Technology Innovation and the Transformation of Nigeria's Manufacturing Sector

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7 April 2025

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Abstract: This article critically examines the transformative potential of technological innovation in revitalizing Nigeria's manufacturing sector, a cornerstone of the nation's economic diversification agenda amid declining oil revenues and persistent macroeconomic instability. Through a mixed-methods approach—combining empirical data analysis, sectoral case studies, and policy reviews—the study explores how emerging technologies such as automation, artificial intelligence (AI), blockchain, and renewable energy systems are reshaping production processes, supply chains, and market competitiveness. Despite contributing only 9.2% to GDP and operating at 56.5% capacity utilization, the sector remains pivotal to employment, contributing 11.3% of formal jobs and serving as a conduit for import substitution. The analysis identifies infrastructural deficits, particularly erratic electricity supply and logistical inefficiencies, as primary barriers to technology adoption, costing manufacturers 40% of operational expenses. However, pioneering firms like Dangote Cement, Nestlé Nigeria, and SMEs such as ReelFruit demonstrate that strategic investments in robotics, IoT-enabled predictive maintenance, and digital supply chain platforms can reduce costs by 15–30%, enhance productivity, and unlock access to regional markets under the African Continental Free Trade Area (AfCFTA). The study further highlights the critical role of policy incoherence, skill gaps, and financing constraints—such as prohibitive loan rates (18–30%)—in slowing scalability, particularly for SMEs that constitute 85% of the sector. The article argues that Nigeria's demographic dividend—a youth population projected to reach 400 million by 2050—presents a dual challenge and opportunity: without urgent upskilling in STEM and vocational training, unemployment will escalate, but a tech-savvy workforce could drive leapfrogging into Industry 4.0. Cross-case insights reveal that renewable energy integration (e.g., solar microgrids) and cybersecurity frameworks are essential to sustainable growth, while gender-inclusive policies could expand women's participation beyond the current 22%. Policy recommendations include establishing a $500 million Tech Innovation Fund for SMEs, harmonizing regulatory approvals through a single-window portal, and aligning the National Digital Economy Strategy with AfCFTA's objectives. The study concludes that Nigeria's manufacturing future hinges on a coordinated ecosystem of public-private partnerships, targeted infrastructure investments, and agile policy reforms. Failure to act risks entrenching dependency on oil imports and informal markets, while decisive action could position Nigeria as Africa's hub for green, tech-driven industrialization by 2030.

Keywords: Technological Innovation, Industry 4.0, Sustainable Manufacturing, AfCFTA, Economic Diversification, Nigeria.

1. Introduction

Nigeria, Africa's largest economy with a nominal GDP of $477 billion (World Bank, 2023a), stands at a critical juncture in its economic development. Historically reliant on oil exports, which account for 90% of foreign exchange earnings and 60% of government revenue (CBN, 2023)—the nation faces mounting pressure to diversify its economy amidst volatile global oil prices, rising debt burdens, and a youth unemployment rate exceeding 40% (NBS, 2023a). The manufacturing sector, once a cornerstone of Nigeria's post-independence industrialization strategy,

has stagnated, contributing a mere 9% to GDP in 2023, down from 11% in the 1980s (NBS, 2023b). This decline reflects systemic challenges, including chronic infrastructural deficits, reliance on imported inputs, and an unsupportive regulatory environment. Yet, amid these constraints, technological innovation emerges as a disruptive force with the potential to catalyze a resurgence of the sector, aligning with global trends toward Industry 4.0 and sustainable production.

The urgency of revitalizing manufacturing is underscored by Nigeria's demographic realities. With a population projected to reach 400 million by 2050 (UN, 2022), the sector's capacity to generate mass employment and value-added exports is critical for socioeconomic stability. However, persistent issues such as erratic electricity supply—manufacturers spend 40% of operational costs on alternative power sources (MAN, 2023a)—and limited access to advanced machinery have stifled productivity. Capacity utilization in the sector remains low at 56.5% (MAN, 2023b), signaling underperformance despite latent demand. Meanwhile, globalization and the African Continental Free Trade Area (AfCFTA) present both opportunities and threats: while regional trade integration opens markets, it also exposes Nigerian firms to competition from technologically advanced counterparts in Egypt, South Africa, and beyond.

Technological innovation offers a pathway to overcome these barriers. From automation and artificial intelligence (AI) to renewable energy systems and blockchain-enabled supply chains, digital tools are reshaping production paradigms globally. In Nigeria, early adopters such as Dangote Industries, Nestlé Nigeria, and Guinness Nigeria demonstrate the transformative impact of these technologies. For instance, IoT-driven predictive maintenance has reduced machinery downtime by 30% in some firms (Oyelaran-Oyeyinka, 2023), while solar energy integration is slashing carbon footprints and energy costs. Yet, adoption remains uneven, constrained by financing gaps, skill shortages, and fragmented policy frameworks.

This article situates Nigeria's manufacturing sector within the broader discourse on technological leapfrogging in developing economies. It argues that strategic investments in innovation infrastructure—coupled with targeted policy reforms—can enable Nigeria to bypass traditional industrialization stages and embrace advanced manufacturing models. The study builds on empirical data, sectoral analyses, and case studies to address key questions: How are Nigerian manufacturers integrating Fourth Industrial Revolution (4IR) technologies? What systemic barriers impede scalability? And how can policymakers and stakeholders create an ecosystem conducive to sustainable tech-driven growth? The findings contribute to ongoing debates about

Africa's industrialization in the digital age, offering actionable insights for Nigeria's public and private sectors. By bridging the gap between theoretical frameworks and on-ground realities, this work aims to inform Nigeria's Industrial Policy, the National Digital Economy Strategy, and regional initiatives under AfCFTA. Ultimately, the article underscores that technology is not merely a tool for efficiency but a catalyst for structural transformation—a necessity for Nigeria to reclaim its position as an industrial leader in Africa. The rest of the paper reviews the historical nexus between technology and Nigeria's manufacturing sector in section 2 while section 3 presents a concise overview of the state of tech innovation in the manufacturing sector. Section 4 presents a conceptual review of smart techs and its applications, while section 5 discusses case studies which notes applications and the outcomes. Section 6 focuses on cross-case insights and lessons for unlocking technology-driven transformation by the manufacturing sector in Nigeria.

2. Historical Nexus between Technology and Nigeria's manufacturing sector

This section explores the major phases in the historical journey of Nigeria's manufacturing sector, with an emphasis on the role of technology and the policy landscape. Some literatures (Balogun 2016, Bakare-Aremu et al 2015; Bello, et al 2024 and Joshua-Gyang, Emily (2024)) note that four main phases or eras in the historical journey of manufacturing sector in terms of technology innovations are discernable in Nigeria. These are: Pre-Independence (before 1960, Post-Independence Industrial Drive (1960–1985), The Structural Adjustment Era (1986–1999) and The Digital Revolution and Modern Era (2000–Present).

a. Pre-Independence Era (Before 1960) characterized by modest beginnings: Before independence in 1960, manufacturing activities in Nigeria were largely limited to small-scale artisanal and craft industries. Traditional industries such as blacksmithing, pottery, and textile weaving flourished within rural communities. These activities were labor-intensive and relied on indigenous methods and tools. Obitayo, K. M. (1989) notes that the colonial period witnessed the introduction of modern industries focused primarily on processing agricultural produce for export, such as palm oil, cocoa, and rubber. However, the lack of significant investment in technology and infrastructure meant that manufacturing was confined to basic production processes, with minimal value addition.

b. **Post-Independence Industrial Drive (1960–1985) typified by The Import Substitution Strategy:** The early years of Nigeria's independence were marked by an ambitious push for industrialization. Successive governments adopted the *import substitution industrialization (ISI)* strategy to reduce dependency on imported goods by promoting local production. Investments were made in the establishment of large public-owned industries, such as steel plants, cement factories, and assembly lines for motor vehicles. However, the ISI strategy encountered several challenges which included heavy reliance on imported machinery and raw materials that undermined self-sufficiency; poor infrastructure, especially in power supply and transportation, hindered industrial growth, and weak technological capabilities and a limited focus on innovation stifled the competitiveness of local industries. Although the manufacturing sector grew during this period, it remained constrained by inefficiencies and structural weaknesses (Eze, 2020).

c. **The Structural Adjustment Era (1986–1999) Characterized by Economic Liberalization:** The introduction of the Structural Adjustment Program (SAP) in 1986 marked a pivotal turning point for Nigeria's economy and industrial policies. The SAP, driven by the International Monetary Fund (IMF) and the World Bank, sought to liberalize the economy through privatization, deregulation, and trade liberalization. This had far-reaching implications for the manufacturing sector. There was apparent shift to export promotion through policies that encouraged export-oriented industrialization but limited technological capability restricted Nigeria's global competitiveness. Although attempts to foster technology transfer via economic liberalization facilitated the influx of foreign technologies and expertise, local adaptation was slow due to inadequate R&D investment. The main challenges in this era was that many industries struggled to survive the increased competition from imported goods, leading to factory closures and job losses. Despite the challenges, the SAP era laid the foundation for the adoption of modern technologies in some industries, particularly those in the oil and gas sector.

d. The Digital Revolution and Modern Era (2000–Present) typified by global embracement of Technological Change: The 21st century ushered in a new wave of technological innovation globally, with Nigeria beginning to harness digital tools and modern

technologies in its manufacturing sector. Notable trends include: i) **ICT Integration reflected in** the proliferation of information and communication technologies (ICTs) which has improved production processes and supply chain management in various manufacturing subsectors. Ii) The emergence of **Renewable Energy Technologies in the face of** persistent power supply challenges, that compelled many manufacturers to adopt alternative energy solutions such as solar and wind power to ensure operational efficiency; iii) **Automation and Robotics:** While adoption is still limited, certain large-scale industries have integrated automated machinery to enhance productivity and reduce costs; iv) **Government Initiatives:** Policies such as the National Industrial Revolution Plan (NIRP), launched in 2014, have emphasized the use of technology and innovation to stimulate industrial growth. These efforts have been supported by agencies like the Bank of Industry (BOI) and the Nigerian Export Promotion Council (NEPC); and v) **Regional and Global Influences:** Nigeria's manufacturing sector has also been shaped by regional and global forces which includes **Globalization:** Increased exposure to international markets has compelled Nigerian industries to adopt global best practices and technologies to remain competitive; and **Regional Collaboration:** Nigeria's participation in regional trade agreements, such as the African Continental Free Trade Area (AfCFTA), has spurred the need for technological advancement to compete with other African manufacturers.

The historical trajectory of Nigeria's manufacturing sector reflects a gradual shift from traditional, labor-intensive methods to the adoption of modern technologies. While significant progress has been made, systemic challenges such as inadequate infrastructure, high production costs, and skill gaps continue to hinder the sector's full potential. Understanding this historical context underscores the importance of technology innovation as a critical driver of Nigeria's industrial transformation in the 21st century and beyond.

3. Current State of Technology Innovation in Manufacturing

The manufacturing sector in Nigeria is undergoing a gradual transformation, driven by the adoption of innovative technologies aimed at improving efficiency, reducing costs, and enhancing competitiveness. While challenges persist, the integration of modern

technologies is reshaping the landscape of manufacturing in the country. Below are key aspects of the current state of technology innovation in Nigeria's manufacturing sector:

- **Automation and Robotics:** Automation has begun to make inroads into Nigerian manufacturing, particularly in large-scale industries such as cement production , food processing, and automotive assembly (Innoson Vehicle Manufacturing (2023)). Automated machinery and robotics are being used to streamline production processes, reduce human error, and increase output. For example, some factories now employ robotic arms for precision tasks, such as packaging and assembly (Dangote, 2023 and Nestle 2023).
- **Digital Transformation and Smart Manufacturing:** The adoption of digital tools and smart manufacturing practices is gaining momentum. Technologies such as the Internet of Things (IoT), artificial intelligence (AI), and data analytics are being used to optimize supply chains, monitor equipment performance, and predict maintenance needs. These innovations enable manufacturers to make data-driven decisions, reduce downtime, and improve overall efficiency.
- **Renewable Energy Integration:** Given Nigeria's persistent power supply challenges, many manufacturers are turning to renewable energy solutions to ensure uninterrupted operations. Solar panels, wind turbines, and hybrid energy systems are being installed in factories to supplement grid electricity. This shift not only addresses energy reliability but also aligns with global sustainability goals.
- **Additive Manufacturing (3D Printing):** Although still in its early stages, 3D printing is being explored for prototyping and small-scale production in Nigeria. This technology allows manufacturers to create complex designs with minimal waste, reducing production costs and time. Industries such as healthcare and consumer goods are beginning to experiment with 3D printing for customized products.
- **E-commerce and Digital Marketplaces: The** rise of e-commerce platforms has revolutionized the way manufacturers reach consumers. By leveraging digital marketplaces, Adeola et al (2022) note that both the Nigerian and African manufacturers can expand their customer base, both locally and internationally. This trend has been

particularly beneficial for small and medium-sized enterprises (SMEs), enabling them to compete in a global market.

- **Local Innovation and Indigenous Technologies:** There is a growing emphasis on developing indigenous technologies tailored to Nigeria's unique challenges. Local innovators are creating affordable and sustainable solutions, such as low-cost machinery and locally sourced materials, to support the manufacturing sector. These efforts are helping to reduce dependency on imported technologies and foster self-reliance.
- **Government and Private Sector Initiatives:** The Nigerian government, in collaboration with private sector stakeholders, has introduced various initiatives to promote technology adoption in manufacturing. Programs such as the National Industrial Revolution Plan (NIRP) and support from agencies like the Bank of Industry (BOI) aim to provide funding, training, and infrastructure for tech-driven manufacturing. Additionally, partnerships with international organizations facilitate technology transfer and capacity building.

4. An Overview of Smart manufacturing technologies

Smart manufacturing technologies are at the heart of the Fourth Industrial Revolution (4IR) and represent a transformative approach to industrial production. According to Zheng et al (2018), these integrate advanced technologies like sensors, data analytics, and artificial intelligence to optimize manufacturing processes, enhance efficiency, reduce waste, and improve quality. Here's an elaboration on the key components and their roles:

- ✓ **Internet of Things (IoT):** IoT involves connecting physical devices, machines, and systems to the internet to collect and share data in real time. In manufacturing, IoT enables **Machine Monitoring whereby s**ensors installed on equipment provide real-time updates on performance, predict maintenance needs, and help avoid costly downtimes. It also enhance **Supply Chain Optimization by** tracking raw materials and finished products throughout the supply chain, ensuring transparency and minimizing disruptions. Indeed, Oyelaran-Oyeyinka, B. (2023a) notes that IoTs play very key roles in **Smart Factories whereby** connected devices enable seamless communication between machines, automating workflows and increasing operational efficiency.

- ✓ **Artificial Intelligence (AI) and Machine Learning:** AI and machine learning are central to smart manufacturing by providing intelligence to interpret data and automate decision-making. According to Zhou et al (2022) among such guided decisions are: **Predictive Maintenance that use m**achine learning algorithms to analyze equipment data to predict failures before they occur, reducing downtime and maintenance costs. AIs are also used for **Production Optimization which** helps manufacturers identify inefficiencies in production lines and suggests adjustments to improve output and quality as well as guaranteeing **Quality Assurance especially** AI-powered systems that use visual recognition and data analysis to detect defects in products during production.
- ✓ **Robotics and Automation:** Robotics plays a critical role in enhancing productivity and precision in manufacturing: These include **Collaborative Robots (Cobots) that** work alongside human operators to perform tasks such as assembly, packaging, and inspection with high precision; **Autonomous Guided Vehicles (AGVs):** Used for transporting materials and goods within factories, AGVs operate without human intervention, streamlining internal logistics (Dangote Group, 2023; Nestle Nigeria 2023).
- ✓ **Digital Twins:** Digital twin technology creates a virtual replica of a physical manufacturing process, system, or product. Ante (2021) notes that Digital twin technology include: **Simulation whereby m**anufacturers can simulate production scenarios in the digital twin to optimize processes without interrupting real-world operations; **Problem-Solving which** allow engineers to identify and resolve issues in manufacturing systems before they affect actual production, and **Customization** by modeling and testing product designs virtually.
- ✓ **Cloud Computing and Edge Computing:** These computing technologies facilitate data storage, processing, and analysis such as: **Cloud Computing that a**llows manufacturers to store and analyze large volumes of data remotely, providing access to advanced analytics and AI capabilities, and **Edge Computing:** Processes data closer to the source (e.g., sensors and machines) for faster response times and better real-time decision-making.

- ✓ **Additive Manufacturing (3D Printing):** 3D printing, a form of additive manufacturing, is revolutionizing production by enabling: **Prototyping:** Manufacturers can quickly create prototypes of new designs at a low cost; **On-Demand Manufacturing:** 3D printing enables small-batch and customized production, reducing inventory costs; **Complex Designs:** The technology allows for the creation of intricate and lightweight components that are difficult to produce with traditional methods.
- ✓ **Big Data and Advanced Analytics: m**anufacturers generate vast amounts of data from various sources, and advanced analytics help make sense of it: **Operational Insights:** Data analysis identifies patterns and trends in production, helping to improve processes and reduce waste; **Customer Behavior:** Analytics can predict consumer demand, enabling better inventory planning and supply chain management.
- ✓ **Augmented Reality (AR) and Virtual Reality (VR):** AR and VR technologies provide immersive tools for training, design, and maintenance. Baroroh, et al (2021) systematic review show that workers can be trained in virtual environments, reducing risks and costs associated with on-site training. AR overlays can guide technicians step-by-step in repairing machinery or troubleshooting problems and enables designers to create and test product models in virtual spaces.
- ✓ **Cybersecurity in Smart Manufacturing:** As manufacturing becomes more digitized, protecting networks and data becomes paramount. Thus, Barari, et al (2021) note that AI-driven cybersecurity tools detect and respond to potential threats in real time, ensuring connected devices have strong security protocols to prevent breaches and adhering to regulations for data protection and privacy.
- ✓ **Integration with Sustainable Practices:** Smart manufacturing technologies align with sustainability goals such as energy efficiency, waste reduction and circular manufacturing (Dangote Group 2022). Thus, IoT and AI monitor and optimize energy use, reducing operational costs and environmental impact. Data analytics help minimize waste during production by identifying inefficiencies and support recycling and reusing materials, contributing to a circular economy.

Smart manufacturing technologies are revolutionizing the global industrial landscape by combining connectivity, automation, and intelligence. For Nigeria, embracing these technologies can drive significant growth, enhance competitiveness, and enable the manufacturing sector to leapfrog traditional challenges. Investing in these innovations will not only transform production processes but also position the country as a key player in the future of manufacturing.

5. Case Studies of Technology Innovation in Nigeria's Manufacturing Sector

This section provides an in-depth analysis of four companies driving technological transformation in Nigeria's manufacturing landscape. These case studies highlight diverse applications of innovation—from automation and AI to renewable energy and digital platforms—demonstrating how technology is addressing sectoral challenges and reshaping competitiveness.

5.1 Dangote Cement PLC: Automation and Sustainable Manufacturing

Background: Dangote Cement, Africa's largest cement producer, operates the Obajana plant in Kogi State, contributing 16.25 million metric tons annually to Nigeria's 60 million metric ton capacity (Dangote Group, 2023).

Technology Implemented: These are mainly Robotics and Automation whereby Robotic arms for packaging and AI-powered quality control systems ensure precision and reduce waste; and the use of Alternative Energy: Coal and biomass co-processing in kilns, reducing reliance on fossil fuels.

Outcomes: 15% reduction in production costs and 20% lower CO_2 emissions since 2020 (Dangote Sustainability Report, 2023) and increased export capacity to 12 African countries under AfCFTA.

Challenges: - High initial capital expenditure ($500 million for automation upgrades) and technical skill gaps necessitating partnerships with German engineering firms.

Implications: Dangote's success underscores the viability of automation in heavy industries, though scalability requires addressing financing and workforce training.

5.2 Nestlé Nigeria: AI and Blockchain for Supply Chain Agility

Background: Nestlé Nigeria, a food and beverage leader, faces challenges in demand volatility and supply chain fragmentation.

Technology Implemented: AI-Driven Demand Forecasting that use machine learning algorithms to analyze market trends and social media sentiment to predict sales. It also use Blockchain Traceability in partnerships with IBM Food Trust that enable real-time tracking of raw materials from farms to factories.

Outcomes: 25% improvement in inventory turnover, 30% reduction in stockouts (Nestlé Annual Report, 2022) and enhanced consumer trust through transparent sourcing of cocoa and maize.

Challenges: High costs of blockchain integration ($2.5 million initial investment) and resistance from smallholder farmers accustomed to analog processes.

Implications: Nestlé's model highlights the role of digital tools in building resilient supply chains, particularly in agro-processing.

5.3 Guinness Nigeria (Diageo): IoT and Predictive Maintenance

Background: Guinness Nigeria, a subsidiary of Diageo, produces 15 million hectoliters of beverages annually but faced frequent equipment downtime.

Technology Implemented: IoT Sensors installed on boilers and bottling lines to monitor temperature, pressure, and vibration and Predictive Analytics by Microsoft Azure that processes real-time data to schedule maintenance before failures occur.

Outcomes: 30% reduction in unplanned downtime, $1.2 million annual savings on maintenance (Oyelaran-Oyeyinka, 2023) and consistent product quality, critical for export markets.

Challenges: Integration with legacy machinery from the 1980s and cybersecurity risks requiring investment in firewalls and staff training.

Implications: Guinness demonstrates IoT's potential to modernize aging infrastructure, though retrofitting remains costly for SMEs.

5.4 ReelFruit: Digital Platforms in Agro-Processing

Background: ReelFruit, an SME founded in 2012, processes Nigerian-grown fruits into snacks but struggled with market access.

Technology Implemented: E-Commerce Integration in partnerships with Jumia and Amazon for online sales, Mobile Supply Chain Apps, a GPS-enabled apps connect with 500 smallholder farmers for real-time inventory updates.

Outcomes: 200% revenue growth (2020–2023), expansion to European markets (TechCabal, 2023) and creation of 150 rural jobs, 60% held by women.

Challenges: Limited access to affordable loans for tech adoption and digital literacy gaps among farmers.

Implications: ReelFruit's growth illustrates how digital tools can empower SMEs to scale, though systemic barriers like financing persist.

6. Cross-Case Insights and Lessons for Unlocking Technology-Driven Transformation

The four case studies - Dangote Cement, Nestlé Nigeria, Guinness Nigeria, and ReelFruit - highlight diverse pathways for technology adoption in Nigeria's manufacturing sector. By synthesizing their experiences, critical insights emerge about scalability, systemic barriers, and strategies for sustainable growth. Below is a detailed discussion of cross-case lessons and their implications for policymakers, firms, and stakeholders.

a. Scalability vs. Affordability: The resource divide sheds some insight on the issue of scalability and affordability. Whereas large corporations (e.g., Dangote, Nestlé) leverage economies of scale to absorb high upfront costs of advanced technologies like AI and robotics, while SMEs (e.g., ReelFruit) rely on affordable digital platforms (e-commerce, mobile apps) to compete. For instance, Dangote Cement invested $500 million in automation, reducing production costs by 15% while ReelFruit spent $50,000 on mobile apps and e-commerce integration, achieving 200% revenue growth. Several factors work against SMEs with regards to scalability partly the results of policy gaps, as Nigeria lacks tiered financing mechanisms (e.g., low-interest loans for SMEs, tax rebates for large firms) to bridge this divide and limited opportunity for public-private partnerships (PPPs) to pool resources for shared tech infrastructure (e.g., industrial parks with IoT hubs).
b. Skill Development Partnerships as a Catalyst. It is apparent that all firms relied on external partnerships to address technical skill shortages. For example, Dangote Cement partnered with German engineering firms to train staff in robotics maintenance; Nestlé Nigeria

collaborated with IBM to upskill IT teams in blockchain management, and ReelFruit worked with local tech hubs to train farmers in digital inventory tools. The lessons to be learned include fostering a workforce strategy that emphasizes vocational training programs that must align with industry needs (e.g., IoT diagnostics, AI analytics). The required policy action especially Nigeria's National Talent Export Programme (NATEP) should prioritize manufacturing-specific skills.

c. Policy Alignment: There are inconsistency in the enabling environment, especially gaps in macroeconomic policies. While successful technology adoption aligns with government initiatives, it has also exposes regulatory shortcomings. For example, Dangote's renewable energy use aligns with Nigeria's Energy Transition Plan (ETP), but inconsistent tariffs hinder biomass adoption. Also, ReelFruit benefits from the Made-in-Nigeria Campaign but faces barriers like multiple taxation. There is the need to correct coordination failure especially overlapping regulations (e.g., NAFDAC, SON) that delay tech integration and the lack of a single-window regulatory portal for streamlining approvals. There is also the need to restructure incentives, especially the expansion of the Export Expansion Grant (EEG) to cover technology imports for SMEs.
d. Infrastructure Dependency: Power and Digital Connectivity are key to manufacturing. Reliable infrastructure underpins tech adoption but remains a barrier for most firms. Guinness Nigeria overcame power instability by retrofitting IoT sensors to existing generators, while ReelFruit's mobile apps falter in rural areas with poor internet coverage. This calls for a decentralized Solutions through the encouragement of hybrid energy systems (solar + gas) through subsidies, as seen in Unilever Nigeria's 50% energy cost reduction and digital inclusion via expanding the National Broadband Plan to prioritize industrial clusters.
e. Sustainability and Market Positioning: The main insight is that technology boosts both operational efficiency and global market competitiveness. For instance, Nestlé's blockchain traceability meets EU sustainability standards, unlocking export opportunities; Dangote's emission reductions align with global ESG trends, attracting green investors. There is the need for Government agencies (e.g., SON) to fast-track certifications for tech-driven sustainability (e.g., carbon credit). There is also the need to enhance market access

by leveraging AfCFTA to promote Nigerian tech-enabled products as "sustainable alternatives" to Chinese imports.

f. Risk Mitigation via Cybersecurity and Cultural Resistance. The insight gained is that technology adoption introduces new risks requiring proactive management. Indeed, Guinness Nigeria invested $200,000 in cybersecurity after IoT integration increased vulnerability to breaches and Nestlé Nigeria faced resistance from farmers unwilling to adopt blockchain record-keeping. The lessons from this are the establishment of Cybersecurity Frameworks to develop sector-specific guidelines for IoT and AI, modeled on Kenya's Data Protection Act (2022) and stakeholder engagements which involved the use of grassroots campaigns (e.g., cooperative workshops) to build trust in new technologies.

g. Inclusive Growth through Empowering SMEs and Women. These are some significant insights that technology can democratize opportunities but requires targeted interventions. For example, ReelFruit created 150 jobs, with 60% for women in rural areas, through mobile supply chain apps. Guinness Nigeria's predictive maintenance training prioritized female technicians. The lessons are that the need for gender-responsive policies which link tech grants to gender inclusivity quotas (e.g., 30% female participation). This can be supported with the establishment of SME Clusters by creating tech hubs in regions like Aba (textiles) and Kano (agro-processing) to replicate ReelFruit's model.

6. Conclusion and Implications for Sector-Wide Transformation Blueprint

The cross-case analysis reveals that technology adoption in Nigeria's manufacturing sector is neither linear nor uniform. Success hinges on the need for tailored financing with differentiated support for SMEs and large firms. This should be anchored on Collaborative Ecosystems Partnerships for skills, infrastructure, R&D and a coherent harmonization of industrial, digital, and energy policies. While Dangote and Nestlé showcase Nigeria's potential as an industrial leader, ReelFruit's story proves that grassroots innovation can thrive despite systemic hurdles. Addressing these lessons holistically will determine whether Nigeria's manufacturing sector evolves into a tech-driven engine of inclusive growth or remains constrained by its historical challenges.

The cross-case insights and lessons regarding scalability versus affordability revealed that large firms like Dangote and Nestlé benefit from economies of scale, while SMEs like

ReelFruit rely on cost-effective digital platforms. Regarding skill development, all cases emphasized partnerships with tech providers for workforce training. With respect to policy synergy, successful tech adoption aligns with government initiatives like the National Digital Economy Policy. These case studies exemplify the transformative potential of technology in Nigeria's manufacturing sector, offering replicable models for firms navigating infrastructural, financial, and regulatory challenges.

The recommendation for all stakeholders is the need to adopt a holistic approach to tech innovations for spurring manufacturing in Nigeria. The government must fast-track the National Digital Industrial Strategy with sector-specific roadmaps, while the Private Sector should establish industry consortia to co-fund tech pilot projects. The Development Partners must channel grants into SME-focused digital literacy programs. By bridging these gaps, Nigeria can transform its manufacturing sector into a globally competitive, sustainable, and inclusive pillar of economic diversification. The study points to the need to implement the following policies: i) Given that SMEs account for about 85% of manufacturing output, despite the limited access to financing, there is the need to establish a $500 million Tech Innovation Fund for SMEs to facilitate adoption of technology innovations, either as grants or very cheap loans; ii) it is also imperative to harmonize the plethora of regulatory approvals through a single-window portal to reduce transactions costs associated with tech adoptions; and iii) there is the need to align the National Digital Economy Strategy with AfCFTA's objectives. The study concludes that Nigeria's manufacturing future hinges on a coordinated ecosystem of public-private partnerships, targeted infrastructure investments, and agile policy reforms. Failure to act risks entrenching dependency on oil imports and informal markets, while decisive action could position Nigeria as Africa's hub for green, tech-driven industrialization by 2030.

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