This is evident in the poor level of competitive advantage, decline in market share growth, dwindling financial growth, decline in productivity and customer retention. This study investigated the effect of entrepreneurial orientation on competitive advantage of quoted pharmaceutical companies in Nigeria. The study

adopted a survey research design. The population of the study was 308 executive manager, directors and marketing department official in these quoted pharmaceutical companies in Nigeria. Data was collected using a valid and reliable questionnaire with a Cronbach alpha value greater than 0.7. Data were analysed using both descriptive and inferential tools. Multiple and Hierarchical Regression Analysis were used to determine the effect of the variables using Statistical Package for Social Science (SPSS). The results revealed that entrepreneurial orientation had significant effect on competitive advantage of quoted pharmaceutical companies in Nigeria (Adj. R² = 0.265; F (5, 296) = 22.726, p < 0.05).

Ude (2025) investigated Technological Capability and Competitiveness of Pharmaceutical Manufacturing Companies in South-South, Nigeria. This study investigated the relationship between technological capability and the competitiveness of pharmaceutical manufacturing companies in South-South, Nigeria. Employing a cross-sectional survey design, data was collected from 50 senior managers across 10 registered pharmaceutical companies in the region. The research focused on three dimensions of competitiveness: market share, cost leadership, and innovativeness. The findings reveal a significant and positive relationship between technological capability and each measure of competitiveness. Specifically, Spearman's rank-order correlation indicated a strong positive correlation between technological capability and both market share and innovativeness, as well as a moderate positive correlation with cost leadership. The results suggest that pharmaceutical companies with advanced technological capabilities are better positioned to increase market share, achieve cost efficiencies, and foster innovation. These findings align with existing literature, reinforcing the critical role of technological capability in enhancing organizational performance and competitiveness.

Technology Adoption and operational cost

Esha et al (2022) conducted a study on the interplay of emerging technologies in pharmaceutical supply chain performance: An empirical investigation for the rise of Pharma 4.0, Technological Forecasting and Social Change. The impact and the relevance of the emerging technologies on the supply chains have attracted researchers and practitioners alike worldwide. Based on the resource-based view and organizational information processing theory, this study attempts to investigate how emerging technologies influence supply chain performance, particularly pharmaceutical supply chain in regards to the rise of Pharma 4.0. The pharmaceutical supply chain processes are considered as the mediators and the emerging technology adoption barriers are proposed as the moderators. The study is evaluated using a survey of pharmaceutical companies in India. The findings indicate that manufacturing, distribution and consumption processes in the supply chain mediate the effects of emerging technologies on supply chain performance; however, mediating effects are weakened due to the presence of intricate barriers.

Luo & Yu, (2022) conducted study on the Regulatory Effect of Firm Size on Digital Transformation: An Empirical Study of Pharmaceutical Companies in China. Digital transformation (DT) has been a key way for pharmaceutical companies to enhance innovation and R&D capabilities, improve product quality, reduce costs, and create competitive advantages. The external environment factors and the internal conditions' factors are the main factors affecting the DT of pharmaceutical companies. This research aimed to probe the effects of the external environment factors, the internal conditions' factors, firm size, and control variables on the DT of pharmaceutical companies based on synergetics. Purposive sampling and snowball sampling were used in this research. In addition, this research collected 395 valid data from Chinese pharmaceutical companies through online questionnaires. This research used quantitative analysis, and SPSS and Amos software were applied to data processing analysis. The results of structural equation modelling (SEM) and regression analysis showed that the external environment factors and the internal conditions' factors had a significantly positive correlation with the DT of pharmaceutical companies, and the effects of the internal conditions on the DT of pharmaceutical companies were greater than that of the external environment. In addition, firm size positively moderated the relationship between the external

environment, internal conditions, and the DT of pharmaceutical companies. The results of this research not only can provide theoretical reference for scholars but also put forward implementation suggestions of DT for Chinese pharmaceutical company managers.

Bilal et al (2024) examined the Impact of Financial Investment and Technology Adoption on Operational Efficiency in Industry Engineering Management: The Mediating Role of Process Innovation in the Pharmaceutical Industry. This study examines the impact of financial investment and technology adoption on operational efficiency in the pharmaceutical industry, with process innovation as a mediating factor. Operational efficiency is critical for pharmaceutical firms to meet regulatory requirements, reduce costs, and remain competitive in a rapidly evolving market. Drawing on Resource-Based View (RBV) and Dynamic Capabilities Theory, this research investigates how financial resources and technological advancements drive performance improvements when coupled with innovative processes. Using a quantitative research approach, data were collected from 250 professionals in the pharmaceutical industry through a structured questionnaire. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess direct and mediated relationships among the variables. The findings reveal that both financial investment and technology adoption significantly enhance operational efficiency, while process innovation plays a pivotal mediating role, amplifying their effects.

Kyeremeh et al (2025) conducted a study on Enhancing pharmaceutical supply chain performance: the impact of technology integration, interorganizational trust, and collaboration in the digital age. This study investigates the impact of technological integration on pharmaceutical supply chain performance in Ghana, with a particular focus on the mediating roles of inter-organizational trust and collaboration. Employing structural equation modeling, data from 221 pharmaceutical distributors and wholesalers revealed a significant positive relationship between technological integration and supply chain performance. This relationship is mediated by both inter-organizational trust and collaboration. These findings underscore the crucial role of technology in enhancing supply chain efficiency, inventory management, and information sharing, while simultaneously fostering cooperative relationships among supply chain partners. By elucidating the intricate interplay between technology, trust, and collaboration, this study contributes novel insights to the pharmaceutical supply chain literature. The findings offer valuable managerial implications for optimizing supply chain performance through strategic technology investments.

Strüssmann et al (2026) carried out a study on the Barriers to Industry 4.0 adoption in pharmaceutical manufacturing companies: A case study. Purpose: Design/methodology/approach: A mixed-methods approach was employed, combining maturity assessments with insights from in-depth interviews with key stakeholders in the pharmaceutical industry. The study identifies and categorizes the main barriers to Industry 4.0 adoption, providing a sector-specific analysis. **Findings:** The primary barriers to Industry 4.0 adoption in pharmaceutical manufacturing were found to be "prioritization and strategic alignment," "technological challenges," and "financial constraints." Contrary to common assumptions in the literature, "regulatory and compliance challenges" were perceived as less impactful by stakeholders, as these are often ingrained in routine operations.

Summary of Empirical Review

The empirical review examined previous studies on technological change and the performance of pharmaceutical manufacturing firms. The reviewed studies generally established that technological change has a significant positive influence on organizational performance. Specifically, innovation was found to enhance the development of new products, improve product quality, and enable firms to respond effectively to changing customer needs. Similarly, technology adoption was shown to improve operational processes, enhance efficiency, reduce waste, and support better utilization of organizational resources. The review further revealed that firms that embrace modern

technologies are better positioned to improve productivity, competitiveness, and overall business performance. However, some studies noted that the benefits of technological change depend on factors such as employees' technological skills, availability of financial resources, and effective management support. Despite these findings, limited empirical attention has been given specifically to pharmaceutical manufacturing firms in Ebonyi State, creating a gap which the present study seeks to address.

Methodology

The area of the study was Ebonyi State, Nigeria. The small and Medium Enterprises in Ebonyi State were used. choice of these firms was due to high number of staff. The study used the descriptive survey design approach. The primary source of data was the administration of questionnaire. The population of the study consisted of three hundred and twelve four (312) employees of selected pharmaceutical firms in Ebonyi State. The whole population was used due to small number. Two hundred and eighty-four (284) respondents returned the questionnaire and accurately filled. The reliability was tested using the Pearson correlation coefficient (r). It gave a reliability co-efficient of 0.720 which was also good. Data was presented and analyzed by mean score and standard deviation. The hypotheses were analyzed using Z - test statistic tool.

Data Presentation and Analyses

The relationship between innovation and new products of pharmaceutical manufacturing firms in Ebonyi State.

Table 4.2.1.1: Responses on the relationship between innovation and new products of pharmaceutical manufacturing firms in Ebonyi State.

		5	4	3	2	1	ΣFX	-	SD	Decision
		SA	A	N	DA	SD		X		
1	Innovation enables pharmaceutical manufacturing firms in Ebonyi State to develop new and improved products that meet emerging healthcare needs.	795	384	15	26	11	1231			Agree
		159	96	5	13	11	284	4.33	1.000	
		56.0	33.8	1.8	4.6	3.9	100%			
2	Increased innovation in pharmaceutical firms encourages the creation of new drug formulations and medical solutions.	795	372	15	26	14	1222			Agree
		159	93	5	13	14	284	4.30	1.057	
		56.0	32.7	1.8	4.6	4.9	100%			
3	Innovative research and development activities enhance the ability of pharmaceutical firms to introduce new products into the market.	795	372	15	26	14	1222			Agree
		159	93	5	13	14	284	4.30	1.057	
		56.0	32.7	1.8	4.6	4.9	100%			
4	The adoption of innovative technologies supports pharmaceutical manufacturers in	795	372	15	26	14	1222			Agree
		159	93		13	14	284	4.30	1.057	

	Ebonyi State in producing unique and competitive new products.	56.0	32.7	5 1.8	4.6	4.9	100%		
5	Continuous innovation strengthens the capacity of pharmaceutical firms to expand their product lines and improve healthcare solutions.	795	384	15	14	18	1226		Agree
		159	96	5	7	18	284	4.35	1.014
		56.0	33.8	1.8	2.1	6.3	100%		
Total Grand mean and standard deviation								4.316	1.037

Source: Field Survey, 2026

Table 4.2.1.1, 255 respondents out of 284 representing 89.8 percent agreed that Innovation enables pharmaceutical manufacturing firms in Ebonyi State to develop new and improved products that meet emerging healthcare needs with mean score of 4.33 and standard deviation of 1.000. Increased innovation in pharmaceutical firms encourages the creation of new drug formulations and medical solutions 252 respondents representing 88.7 percent agreed with mean score of 4.30 and standard deviation of 1.057. Innovative research and development activities enhance the ability of pharmaceutical firms to introduce new products into the market 252 respondents representing 88.7 percent agreed with mean score of 4.30 and standard deviation of 1.057. The adoption of innovative technologies supports pharmaceutical manufacturers in Ebonyi State in producing unique and competitive new products 252 respondents representing 88.7 percent agreed with mean score of 4.30 and 1.057. Continuous innovation strengthens the capacity of pharmaceutical firms to expand their product lines and improve healthcare solutions 255 respondents representing 89.8 percent agreed with a mean score of 4.35 and standard deviation 1.014.

The relationship between Technology Adoption and operational cost of pharmaceutical manufacturing firms in Ebonyi State.

Table 4.2.2.1: Responses on the relationship between Technology Adoption and operational cost of pharmaceutical manufacturing firms in Ebonyi State.

		5	4	3	2	1	ΣFX	-	SD	Decisi on
		SA	A	N	DA	SD		X		
1	Technology adoption helps pharmaceutical manufacturing firms in Ebonyi State reduce operational costs through improved efficiency.	750	376	15	24	23	1188			Agree
		150	94	5	12	23	284	4.18	1.190	
		52.8	33.1	1.8	4.2	8.1	100%			
2	The use of modern technologies minimizes waste and lowers production expenses in pharmaceutical firms.	780	372	15	44	8	1219			Agree
		156	93	5	22	8	284	4.29	1.024	
		54.9	32.7	1.8	7.7	2.8	100%			

3	Technology adoption streamlines production processes, thereby reducing operational costs.	740	352	15	60	13	1180	Agree			
		148	88	5	30	13	284			4.15	1.164
		52.1	31.0	1.8	10.6	4.6	100%				
4	Digital systems enhance inventory and resource management, helping firms control operational expenditures.	760	352	15	42	18	1187	Agree			
		152	88	5	21	18	284			4.18	1.180
		53.5	31.0	1.8	7.4	6.3	100%				
5	The adoption of advanced technologies enables pharmaceutical firms to optimize operations and achieve cost reduction.	715	352	15	32	21	1135	Agree			
		143	88	5	16	21	262			4.07	1.259
		50.4	31.0	1.8	9.2	7.7	100%				
Total Grand mean and standard deviation							4.174	1.1634			

Source: Field Survey, 2026

Table 4.2.2.1, 244 respondents out of 284 representing 85.9 percent agreed that Technology adoption helps pharmaceutical manufacturing firms in Ebonyi State reduce operational costs through improved efficiency with mean score of 4.18 and standard deviation of 1.190. The use of modern technologies minimizes waste and lowers production expenses in pharmaceutical firms 249 respondents representing 87.6 percent agreed with mean score of 4.29 and standard deviation of 1.024. Technology adoption streamlines production processes, thereby reducing operational costs 236 respondents representing 83.1 percent agreed with mean score of 4.15 and standard deviation of 1.164. Digital systems enhance inventory and resource management, helping firms control operational expenditures 240 respondents representing 84.5 percent agreed with mean score of 4.18 and 1.180. The adoption of advanced technologies enables pharmaceutical firms to optimize operations and achieve cost reduction 231 respondents representing 81.4 percent agreed with a mean score of 4.07 and standard deviation 1.259.

Test of Hypotheses

Test of Hypotheses One: Innovation has no relationship with new products of pharmaceutical manufacturing firms in Ebonyi State.

One-Sample Kolmogorov-Smirnov Test

	Innovation enables pharmaceutical manufacturing firms in Ebonyi State to develop new and improved products that meet emerging healthcare needs.	Increased innovation in pharmaceutical firms encourages the creation of new drug formulations and medical solutions.	Innovative research and development activities enhance the ability of pharmaceutical firms to introduce new products into the market.	The adoption of innovative technologies supports pharmaceutical manufacturers in Ebonyi State in producing unique and competitive new products.	Continuous innovation strengthens the capacity of pharmaceutical firms to expand their product lines and improve healthcare solutions.
N	284	284	284	284	284
Uniform Minimum	1	1	1	1	1
Parameters ^{a,b} Maximum	5	5	5	5	5
Most Absolute	.648	.637	.637	.637	.669
Extreme Positive	.039	.049	.049	.049	.063
Differences Negative	-.648	-.637	-.637	-.637	-.669
Kolmogorov-Smirnov Z	10.918	10.740	10.740	10.740	11.274
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 (11. 274) > critical z-value (.000) at the 5% significance level, we reject the null hypothesis (H_0).

Decision:

Furthermore, comparing the calculated Z- value ranges from $10.740 < 11. 274$ 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 **Innovation had significant positive relationship with new products of pharmaceutical manufacturing firms in Ebonyi State.**

Test of Hypotheses Two: Technology Adoption has no relationship with operational cost of pharmaceutical manufacturing firms in Ebonyi State.

One-Sample Kolmogorov-Smirnov Test

	Technology adoption helps pharmaceutical manufacturing firms in Ebonyi State reduce operational costs through improved efficiency.	The use of modern technologies minimizes waste and lowers production expenses in pharmaceutical firms.	Technology adoption streamlines production processes, thereby reducing operational costs.	Digital systems enhance inventory and resource management, helping firms control operational expenditures.	The adoption of advanced technologies enables pharmaceutical firms to optimize operations and achieve cost reduction.
N	284	284	284	284	284
Uniform Parameters ^a					
Minimum	1	1	1	1	1
Maximum	5	5	5	5	5
Absolute	.609	.627	.581	.595	.563
Most Extreme Differences					
Positive	.081	.028	.046	.063	.077
Negative	-.609	-.627	-.581	-.595	-.563
Kolmogorov-Smirnov Z	10.266	10.562	9.791	10.028	9.494
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 (10.542) > 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 $9.494 < 10.542$ 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 **Technology Adoption had significant positive relationship with operational cost of pharmaceutical manufacturing firms in Ebonyi State.**

Discussion of Findings

From the result of Hypotheses one, the calculated Z- value ranges from $10.740 < 11.274$ against the critical Z- value of .000 which implies that Innovation had significant positive relationship with new products of pharmaceutical manufacturing firms in Ebonyi State. In support of the result in the literature review,

From the result of Hypotheses two, the calculated Z- value ranges from $9.494 < 10.542$ against the critical Z- value of .000 which implies that Technology Adoption had significant positive relationship with operational cost of pharmaceutical manufacturing firms in Ebonyi State. In support of the result in the literature review,

Summary of findings, Conclusion and Recommendations

Summary of findings

- i. Innovation had a significant positive relationship with new products of pharmaceutical manufacturing firms in Ebonyi State, $Z = 11.274$ p. < .05. This indicates that increased innovation among pharmaceutical manufacturing firms contributes to the development and introduction of new products. Firms that encourage research, creativity, and new ideas are more likely to develop improved pharmaceutical products that meet changing customer and healthcare needs.
- ii. Technology Adoption had a significant positive relationship with operational cost of pharmaceutical manufacturing firms in Ebonyi State, $Z = 10.542$ p. < .05. This indicates that the adoption of modern technology has a significant influence on the operational costs of pharmaceutical manufacturing firms. Effective use of technology can improve production processes, reduce waste, minimize manual errors, and enhance resource utilization.

Conclusion

The study established that **technological change plays an important role in improving the performance of pharmaceutical manufacturing firms in Ebonyi State.** The findings indicate that the adoption of new technologies and innovative practices enables firms to improve their production processes, develop new products, and respond more effectively to changes in the pharmaceutical market. Technological change also helps firms improve efficiency, reduce waste, enhance the quality of products, and make better use of available resources. Furthermore, the study shows that **innovation and technology adoption are important drivers of organizational performance.** Pharmaceutical firms that continuously embrace technological developments are more capable of improving their products and strengthening their operational activities. Therefore, pharmaceutical manufacturing firms in Ebonyi State should view technological change not merely as an investment in equipment but as a strategic approach to achieving sustainable growth, competitiveness, and improved performance.

Recommendations

- i. Pharmaceutical firms should strengthen their research and development activities by investing in innovative product development and encouraging employees to generate and implement new product ideas.
- ii. Pharmaceutical firms should invest in appropriate modern technologies and train employees to use them effectively in order to improve production efficiency and achieve better control of operational costs.

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