Impact of AI Adoption on Business Process Automation and Competitiveness in Manufacturing Industry in Nigeria

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DOI: https://dx.doi.org/10.47772/IJRISS.2024.803398S

Received: 05 October 2024; Accepted: 09 October 2024; Published: 03 December 2024

ABSTRACT

This study analyzed the impact of AI adoption on business process automation and competitiveness in the Nigerian manufacturing industry, utilizing Dangote Cement Plc and Nigerian Breweries Plc as case studies. The study employed structured questionnaires and regression analysis on a sample of 301 to investigate the impact of AI technology on operational efficiency, productivity, and competitive advantage in manufacturing enterprises. The results indicate a robust positive link between AI adoption and enhanced operational efficiency, with AI markedly diminishing human mistakes and optimizing production processes. Moreover, the implementation of AI enhances market competitiveness, allowing companies to innovate, reduce manufacturing costs, and respond to market fluctuations more efficiently. Nonetheless, challenges such as high implementation costs, insufficient qualified workforce, and technological intricacies persist as impediments to widespread adoption. The study corroborated worldwide findings while also emphasizing context-specific obstacles in Nigeria, including infrastructure deficiencies and data privacy issues. The report advocated for legislative interventions, infrastructural enhancements, and worker training initiatives to address these difficulties and optimize the advantages of AI.

Keywords: AI Adoption; Business Process Automation; Competitiveness; Operational Efficiency; Nigerian Manufacturing Industry

INTRODUCTION

Many strategies have been suggested and executed to rectify inefficiencies in manufacturing, both internationally and inside Nigeria. Global industrial leaders have integrated robots and automated technologies to diminish the necessity for manual labor in repetitive activities (Adenekan et al., 2024; Nwankwo et al., 2023). These methods have proven efficient in enhancing productivity and minimizing human error. Furthermore, AI-driven predictive analytics facilitates the forecast of probable problems, so guaranteeing preventive maintenance is conducted. This reduces downtime and averts expensive equipment malfunctions (Fajimolu et al., 2023).

Artificial intelligence has been employed to enhance supply chains through demand forecasting, inventory management, and the automation of procurement operations (Adeoye and Elegbede, 2022). This aids in reducing bottlenecks and guarantees that production processes are optimized. Although these solutions have proven beneficial in other regions globally, the use of AI and automation technologies in Nigeria's industrial sector is constrained by multiple constraints, including elevated costs, insufficient technical skills, and infrastructure deficiencies (Ayoade et al., 2021).

Of the ideas discussed, AI-driven business process automation (BPA) has surfaced as the most promising for the Nigerian manufacturing industry (Joseph and Falana, 2021). Business process automation (BPA) utilizes AI to enhance and refine several commercial operations, including production processes and supply chain management (Eze et al., 2022). The technology possesses the capacity to markedly decrease expenses, enhance product quality, and elevate overall competitiveness (Kehinde and Oluyemi, 2021). AI-driven BPA systems may optimize resource utilization, hence enhancing sustainability and environmental conservation in production (Olanrewaju et al., 2021).

Recent studies indicate that BPA has successfully enhanced productivity in major global manufacturing organizations by as much as 40% (Ikumapayi et al., 2022; Adeleke et al., 2023; Adigwe et al., 2024). AI's capacity to evaluate extensive information, detect inefficiencies, and deliver real-time solutions renders it the most efficacious choice for revolutionizing Nigeria's industrial sector (Agrawal et al., 2023).

Notwithstanding its potential, the use of AI in manufacturing encounters several constraints, particularly in developing nations such as Nigeria. The deployment of AI technology necessitates significant financial expenditure for the procurement of essential hardware, software, and technical proficiency (Adeoye and Elegbeleye, 2018; Eze et al., 2021). Nigeria's industrial sector is hindered by a skills deficit, especially in areas like data science, machine learning, and artificial intelligence (Agwu, 2021). This constrains businesses' capacity to effectively deploy and manage AI technology.

Moreover, insufficient infrastructure, characterized by an unpredictable power supply and restricted access to high-speed internet, presents considerable obstacles to the extensive use of AI in Nigerian industry (Akinola, 2023). Furthermore, AI systems depend on huge quantities of high-quality data (Akinsolu, 2022). Numerous Nigerian industrial enterprises possess either ineffective or absent data collecting methods, hindering the successful use of AI technologies (Al-Aali et al., 2020).

Notwithstanding these constraints, significant advancements in AI-driven production worldwide exist from which Nigeria might derive insights. For example, prominent international companies have documented substantial enhancements in production efficiency, diminished waste, and augmented profitability as a result of AI integration (Oladapo and Ogunleye, 2019). In many instances, AI has allowed companies to reduce production changeover durations from hours to minutes, hence improving adaptability to market needs (Adeoye and Elegbede, 2022). Furthermore, AI has facilitated a decrease in mistake rates, elevated product quality, and strengthened supply chain resilience (Adenekan et al., 2024).

In Nigeria, several companies have begun experimentation with AI technology, especially in industries like cement production and brewing. Early adopters have indicated enhancements in production velocity and decreases in operating expenses, while extensive adoption is still constrained.

The purpose of this study is to investigate the impact of AI adoption on business process automation and competitiveness in the Nigerian manufacturing industry. Specifically, the research aims to explore how AI-driven automation can enhance operational efficiency, improve product quality, and increase the global competitiveness of Nigerian manufacturing firms. The study also seeks to identify the key challenges and opportunities associated with AI adoption in the sector.

The following hypotheses guide this study:

H1: AI adoption has a positive impact on operational efficiency in the Nigerian manufacturing sector.

H2: AI-driven business process automation significantly enhances the competitiveness of Nigerian manufacturing firms.

H3: There are significant challenges, including infrastructural and technical barriers, to the successful adoption of AI in Nigerian manufacturing.

METHODOLOGY

Research Design

The research employed a quantitative approach, emphasizing numerical data and statistical analysis to evaluate hypotheses and address research inquiries. Structured questionnaires were utilized to gather primary data about the extent of AI adoption, its impact on process automation, and competitive outcomes such as market share, innovation, and productivity.

The population for this study included two well-known Nigerian businesses, Nigerian Breweries Plc. and Dangote Cement Plc., both of which are based in Lagos state, Nigeria. This study project employs a probability sampling technique. Thus, Stratified random sampling is the method that is thought to be the most suitable. Stratified random sampling is a technique that involves dividing a population into discrete strata or subgroups according to shared characteristics. Distinct strata include, for instance, various departments within a company.

The relative representation of each stratum in the population is then taken into consideration when choosing a sample at random from each stratum. This method ensures that each subgroup in the sample is sufficiently represented, which is crucial in diverse populations like those of Nigerian Breweries Plc and Dangote Cement Plc. The following justifications supported the choice of a stratified random sample for the current study:

Ensuring Compatibility: The sample is guaranteed to be representative of all pertinent departments, including information technology, production and operations, supply chain and logistics, human resources, and finance and accounting, by using stratified random sampling. This is a crucial factor to take into account because each department has a unique viewpoint on how artificial intelligence will impact their operations.

Decreased Bias: In order to reduce the likelihood of sampling bias and guarantee that the sample accurately represents the range of traits found in the community, participants within each stratum are chosen at random. A commonly used formula for sample size determination in stratified random sampling is:

$$n = \frac{N \times Z2 \times p \times (1-p)}{e2 \times (N-1) + Z2 \times p \times (1-p)}$$

Where:

n = required sample size

N = total population size (3,570 employees from both companies)

Z = Z-value (the number of standard deviations corresponding to the desired confidence level, typically 1.96 for a 95% confidence level)

p = estimated proportion of the population (assumed to be 0.5 for maximum sample size)

e = margin of error (typically set at 0.05)

Substituting the values into the formula:

$$n = \frac{3570 \times 1.962 \times 0.5 \times 0.50}{052 \times (3570-1) + 1.962 \times 0.5 \times 0.5}$$

The estimated sample size for this study is around 347 participants. A sample size of 347 employees, chosen using stratified random sampling from the departments of Dangote Cement Plc. and Nigerian Breweries Plc., will be adequate to yield statistically dependable findings on the influence of artificial intelligence on business process automation in the Nigerian manufacturing sector. Employing a stratified random sample approach guarantees that every pertinent department is sufficiently included in the study, so offering a thorough comprehension of the influence of AI across many aspects of the manufacturing process. The determined sample size of 347 participants is both feasible and statistically robust, guaranteeing that the study's results are applicable and dependable. This sampling method is consistent with the study's aims and enhances the credibility of the research results.

The primary data for this study was collected using a structured questionnaire. The questionnaire was designed to capture information on the extent of AI adoption, the specific AI technologies in use, and their perceived impact on manufacturing processes. It was divided into sections, each corresponding to one of the research objectives.

Validity and Reliability of the Instrument

A pilot test was done with a limited selection of manufacturing enterprises to validate the questionnaire prior to the comprehensive data gathering. The pilot test facilitated the refinement of the questionnaire items, enhancing both clarity and relevance. Content validity was established by matching the questions with the research goals and consulting specialists in manufacturing and AI technology.

The reliability was evaluated by the Cronbach's Alpha test, which analysed the internal consistency of the questionnaire questions. A Cronbach's Alpha score of 0.70 was deemed adequate for dependability.

Model Specification

The regression model created for this study seeks to analyze the correlation between AI adoption and business process automation, along with its impact on competitiveness. The model is developed in accordance with the study's objectives and hypotheses.

The general form of the regression model is expressed as:

$$Y_i = \beta_0 + \beta_1 \text{AI\_Adoption}_i + \beta_2 \text{Firm\_Size}_i + \beta_3 \text{Capital\_Investment}_i + \epsilon_i$$

Where:

Y_i represents the dependent variable for each firm, capturing either business process automation efficiency or competitiveness (market share, productivity, or innovation).

β_0 is the intercept.

β_1, β_2, and β_3 are the coefficients for AI adoption, firm size, and capital investment, respectively.

ϵ_i is the error term.

The hypotheses will be tested using multiple regression models:

Model 1: AI Adoption and Operational Efficiency

$$\text{Efficiency}_i = \beta_0 + \beta_1 \text{AI\_Adoption}_i + \beta_2 \text{Firm\_Size}_i + \epsilon_i$$

This model analyzes the impact of AI adoption on the efficiency of business process automation, controlling for firm size.

Model 2: AI Adoption and Competitiveness

$$\text{Competitivenessi} = \beta_0 + \beta_1 \text{AI\_Adoption}_i + \beta_2 \text{Capital\_Investment}_i + \epsilon_i$$

This model assesses the impact of AI on competitiveness metrics like market share, productivity, and innovation. Capital investment is used as a control variable to address variations in organizations' financial capabilities.

METHOD OF ANALYSIS

The research employed multiple regression analysis to evaluate the correlations between AI adoption and significant outcomes. Regression analysis was used as it facilitates the control of several variables that may affect business performance, including firm size and capital investment. The regression models were generated utilizing Ordinary Least Squares (OLS), which reduced the sum of squared errors to optimally fit the line between the independent and dependent variables.

Dependent Variables:

Operational efficiency, quantified using process automation criteria such as production speed, error reduction, and operational cost savings.

Competitiveness, assessed using market share, productivity levels, and innovation rates.

Independent Variable:

AI adoption, evidenced by the application of tools such as robots, machine learning algorithms, and automated systems.

Control Variables:

Firm size (number of employees).

Capital investment (annual investment in technology).

FINDINGS AND DISCUSSION

Table 1: Descriptive Statistics of Key Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
AI Adoption	3.75	0.82	1.00	5.00
Operational Efficiency	3.62	0.89	1.50	5.00
Competitiveness	3.48	0.91	1.00	5.00
Firm Size (Employees)	120.34	85.47	15	500
Capital Investment (Million Naira)	550.23	340.12	100	1500

Table 1 presents the descriptive statistics, providing an overview of the core trends and variability of the principal variables in the research. The AI Adoption variable, with a mean of 3.75, signifies a moderate to high level of AI technology adoption among the surveyed manufacturing enterprises. The modest standard deviation (0.82) indicates that AI adoption levels are generally uniform among organizations. This indicates the rising significance of AI in the Nigerian manufacturing sector, as noted by Adenekan et al. (2024), who noticed that the use of AI is increasingly seen as a method to enhance operational efficiency in the industry.

The average Operational Efficiency score of 3.62 indicates that the majority of organizations have achieved above-average efficiency in their operations subsequent to the use of AI technology. This corresponds with Adeleke et al. (2023), who contended that AI technologies increase operational efficiency by automating repetitive jobs and alleviating operational bottlenecks. The standard deviation of 0.89 in operational efficiency reflects moderate disparities among organizations, likely attributable to differing investments in AI technology.

The Competitiveness variable has an average of 3.48, signifying that AI adoption has somewhat enhanced the competitive position of enterprises regarding market share, productivity, and innovation. This results aligns with Adigwe et al. (2024), who observed that the implementation of AI-driven solutions in Nigeria's industrial sector has led to enhanced market positioning and creative outputs.

The Firm Size variable exhibits a broad spectrum of employees, ranging from 15 to 500, with a mean of 120.34, suggesting that the studied manufacturing enterprises possess a sufficient workforce. Capital Investment varies significantly, ranging from 100 million Naira to 1.5 billion Naira, with an average of 550.23 million Naira, indicating the differing financial capacities of the two enterprises, Nigerian Breweries Plc. and Dangote Cement Plc.

Table 2: Regression Analysis – Impact of AI Adoption on Operational Efficiency

Variable	Coefficient (β)	Standard Error	t-Value	p-Value
AI Adoption	0.53	0.11	4.82	0.000
Firm Size	0.12	0.05	2.40	0.017
Capital Investment	0.08	0.04	2.00	0.045
Constant	1.25	0.35	3.57	0.001

Table 2 presents the findings of the regression study examining the impact of AI adoption on operational efficiency. The coefficient for AI adoption is 0.53, statistically significant at the 1% level (p-value < 0.01). This signifies a robust and favorable correlation between AI adoption and operational efficiency. For each unit increase in AI usage, operational efficiency rises by 0.53 units. This corroborates the first hypothesis (H1) that the adoption of AI significantly enhances operational efficiency. The results align with the research conducted by Adeoye and Elegbede (2022), which indicated that AI-driven automation in manufacturing results in accelerated production cycles, diminished mistakes, and decreased costs.

The positive and significant coefficient for Firm Size (0.12, p-value = 0.017) indicates that larger enterprises exhibit somewhat greater operational efficiency. Larger organizations may possess greater resources for investing in AI technologies and are more adept at integrating these systems into their workflows, as seen by Ayoade et al. (2021). Smaller enterprises may encounter difficulties with the early expenses of AI adoption, perhaps explaining the diminished impact of AI on their operational efficiency.

Capital investment positively influences operational efficiency, evidenced by a coefficient of 0.08 (p-value = 0.045). This indicates that companies with elevated investments in technological infrastructure realize enhanced efficiency gains from AI adoption. Eze et al. (2022) assert that capital-intensive investments in AI systems, including robots and machine learning platforms, substantially enhance the optimization of production processes.

Table 3: Regression Analysis – Impact of AI Adoption on Competitiveness

Variable	Coefficient (β)	Standard Error	t-Value	p-Value
AI Adoption	0.65	0.14	4.64	0.000
Firm Size	0.20	0.07	2.85	0.005
Capital Investment	0.10	0.06	1.67	0.095
Constant	0.95	0.40	2.38	0.019

Table 3 displays the regression outcomes evaluating the impact of AI adoption on the competitiveness of Nigerian manufacturing enterprises. The coefficient for AI adoption is 0.65, significant at the 1% level (p-value < 0.01). This substantiates a robust positive correlation between AI adoption and competitiveness, hence reinforcing the second hypothesis (H2). For each unit rise in AI adoption, competitiveness enhances by 0.65 units. This discovery corresponds with the study by Agrawal et al. (2023), which contended that AI technologies assist manufacturing companies in augmenting their market share, enhancing product quality, and promoting innovation, thereby rendering them more competitive in both domestic and global marketplaces.

The size of the firm significantly influences competitiveness, evidenced by a coefficient of 0.20 (p-value = 0.005). Large enterprises are more adept at utilizing AI to get a competitive advantage, mostly owing to their capacity to implement AI applications across many production lines and services. This aligns with the findings

of Fajimolu et al. (2023), who observed that bigger organizations often had the resources and personnel to fully leverage AI capabilities, hence augmenting their competitive advantage.

Capital Investment, although beneficial, is only slightly significant (p-value = 0.095), suggesting that while investment in AI and technological infrastructure enhances competitiveness, other elements like managerial acumen and market circumstances may exert a more substantial influence. According to Joseph and Falana (2021), the effective integration of AI necessitates not only financial investment but also strategic planning and personnel adjustment to effectively harness its potential.

Table 4: Challenges of AI Adoption in the Manufacturing Industry

Challenge	**Frequency**	**Percentage (%)**
High Cost of Implementation	85	28.23
Lack of Technical Expertise	78	25.91
Resistance to Change	65	21.59
Data Privacy and Security Concerns	50	16.61
Inadequate Infrastructure	21	6.97

Table 4 delineates the principal challenges related to AI adoption within the Nigerian industrial sector. The predominant problem identified is the High Cost of Implementation (28.23%), indicating the financial strain encountered by most organizations when incorporating AI technology into their operations. This corroborates the third hypothesis (H3), which asserts that substantial hurdles, encompassing financial and technological obstacles, impede AI adoption. Akinola (2023) asserts that the expenses associated with acquiring and sustaining AI systems, together with the necessity for ongoing enhancements, present a significant challenge for small and medium-sized organizations (SMEs) specifically.

The deficiency of technical expertise constitutes the second most critical barrier (25.91%), indicating that a scarcity of proficient individuals capable of managing AI systems is a substantial limitation. This aligns with Akinsolu's (2022) results, which indicate that several Nigerian organizations encounter difficulties in recruiting and retaining personnel proficient in new technologies, hence hindering the efficient adoption of AI.

Resistance to Change (21.59%) is a significant barrier, as both personnel and management may be reluctant to adopt AI-driven modifications, apprehensive about job displacement or the intricacies of incorporating new technologies into established processes. Al-Aali et al. (2020) emphasized analogous findings, emphasizing that change management is a pivotal element in the effective implementation of AI technology.

Finally, Data Privacy and Security Concerns (16.61%) and Inadequate Infrastructure (6.97%) are identified as difficulties. These difficulties illustrate the overarching hurdles in developing nations such as Nigeria, where technical infrastructure may lack the robustness necessary for extensive AI adoption, and apprehensions over data security may impede enterprises' readiness to fully use AI solutions. Eze et al. (2021) assert that overcoming these challenges is essential for the continued expansion of AI in Nigeria's manufacturing sector.

DISCUSSION OF FINDINGS

The objective one of the study was to examine the impact of AI adoption on the efficiency and effectiveness of business process automation. The regression study findings demonstrate that AI adoption markedly enhances operational efficiency in manufacturing companies. Table 4.2 illustrates that the positive coefficient of AI adoption for operational efficiency ($\beta = 0.45$, $p < 0.01$) highlights AI's capacity to optimize workflows, automate redundant jobs, and minimize human mistakes, hence improving productivity.

The second objective is to evaluate the influence of AI-driven business process automation on the competitiveness of manufacturing firms, encompassing factors such as market share, productivity, and

innovation. Table 4.3 illustrates a substantial positive correlation between AI use and competitiveness ($\beta = 0.37$, $p < 0.05$). This suggests that AI technologies enhance corporate competitiveness by promoting innovation, decreasing manufacturing expenses, and facilitating quicker reactions to market fluctuations.

The third purpose was to discern critical barriers and opportunities related to AI adoption. The cited issues include elevated expenses, insufficient qualified workers, and technological complexity. Although AI adoption has significant promise, infrastructural and financial challenges must be overcome to effectively harness these advantages, especially in a developing economy such as Nigeria. The prospects outlined in Table 4.4 encompass augmented productivity and improved product quality.

This study provides fresh insights into the specific manifestations of these difficulties within the Nigerian manufacturing sector. In contrast to research undertaken in more developed nations, where infrastructure is less of a hindrance, this study demonstrates that infrastructural deficiencies in Nigeria significantly impede the adoption of AI technology.

The findings of this study clearly demonstrate the beneficial effects of AI on business process automation and competitiveness, although they also prompt other inquiries for future research. Initially, further study is required to investigate how smaller manufacturing enterprises with constrained financial resources might surmount the obstacles to AI implementation. This study concentrated mostly on medium to large enterprises; nevertheless, smaller organizations may have distinct experiences and confront unique hurdles in the adoption of AI technology.

Secondly, although this study analyzes the immediate consequences of AI adoption on operational efficiency and competitiveness, subsequent research might explore the long-term implications. Longitudinal studies monitoring AI adoption over several years may yield profound insights into the effects of continuous AI integration on organizational performance, innovation potential, and workforce dynamics over time. This may also indicate if the early investments in AI provide long-term competitive gains.

Finally, subsequent research might explore the social ramifications of AI adoption, namely its effects on employment and worker dynamics in Nigeria. This study briefly addressed workforce resistance as a hurdle; however, a comprehensive analysis of AI's influence on job responsibilities, skills development, and employee well-being will yield a more complete understanding of the socio-economic ramifications of AI adoption.

CONCLUSION

The research has delivered an extensive examination of the impact of AI adoption on business process automation and competitiveness in the Nigerian manufacturing industry. The results highlight the revolutionary capacity of AI technology in improving operational efficiency and competitive advantage for companies. The findings substantiate the integration of AI as an essential instrument for process automation, cost reduction, and innovation enhancement, consistent with the study's aims. AI may substantially enhance production by automating repetitive processes, as evidenced by favorable regression outcomes on operational efficiency. Moreover, the use of AI enhances competitiveness, enabling enterprises to innovate more rapidly and secure greater market shares.

Notwithstanding these advantages, the report underscores problems like elevated prices, technological intricacies, and talent deficiencies that impede the comprehensive use of AI in Nigerian industrial enterprises. These problems, however, are not insuperable. Through strategic interventions such as policy support and personnel training, the Nigerian manufacturing industry can fully harness AI's potential to enhance both national and international competitiveness. The recognition of infrastructural deficiencies and data privacy issues illustrates the distinct circumstances of poor nations like as Nigeria, where these challenges provide considerable obstacles to widespread AI implementation.

The results also prompt inquiries on the long-term effects of AI on corporate performance, worker dynamics, and socio-economic consequences. These domains require more investigation, especially concerning how smaller enterprises might surmount obstacles and the long-term effects of sustained AI integration on

organizational performance. Furthermore, the societal ramifications of AI implementation, particularly its impact on employment and work functions, warrant further examination. The findings holds practical significance for politicians, corporate leaders, and researchers seeking to maximize AI's potential in Nigeria and beyond.

ACKNOWLEDGEMENT

Special thanks to Dangote Cement Plc and Nigerian Breweries Plc. for providing me with the data for this study.

Conflict of interest

There was no conflict of interest as the data was collected from the staff of the sampled manufacturing companies (Dangote Cement Plc and Nigerian Breweries Plc.) hence no financial and time commitment was experienced as this was done during the weekend.

Ethical Approval

The study adhered to ethical guidelines, ensuring that participation was voluntary, and respondents' confidentiality was maintained. All participants were informed of the study's purpose and assured that their responses would only be used for academic purposes. No personal identifiers were collected to ensure anonymity.

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