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Stakeholder Perspectives on Enhancing Vaccine Manufacturing in Nigeria: A Quantitative Assessment of Influencing Factors

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Abstract

Nigeria has long experienced vaccine supply disruptions due to limited resources, inadequate infrastructure, and high dependence on imports—factors that have stalled the growth of local vaccine manufacturing. Achieving vaccine self-sufficiency and strengthening public health infrastructure require strategic investments, particularly in technology transfer. This study explores challenges and opportunities for enhancing vaccine production in Nigeria and provides recommendations for effective implementation. A descriptive cross-sectional survey was conducted using a structured questionnaire administered to 111 purposively selected stakeholders, representatives from academia, regulatory agencies, research institutions, development partners, and private industry. The questionnaire assessed six domains: regulatory environment, infrastructure, technical capacity, finance, human resources, and market dynamics. Data were analyzed using IBM SPSS version 25 with descriptive statistics and Spearman rank correlation. Out of the 111 participants, 57 responded to the question on key interventions to promote vaccine manufacturing. Among them, 68% identified technology-sharing with international manufacturers, government subsidies and tax incentives, and workforce development as top strategies. (Spearman's rank) Strong positive correlations were found between local vaccine production capacity and regulatory support ($\rho = 0.811$, $p < 0.01$), infrastructure ($\rho = 0.823$, $p < 0.01$), access to finance ($\rho = 0.844$, $p < 0.01$), and market sustainability ($\rho = 0.839$, $p < 0.01$). Technical capacity ($\rho = 0.693$) and human resources ($\rho = 0.637$) showed moderate correlations. These findings highlight the multifaceted nature of barriers and enablers. Collaborative efforts among government, private sector, and international partners are essential to build sustainable, equitable vaccine manufacturing in Nigeria.

Keywords: *Local Vaccine Manufacturing Challenges, Pharmaceutical Investment in Nigeria, Technology Transfer, Vaccine Production in Nigeria.*

Introduction

Nigeria has historically been vulnerable to vaccine supply chain disruptions due to limited resources, inadequate infrastructure, and a heavy reliance on vaccine imports—factors that have significantly constrained its capacity for local vaccine manufacturing. [1, 2] One of the most promising strategies to enhance local production is technology transfer, which involves the sharing of technical know-how, manufacturing processes, and confidential data to enable domestic production capabilities. [3] This article critically examines the role of international partnerships and explores how technology transfer can be structured to address vaccine manufacturing barriers in a sustainable

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manner. It also identifies the operational and policy frameworks necessary to support a robust local vaccine manufacturing sector in Nigeria. A notable development is the partnership between the African Pharmaceutical Technology Foundation (APTF) and Nigeria to establish vaccine production facilities that comply with Good Manufacturing Practices (GMP). This collaboration aims to elevate the quality and safety of locally produced vaccines, aligning them with World Health Organization (WHO) standards. [4] The APTF further emphasizes the importance of developing local capacity and specialized skills to sustain Nigeria's pharmaceutical and vaccine manufacturing sector. The establishment of an mRNA vaccine technology transfer hub in Cape Town, South Africa, provides a valuable model for Nigeria. Designed as a center of excellence and training, the hub seeks to strengthen vaccine self-sufficiency in low- and middle-income countries by expanding mRNA production capacity. [5] Such initiatives underscore the critical role of technology transfer in building resilient, locally driven vaccine manufacturing systems.

While global health organizations currently address vaccine access in Nigeria through donations, foreign procurement, and partnerships with multinational pharmaceutical companies, these measures offer only short-term solutions. [6] They do not provide a sustainable path toward vaccine independence. Among various options, technology transfer stands out as the most effective long-term strategy, as it equips local manufacturers with the tools, expertise, and regulatory guidance necessary for independent production. [7] However, implementing technology transfer in Nigeria comes with significant challenges, including the high cost of acquiring and maintaining advanced manufacturing equipment, a shortage of skilled personnel, weak regulatory frameworks, and insufficient infrastructure. [8, 9] Despite these obstacles, successful models from countries such as Brazil and India demonstrate that well-executed technology transfer programs—supported by foreign collaborations, license agreements, and workforce development—can result in strong local vaccine manufacturing capabilities. [10] These components can be visually represented through a schematic diagram or graphical description as seen in *(Figure 1) below*, depicting the key mechanisms of knowledge and technology transfer in the vaccine production process [11].

Figure 1. Visual illustration of key concepts, theoretical framework, relationships, and impact on local vaccine manufacturing capability in Nigeria

Collaborative partnerships with multinational pharmaceutical companies and academic institutions can play a pivotal role in facilitating the transfer of technology and knowledge. Licensing agreements allow Nigerian manufacturers to produce vaccines under the guidance and supervision of originating companies, ensuring adherence to international standards. The establishment of joint ventures between Nigerian and foreign vaccine producers provides an opportunity to leverage shared resources, technical expertise, and infrastructure [12]. Technology transfer also enables the development of manufacturing facilities in Nigeria that comply with WHO GMP. This is essential not only for meeting global quality standards but also for providing Nigerian scientists [13] and professionals with practical, hands-on experience in advanced manufacturing processes and quality control techniques. This result is the cultivation of a skilled workforce and the establishment of a sustainable local vaccine production ecosystem.

[14] Furthermore, collaborative technology transfer activities can contribute to the strengthening of Nigeria's regulatory frameworks by offering critical insights into international compliance standards. This enhances the country's ability to implement effective and credible vaccine manufacturing authorization processes [15].

This study is unique in that it presents a comprehensive assessment of Nigeria's vaccine manufacturing landscape through the lens of technology transfer, *(Figure 2)* offering practical and context-specific recommendations tailored to the country's distinct challenges and opportunities. See below for visual illustration of the Use of Tech transfer as an enabler for vaccine manufacturing in Nigeria.

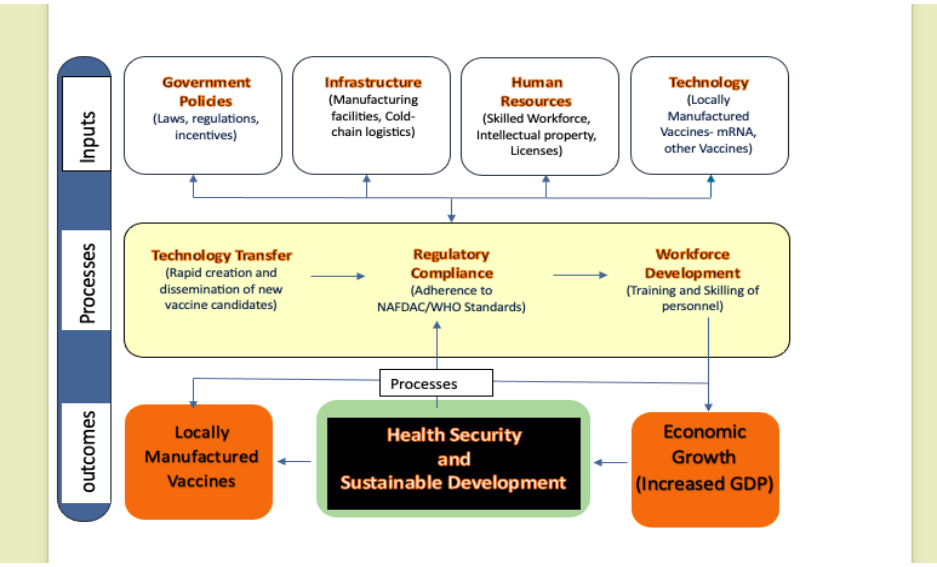

Figure 2. Visual illustration of the key concept of technology transfer and its likely outcomes for local vaccine manufacturing in Nigeria

Materials & Methods

Research Design

This study employed a cross-sectional mixed-methods design, integrating both quantitative and qualitative approaches to capture a comprehensive understanding of local vaccine manufacturing capacity in Nigeria. Data were collected through a structured questionnaire-based survey administered to 111 key stakeholders across the Nigerian health and pharmaceutical sectors. The questionnaire included a combination of closed-ended questions for statistical analysis and open-ended questions to capture detailed insights and stakeholder perspectives. The survey focused

on assessing perceptions of regarding existing vaccine production capabilities, identifying technological needs, and understanding the barriers and enablers to effective technology transfer in the Nigerian context.

Sampling Strategy

A **stratified random sampling** approach was used to ensure representative participation from key sectors involved in vaccine policy, production, and distribution in Nigeria. Participants were categorized into distinct strata based on institutional affiliation, allowing for balanced input across relevant domains. The distribution of respondents was as follows:

1. Government agencies (27 %)
2. Pharmaceutical companies (50.5 %)
3. Academic institutions (14.4 %)
4. NGOs and community pharmacists (8.1 %)

Sample Population

The target population comprised professionals from pharmaceutical and biotechnology sectors, public health institutions, research organizations, and government regulatory bodies in Nigeria. A purposive sampling technique was used to select key informants and respondents with relevant expertise in vaccine development, production, regulation, and distribution. The final sample included 111 participants, distributed as follows:

1. Approximately 80 % from public and private organization including government agencies and pharmaceutical companies
2. About 14 % from academic institutions
3. Around six % from healthcare-focused groups and non-governmental organizations (NGOs).

Data Collection Instruments

Data were collected using a structured questionnaire designed to gather both quantitative and qualitative data. The questionnaire comprised closed- and open-ended questions, addressing key domains such as infrastructure, workforce capacity, regulatory environment, and technology transfer. The survey was specifically targeted at senior-level stakeholders across relevant sectors to gain informed insights into policy-level and operational challenges. Questions were formulated to elicit responses based on participant's professional experience, enabling a deeper understanding of systemic gaps and opportunities for strengthening local vaccine manufacturing in Nigeria.

Data Sources

Primary Data: Primary data were collected using a structured questionnaire developed from themes identified through an extensive literature review. The questionnaire was validated and covered key areas including financial readiness, technological infrastructure, regulatory environment, and human capital. Key stakeholders, such as academics, pharmaceutical executives, and researchers from vaccine-producing institutions participated in the survey to provide firsthand insights into the challenges and opportunities in local vaccine manufacturing.

Secondary Data: Secondary data were obtained through review of peer-reviewed research articles, policy documents, and institutional reports from credible organizations, including the WHO, GAVI, the African Development Bank (AfDB), and Nigeria's National Agency for Food and Drug Administration and Control (NAFDAC). The study also reviewed technology transfer case studies from countries such as India, Brazil, and South Africa, focusing on success factors and lessons to the Nigerian context. Databases searched included *PubMed, Scopus, Google Scholar,* and the *WHO institutional archives.*

Data Analysis

Quantitative data were analyzed using **IBM SPSS (Version 25)**, Descriptive statistics such as frequencies and %ages including means and standard deviations, to summarize respondents' perspectives. For the qualitative data, thematic

analysis was employed to identify recurring patterns, themes, and insights related to vaccine manufacturing challenges and technology transfer needs. Data triangulation was utilized to enhance the validity of the findings by cross-verifying information from gathered from both primary and secondary data sources.

Validity and Reliability

To ensure content validity, the data collection instruments were reviewed by experts in vaccine development, public health and pharmaceutical manufacturing. A pilot study was conducted with 10 respondents outside the main study population to refine and validate the questionnaire. Based on feedback, necessary adjustments were made to improve clarity and relevance. The Cronbach's alpha coefficient for the final questionnaire was 0.945, indicating a high level of internal consistency and reliability.

Ethical Considerations

This study adhered strictly to ethical research standards throughout its design, data collection, and analysis. Informed consent was obtained from all participants prior to their inclusion in the survey. The structured questionnaire was developed to ensure confidentiality, voluntary participation, and protection of personally identifiable information.

Ethical approval was granted by the University of Ibadan (UI)/University College Hospital (UCH) Ethics Committee, with registration number NHREC/05/01/2008a. All collected data were anonymized and securely stored in compliance with relevant data protection and privacy guidelines. Expert interviews and the use of secondary data sources followed established ethical norms for academic research, with full transparency in the citation and interpretation of materials.

Limitations of the Study

The study acknowledges several limitations. First, the availability and scope of secondary data may have influenced the comprehensiveness of comparative analysis. Second, potential biases in expert opinions may have affected the objectivity of qualitative findings. Finally, the dynamic nature of Nigeria's vaccine manufacturing ecosystem, including evolving policy and investment landscapes, may impact the long-term relevance of some insights presented in this study.

Results

Socio-Demographic Characteristics of Respondents

The analysis revealed that majority of the respondents were within the 31-40 years age group, accounting for more than one-third 45(40.5%), followed by those aged 41-50 years, comprising one-third participants 36(32.4%). In terms of work experience, one-quarter 23(20.7%) of participants reported having one to five years of experience in their current organizations. Regarding institutional affiliation, more than half 56(50.5%) of the participants were employed in pharmaceutical companies. The distribution of respondents by professional roles as seen in *(Figure 3)* showed that the largest group were operations managers 27(24.3%), followed by quality assurance officers 21(18.9%), nurses 18(16.2%), and lecturers 16(14.4 %).

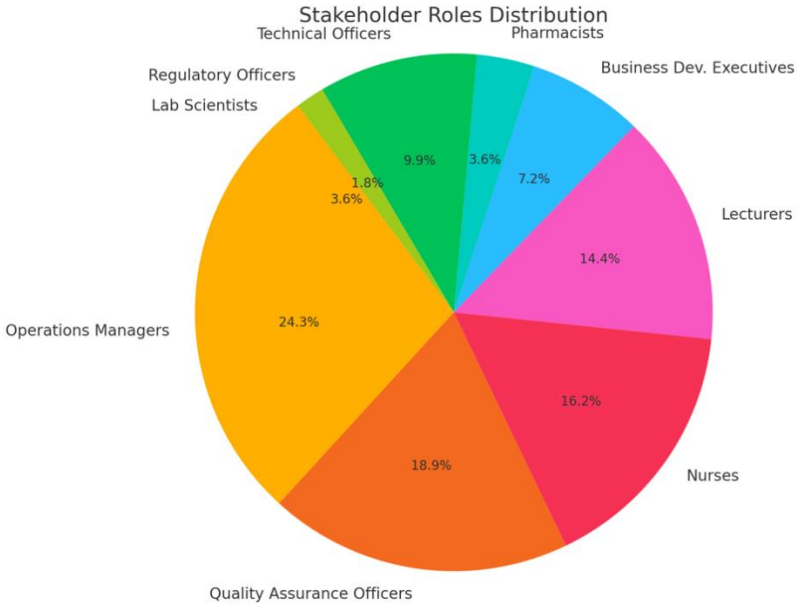

Figure 3. Role-wise distribution of study respondents

Table 1. Socio-demographic characteristics of respondents

Variables	**Frequency (N=111)**	**%age (%)**
Age		
20-30	6	5.4
31-40	45	40.5
41-50	36	32.4
51-60	24	21.6
Years of experience		
1-5	23	20.7
6-10	18	16.2
11-15	22	19.8
16-20	21	18.9
Organization/Institutions		
Academia	16	14.4
Government agency	30	27.0
Pharmaceutical company	56	50.5
Community pharmacist	1	0.9
NGO	8	7.2

The Distribution of Respondents Based on Years of Experience

Out of a total of 111 respondents who participated in this study, as shown in *(Table 1) above*, a cumulative total of 79(73%) were between the ages of 31 and 50 years. Approximately two-thirds (61%) of the participants had relevant professional experience, with an average of over 11 years in the field. This suggests that majority of respondents possessed substantial expertise, which lends credibility and depth to the data collected regarding knowledge and practice. As shown in Table 1, the largest proportion of

respondents, 26 (24.53%) reported having 20 or more years of work experience, followed closely by 23 (21.7 %) participants with one to five years of experience. Those with 6-20 years of experience were distributed relatively evenly across the remaining categories.

Identified Current Barriers affecting Vaccine Production in Nigeria

The barriers and challenges obstructing the development and establishment of vaccine production facilities in Nigeria were assessed in terms of financial constraints, technological limitations, Infrastructural inadequacies, regulatory challenge, limited demand forecasting and market establishment. Slightly more than half 57(51.4%) of the participants *(Table 2)* perceived that high initial investment requirements were the major barriers preventing the establishment of vaccine production facilities in Nigeria. About half 54(48.6%) of the participants perceived that inadequate infrastructure (e.g., cold storage, production plants), while 39 (35.1%) of the participants perceived that limited access to raw materials, 37(33.3%) challenges in meeting regulatory standards were also identified as barriers and challenges to establishing of vaccine production facilities in Nigeria.

Table 2. The Challenges preventing manufacturing of vaccines in Nigeria

Variables	Frequency	%age (%)
High initial investment requirements	57	51.4
Lack of skilled workforce	24	21.6
Limited access to raw materials	39	35.1
Challenges in meeting regulatory standards	37	33.3
Inadequate infrastructure (e.g., cold storage,production plants)	54	48.6
Public health policy and administrative challenges	24	21.6

Requirements for Vaccine Production in Nigeria

The key requirements for effective vaccine production in Nigerian were assessed across four main domains: **financial, technological, infrastructural, and regulatory.** Among these, financial requirements emerged as the most critical factor.

Financial Requirements

The mean score as indicated in *(Table 3)* for financial requirement was 23.1±13.6, reflecting strong concern regarding the availability and adequacy of funding to support vaccine manufacturing. Notably, more than half of the respondents—56 (50.5%)—identified financial investment as having a significant impact on the feasibility and sustainability of local vaccine production in Nigeria.

Table 3. Cumulative score perceived financial requirements

Perceived financial requirements	Frequency	%age	Mean±SD	Median	Min score	Max score
Low(<12.0)	55	45.5	23.1±13.6	12.0	0	50
High(≥12.0)	56	50.5				

Regarding the types of financial support critical for establishing vaccine production in Nigeria, *(Table 4) indicates that* more than one-third 38(34.2%) of the participants identified government grants 38(34.2%), low-interest loans 37(33.3%), Public-private partnerships (PPP) 37(33.3%) and international funding 32(28.8%) as major types of financial supports.

Table 4. Financial support critical for establishing vaccine production in Nigeria

Variables	Frequency	%age (%)
Government grants	38	34.2
Tax incentives	29	26.1
Low-interest loans	37	33.3
Private investment	14	12.6
Public-private partnerships	37	33.3
International funding	32	28.8

When asked about viable financial models for sustaining vaccine production facilities in Nigeria, *(Table 5) shows that* over one-third 40(36.0%) identified (PPP) as the most financial model. Additionally, 30(27.0%) participants pointed to government funding, and 23(20.7%) international funding.

Table 5. Financial models most viable for sustaining vaccine production in Nigeria

Variables	Frequency	%age (%)
Government funding	30	27.0
Private funding	11	9.9
Public-private partnerships	40	36.0
International funding	23	20.7

Regarding financial costs to consider when selecting vaccine candidates, more than one-third of the participants *(Table 6)* identified research and development (R&D) costs 47(42.3%) and manufacturing setup costs 46 (41.4 %) as critical. Other important costs included distribution and logistics costs 30(27%), funding and financing options 26(23.4%), and technology transfer costs 24(21.6%).

Table 6. Financial costs to be accounted for when selecting vaccine candidates

Variables	Frequency	%age (%)
Research and development (R&D) costs	47	42.3
Manufacturing setup costs	46	41.4
Distribution and logistics costs	30	27.0
Funding and financing Options	26	23.4
Licensing and intellectual property (IP) costs	16	14.4
Technology Transfer costs	24	21.6

Technological Requirements

The mean score for technological requirement for effective vaccine production in the Nigerian context *(Table 7)* was 21.6±11.1. Overall, more than half of the participants, 56(50.5%), perceived technological requirements as having a high impact on effective vaccine production.

Table 7. Cumulative score perceived technology requirements.

Perceived technology requirements	Frequency	%age	Mean ±SD	Median	Min score	Max score
Low (<4.0)	55	45.5	21.6±11.1	4.0	0	50
High (≥4.0)	56	50.5				

Regarding essential technologies required for local vaccine production *(Table 8)*, more than half 56(50.5%) identified cold-chain logistics and distribution technology as most essential. This was followed by quality assurance and testing technology 52(46.8%) and research and development technology 51(45.9%).

Table 8. Technologies required for local vaccine production

Variables	Frequency	%age
Research and development technology	51	45.9
High-throughput production machinery	43	38.7
Cold-chain logistics and distribution technology	56	50.5
Quality assurance and testing technology	52	46.8

The major challenge in maintaining the required technological capabilities *(Table 9)* was technical know-how, cited by more than half of the participants 68(61.3%). Other challenges included the cost of maintenance 21(18.9%) and funding 18(16.2%).

Table 9. Challenges of maintaining required technologies

Variables	Frequency	%age (%)
Technical know-how	68	61.3
Funding	18	16.2
Cost of maintenance	21	18.9
Insufficient trained personnel	4	3.6

Infrastructural Requirements

The mean score *(Table 10)* for infrastructural requirements for effective vaccine production in the Nigerian context was 21.8±10.6. Overall, more than half of the participants, 56 (50.5 %), perceived infrastructural requirements as having a high impact on effective vaccine production.

Table 10. Cumulative score perceived infrastructural requirements

Perceived infrastructural requirements	Frequency	%age	Mean±SD	Median	Min score	Max score
Low(<24.0)	55	45.5	21.8±10.6	24.0	0	69
High(≥24.0)	56	50.5				

Regarding the adequacy of Nigeria's infrastructure to support local vaccine production, 31(27.9%) of participants perceived laboratory facilities as having minimal impact. Manufacturing facilities were also perceived to have minimal impact, while vaccine storage and transport facilities were rated as having a major impact, accounted for only four (3.6 %) of the responses.

Key infrastructure improvements required to support vaccine production in Nigeria included cold-chain logistics and distribution networks (59, 53.2 %), quality control laboratories (54, 48.6 %), and manufacturing plants (53, 47.7 %). See *(Table 11)* for details.

Table 11. Key Infrastructure improvements required to support vaccine production in Nigeria

Variables	Frequency	%age (%)
Manufacturing plants	53	47.7
Cold-chain logistics and distribution networks	59	53.2
Quality control laboratories	54	48.6
Waste management facilities	32	28.8

Regulatory Requirements

The mean score as highlighted in *(Table 12)* for regulatory requirements for effective vaccine production in the Nigerian context was 28.4±19. Overall, more than half of the participants, 56 (50.5%), perceived regulatory requirements as having a high impact on effective vaccine production.

Table 12. Cumulative score perceived regulatory requirements

Perceived regulatory requirements	Frequency	%age	Mean±SD	Median	Min score	Max score
Low(<12.0)	55	45.5	28.4±19.6	12.0	0	61
High(≥12.0)	56	50.5				

Regarding regulatory standards that present obstacles to local vaccine production in Nigeria, international certification (e.g., WHO prequalification) was identified by participants, 45(40.5%) who perceived that this is a major challenge. Other challenges included licensing and approval processes 41(36.9%), quality control standards 36(31.5%), and compliance with safety and efficacy standards 34(30.6 %). See *(Table 13)* for details.

Table 13. Regulatory standards with the greatest obstacles to local vaccine manufacture in Nigeria

Variables	Frequency	%age (%)
Licensing and approval processes	41	36.9
Quality control standards	36	31.5
Safety and efficacy compliance	34	30.6
International certification (e.g., WHO prequalification)	45	40.5

In terms of regulatory requirements that are currently lacking or need enhancement, more than one-third of participants 38(34.2%) pointed to cold chain and supply chain requirements as shown in *(Table 14)*. Additionally, the need for strengthened quality control (QC) and quality assurance (QA) standards 33(29.7%) and transparent regulatory pathways for technology transfer were emphasized. Almost half of the participants 50(45%) believed that harmonization with international standards would improve regulatory processes and support vaccine production efforts in Nigeria. Similarly, more than one-third 39(35.1%) perceived that streamlining pathways to fast-track approvals would enhance the regulatory environment.

Table 14. Improvements to the regulatory process required to support vaccine manufacturing efforts in Nigeria.

Variables	Frequency	%age (%)
Streamlining pathways to fast-track approvals	39	35.1
Harmonization with International Standards	50	45.0
Enhancing Transparency and Communication	33	29.7
Digitization of Regulatory Processes	36	32.4
Flexible Frameworks for New Technologies	37	33.3

Analysis of Vaccine Production Challenges & Trends in Nigeria

Vaccine manufacturing challenges and trends were analyzed using a combination of survey data and historical data from the WHO, the Nigerian Ministry of Health, and the NAFDAC. This approach aimed to provide insight into the Compound Annual Growth Rate (CAGR) and to estimate the trajectory of Nigeria's vaccine production capacity over time, as well as to identify key barriers inhibiting its growth.

Technology Adoption Rates

The Diffusion of Innovation Model [16] was applied to categorize stakeholders in Nigeria's pharmaceutical sector into early adopters, majority adopters, and laggards. Kraus used regression analysis to examine the relationship between technological advancements, investment, and production

efficiency—an approach that informed this study's analytical framework [17].

Investment Patterns

Investment trends were assessed using descriptive statistics (mean, median, standard deviation) derived from the current survey, as well as data from annual reports by the AfDB, WHO, and the Nigerian Investment Promotion Commission (NIPC).

Comparative Analysis

Survey data on vaccine manufacturing investments were compared with investment levels in other pharmaceutical sub-sectors to highlight potential funding gaps. Gavi notes the lack of concessional financing, fragmented demand, and high capital costs as key reasons Africa has lagged in vaccine production capacity [18]. This comparative analysis helped identify areas where vaccine manufacturing is underfunded relative to other segments of the pharmaceutical industry.

Discussion

Overall, this study revealed that more than half of the participants (55 %) believed that the barriers and challenges to the development and establishment of vaccine production facilities in Nigeria are significant. Key issues identified include the high initial capital investment required, inadequate infrastructure (such as cold storage and production plants), limited access to raw materials, and difficulties in meeting regulatory standards. These findings align with those of Kraus and Okereke, who highlighted that limited technology transfer—largely due to the absence of well-structured collaborations between multinational pharmaceutical corporations and Nigerian manufacturers—remains a major obstacle to local vaccine development and production [8, 10]. Regulatory hurdles, such as delays in securing approvals from NAFDAC and meeting WHO prequalification standards, were also identified as significant impediments [19, 2]. Additionally, Nigeria faces a shortage of skilled professionals in bio-process engineering, quality assurance, and vaccine development [20, 21]. The studies referenced suggest that PPPs and sustained government funding commitments could play a crucial role in strengthening Nigeria's vaccine manufacturing capabilities. Analysis of reports from GAVI and the AfDB further highlighted successful implementations in other regions. Notably, the South African Biovac Partnership—a collaborative government-private sector initiative—has proven effective in promoting vaccine self-sufficiency [2]. Similarly, Chakraborty and Singh cited the India's Bharat Biotech Model as a successful example of how early investments in R&D, along with protection of intellectual property (IP) rights, enabled large-scale vaccine production and international exports [11].

This study assessed the financial support critical for establishing vaccine production in Nigeria. Findings indicated that, in terms of financial models viable for sustaining vaccine production facilities, more than one-third of participants identified PPPs as the most promising approach. This aligns with a study conducted by Chakrabarti, which reported that data from the Nigerian Ministry of Health (2010-2024) showed a CAGR of 4.8 % in local vaccine production, though growth has been inconsistent due to irregular expenditure patterns [22]. Currently, over 70 % of vaccines in Nigeria are imported, highlighting the urgent need to strengthen local vaccine development capacity [19]. Regarding technology adoption rates, early adopters (10 %) include organizations such as Bio-vaccines Nigeria Ltd and private research laboratories. The majority of adopters (55 %) are pharmaceutical companies with limited resources, primarily interested in technology transfer. Laggards (35 %) consist of small-scale manufacturers lacking access to advanced biotechnology infrastructure [7]. In terms of investment levels, the AfDB reports (2015-2023) indicate that vaccine manufacturing

represents only five % of total healthcare investments in Nigeria, compared to 15 % in India and 12 % in South Africa [4].

GAVI financing research indicates that Nigeria got $750 million from 2010 to 2024, with less than 30 % allocated to developing manufacturing facilities [6]. These findings align with global challenges facing vaccine manufacturing capacity in most low-and middle-income countries (LMICs). Although Nigeria's vaccine production is growing at a CAGR of 4.8 %, it remains insufficient to meet national demand. In contrast, India's vaccine manufacturing sector grew at a CAGR of 12.5 % between 2010 and 2022, primarily due to strong government incentives [22]. The low adoption rate (10 %) of advanced biomanufacturing methods in Nigeria mirrors challenges faced by South Africa's Biovac Institute, which has struggled to implement technology transfer despite partnerships with companies like Pfizer and Sanofi [2]. Additionally, Nigeria's allocation of just five % healthcare investment to vaccine production falls significantly short of the 15 % target set by Abuja Declaration. This underscores the urgent need for strategic financing, as demonstrated by Rwanda's BioNTech mRNA facility, which received $100 million in public-private funding [19]. These results confirm that Nigeria's vaccine production deficits are primarily driven by inadequate investment, slow technology diffusion, and persistent regulatory bottlenecks.

Recommended Policy Actions

Nigeria stands at a critical juncture with the opportunity to achieve vaccine self-sufficiency by adopting a structured and strategic technology transfer (TT) and PPP framework. TT enables local manufacturers to acquire proven vaccine production technologies, build capacity, reduce costs, and enhance quality. This policy brief outlines the importance of TT, key enablers for successful implementation, and actionable steps Nigeria can take to position itself as a regional vaccine manufacturing hub within the next decade.

Develop a National Technology Transfer Policy

Integrate TT and PPP objectives into Nigeria's national pharmaceutical and vaccine manufacturing strategy. The policy should include provisions for IP protection, transparent regulatory processes, and alignment with global regulatory and manufacturing standards.

Establish a Vaccine Technology Transfer Coordination Unit

Create a dedicated TT and PPP coordination unit within the NAFDAC, or a joint task force under the Federal Ministry of Health. This body should serve as the central liaison among foreign partners, local manufacturers, and regulatory authorities (including NAFDAC and the Pharmacists Council of Nigeria (PCN).

Prioritize Partnerships with Proven Providers

Proactively engage with reputable global institutions and firms such as: Serum Institute of India, BioNTech, WHO mRNA Technology Hub. Establish structured agreement encompassing: licensing arrangement, co-development initiatives, human capital development and long-term training program for interested private investors in vaccine manufacturing.

Incentivize Local Manufacturers

Stimulate private sector participation through: tax relief and investment credits, import waivers for specialized equipment and inputs, and startup grants tied to clearly defined milestones, such as GMP certification, batch production consistency, and workforce upskilling and certification.

Leverage Regional and Global Platforms

Collaborate with Africa CDC, AUDA-NEPAD, Gavi, and the African Medicines Agency to leverage regional and global platforms for vaccine technology transfer. Advocate for Nigeria's active inclusion in continental vaccine manufacturing consortia. Share resources, access pooled procurement opportunities, and benefit from shared R&D infrastructures. A six-year implementation road-map for implementing these recommendations (Table 15).

Table 15. Six years Implementation Roadmap 2025–2030

Timeline	Milestone
2025	Conduct a comprehensive national TT & PPP needs assessment to identify infrastructure, regulatory, and workforce gaps.
2026	Draft, validate, and adopt the National TT & PPP Policy for vaccine manufacturing
2027	Finalize two–three international TT and PPP agreements with global vaccine producers, including licensing and training components.
2028	Establish and operationalize two pilot manufacturing facilities using licensed technology and trained local personnel.
2029	Secure WHO prequalification for at least one locally manufactured vaccine, demonstrating global regulatory compliance.
2030	Begin export of vaccines to at least three ECOWAS countries, solidifying Nigeria's role as a regional supplier.

Conclusion

The study underscores that Nigeria trails behind peer nations such as India, South Africa, and Rwanda in vaccine manufacturing due to constraints in financing, limited technological capacity, and a shortage of specialized workforce. Despite these challenges, Nigeria has a unique opportunity to reverse this trend through deliberate policy reforms, strategic public-private partnerships (PPP), and targeted investment incentives.

Adopting a structured national TT and PPP framework is a critical lever for accelerating local vaccine manufacturing. Compared to building technology from the ground up, TT offers a faster, more cost-effective, and lower-risk approach to capacity building. If effectively implemented, this strategy can shift Nigeria from being a vaccine importer to a regional supplier by 2030.

TT and PPP—when backed by coordinated action, enabling policies, and committed funding—can catalyze the growth of a sustainable vaccine manufacturing ecosystem in Nigeria. A collaborative effort between government agencies, private sector players, and international partners is essential to advance local production capabilities, strengthen regulatory framework, develop technical expertise and ensure readiness to respond to both national and regional health emergencies.

With political will, structured implementation, and international cooperation, Nigeria is well-positioned to emerge as a vaccine manufacturing hub in West Africa.

Conflict of Interest

The authors declare no conflict of interest related to this study.

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