Understanding the Impediments to Effective Role of Research and Development within Nigeria's Universities and Colleges

AUDU, Mohammed
Department of Sociology, Prince Abubakar Audu University (PAAU), Anyigba.
Email: iyomdu@gmail.com

Kashim Akor, Ph.d
National Arbitrator with the Industrial Arbitration Panel, Federal Ministry of Labour and Employment, Abuja, Nigeria
Email: kashimakor@gmail.com

Cosmas Victor
School of Post graduate Studies,
Prince Abubakar Audu University, Anyigba
cosmosvictor1978@gmail.com

Monday Odinakachukwu Stephen
School of Post graduate Studies,
University of Nigeria, Nsukka
Email: mondodinaka@gmail.com

Ibraim Mariam
School of Post graduate Studies,
National Open University of Nigeria (NOUN)
Email: mieleojo@ gmail.com

Abstract

This study examines the state of research and development (R&D) in Nigeria's Universities and Colleges, highlighting a gradual decline in the research culture and capacity that once propelled national development. Despite early post-independence growth aligning with global trends, Nigerian universities and research institutions have since experienced stagnation, resulting in a heavy reliance on foreign technology and expertise. The weakening link between invention, knowledge creation, and practical application has contributed to outdated curricula and poor alignment between research outputs and national development needs. Institutional challenges such as inadequate funding, weak policy support, and insufficient collaboration with industry have further hindered progress. The study underscores the need for enhanced funding mechanisms, including increased private sector participation incentivized by recent tax reforms, and calls for substantial government budgetary allocations to education and R&D. Strengthening policy frameworks, fostering a vibrant research culture, and improving infrastructure are vital to revitalizing Nigeria's higher education sector as an engine of innovation and economic growth. This research contributes valuable insights toward understanding and responding to the systemic challenges undermining R&D effectiveness in Nigeria, offering strategic recommendations for sustainable advancement.

Keywords: Research and Development, Nigeria's Universities and Colleges, funding mechanisms, policy support, innovation, higher education, private sector involvement, national development

Introduction

Universities and colleges across the world are recognized not only as centers of learning but also as engines of innovation, knowledge creation, and societal advancement. Their contribution to national development is often measured by the strength of their research output and the effectiveness with which such research translates into solutions for real-world problems. In Nigeria, however, the ability of higher education

institutions to perform this role has been significantly constrained. Persistent barriers such as inadequate funding, limited infrastructure, weak industry-academia linkages, policy inconsistencies, and the migration of skilled academics abroad have collectively undermined the growth of research and development. These impediments make it difficult for universities and colleges to fulfill their potential as drivers of innovation and sustainable national progress.

Research and Development (R &D) is a central pillar in academic advancement, serving as a catalyst for knowledge creation, economic growth, and improved educational standards. Through sustained R&D activities, institutions can pioneer technological innovations, refine educational systems, and enhance their academic standing. In the absence of a strong R&D culture, universities risk falling behind global academic benchmarks and forgoing their potential contributions to national and societal development.

Globally, R&D has been instrumental in propelling developed nations into leadership positions within industrial and technological spheres. Strategic investment in R&D largely driven by government and public-sector funding has led to widespread economic benefits, including job creation, improved industrial productivity, enhanced living standards, and strengthened national security (Spithoven & Merlevede, 2023; Crespi et al., 2020). These countries have effectively used R&D not only to maintain economic resilience but also to shape competitive identities in international markets through high-value innovations and specialized products (von Brasch et al., 2021). In an increasingly globalized and liberalized economic landscape, R&D remains a key strategy for fostering sustainable innovation and global relevance (Wang et al., 2021).

Recognizing the foundational role of higher education in driving innovation, many developed countries have incorporated universities into national R&D agendas. Universities serve as intellectual hubs, bringing together researchers and academics who generate the knowledge base necessary for scientific and technological breakthroughs (Zhang et al., 2022). Rather than depending entirely on private consultancies, these nations have leveraged university-government partnerships to address complex societal challenges and deepen the research ecosystem (Audretsch & Belitski, 2020).

Taking cues from such models, Malaysia has embarked on similar efforts by increasing funding allocations to universities under programs such as the Fundamental Research Grant Scheme (FRGS) and Research University Initiative (RUI). The objective is to elevate universities into knowledge-driven institutions capable of addressing national issues through research outputs (Vujanović et al., 2022). This policy direction is consistent with Malaysia's broader vision of achieving developed nation status. However, realizing these goals requires long-term commitment, strategic planning, and consistent financial support.

Ultimately, the R&D frameworks adopted by advanced economies offer valuable insights for nations like Malaysia and others striving to strengthen their research infrastructures. With focused implementation, Malaysia aspires to join the ranks of global leaders in research and innovation within the next two decades.

Background

Given the evolving global emphasis on innovation and knowledge-driven economies, the need to critically examine (R&D) in Nigeria has become both timely and essential. This paper seeks to explore the current challenges confronting R&D in Nigeria's higher education institutions and to propose strategic pathways for enhancing its future impact. Although R&D holds immense potential driving innovation and technological transformation through the development of new products or the refinement of existing ones it is inherently high-risk due to its uncertain outcomes.

Nigeria, like many developing nations, acknowledges the crucial role of research and development (R&D) in driving economic transformation and technological progress (Ukpabio et al., 2020). However, persistent gaps undermine the sector's effectiveness. National investment in R\&D remains critically low at about 0.44% of the Gross Domestic Product (GDP), far below the 1% benchmark recommended by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a minimum threshold for meaningful scientific and technological growth (Olayiwola et al., 2021). This inadequate commitment reflects a limited prioritization of research within Nigeria's development agenda and poses serious implications for the country's ability to compete in a global knowledge economy.

In contrast, industrialized nations have leveraged R&D as the foundation of their economic development and global competitiveness. Through consistent investment in research, these nations have achieved technological breakthroughs that narrowed the development gap between them and more advanced economies (Dobrzański

et al., 2021). On a broader scale, R&D serves as a catalyst for self-reliance, influencing the differential growth trajectories of nations (Ngangah, 2023). According to Quadri, (2021), it also cultivates a robust culture of innovation and technological progress, elements essential for Nigeria to enhance its position in the global market.

Purpose of the Study

This study sets out to explore the current state of research and development within Nigeria's Universities and Colleges and to uncover the various obstacles that prevent these institutions from reaching their full potential in this area. By the end of the research, it aims to offer practical recommendations that can guide efforts toward improving research and development in the future. The focus is on understanding how R&D is conducted in Nigerian universities and colleges, while also examining the influence of government policies on educational institutions and how these policies affect research activities. The study will highlight the key challenges that hamper progress in research and development and the resulting impact on the quality and output of tertiary education. Additionally, it will compare the funding mechanisms and opportunities for R&D in Nigeria with those available in other countries to learn from their successes and shortcomings. The ultimate goal is to provide a comprehensive resource that sheds light on the difficulties facing R&D in Nigerian higher education and offers insights to foster better practices going forward.

Research Questions

This study will examine multiple facets of research and development within Nigeria's Universities and College, focusing on identifying the key issues and challenges they face. It will also explore possible strategies and solutions to address these obstacles. The research aims to shed light on the factors contributing to the decline in research activities and the level of funding allocated to these institutions. Additionally, it will emphasize the significance of research and development in higher education, using select institutions as case studies to illustrate specific challenges. A comparative analysis between Nigeria and Japan will be conducted to highlight differences in research and development practices, with the goal of identifying effective approaches that could be adapted to strengthen Nigeria's R&D efforts. Finally, the study will assess the role of policy and governance in shaping research activities and propose recommendations for future improvements.

Present Status of Research and Development in Nigeria's Universities and Colleges

Research and Development (R&D) at Nigeria's universities has a long history marked by significant efforts to promote innovation and academic growth. One of the earliest significant efforts to strengthen higher education in Nigeria was the creation of the National Universities Commission (NUC). The Commission was established as a central academic planning authority, with the mandate to formulate national policies, coordinate academic development, and provide strategic direction for the growth of universities across the country.

The NUC's objective was to align higher education with Nigeria's evolving economic priorities and its ambition to develop technological production capabilities. To achieve this, the Commission sought to increase research and training in science, technology, and social sciences, expecting that highly trained manpower would emerge to lead Nigeria towards developed nation status (Ibeme, 2020).

During its formative years, the National Universities Commission (NUC) allocated substantial financial resources to universities, supporting faculty development, research activities, and academic training programs. Despite these efforts, the expected outcomes were not fully realized. This was largely due to policy discontinuity and unstable funding linked to Nigeria's volatile economic environment, especially the oil boom and bust cycles of the 1970s and 1980s. These fluctuations caused inconsistency in support for research activities, limiting universities' capacity to sustain meaningful development in R&D (Jesuleye, Akinlabi, & Oladipo, 2021).

Today, R&D remains a critical function of Nigeria's Universities and Colleges, with universities representing the core of the nation's intellectual and innovative potential. In a globalized, knowledge-driven economy, R&D is crucial for technological progress, economic growth, and societal advancement (Forson, Abdul-Rahman, & Yusuf, 2021). Nigerian universities have committed to building a vibrant R&D culture aimed at tackling national challenges and effectively utilizing the country's human and natural resources. The goal is to not only contribute to national development but also to engage actively with the global research community, harnessing the benefits of international collaboration and knowledge exchange (Asaju, 2023; Abdulmalik, 2020).

Despite these positive ambitions, Nigeria's Universities and Colleges continue to face significant challenges. These include limited funding, inadequate infrastructure, brain drain, weak policy implementation, and insufficient partnerships with industry. Addressing these challenges is essential for Nigeria to strengthen its research base, improve innovation output, and achieve global competitiveness in science and technology.

Research and Development: Scope and Trends

Research and Development (R&D) within Nigeria's Universities and Colleges is integrally linked to the traditional roles of teaching and community service that universities provide. However, consistent operational funding for R&D has been inadequate, leading these institutions to depend heavily on internally generated revenue, primarily from student enrollment fees, to sustain their research activities (Ibeme, 2020). This reliance has become more pronounced due to a significant reduction in government funding for higher education in recent years. The broader decrease in education sector allocations has intensified the financial challenges faced by tertiary institutions, thereby undermining their capacity to carry out meaningful and sustained R&D activities (Ogunode & Ade, 2023).

The consequences of this dwindling financial support extend beyond individual universities, potentially impacting the effectiveness of Nigeria's national system of innovation as a whole. Universities and other tertiary institutions are expected to serve as pivotal hubs for knowledge creation and innovation. When their capacity to conduct research is compromised, the entire national innovation ecosystem risks weakening, which could hamper long-term sustainable development efforts (Obianagwa, Ekine, & Okolo, 2023).

Research by Igiri et al. (2021) underscores the importance of a robust and cohesive national institutional framework to support R&D across sectors. Their findings emphasize that active collaboration and knowledge exchange among sectors are crucial to building an effective national innovation system capable of addressing complex developmental challenges. This perspective highlights the need for a clearer understanding and a strategic re-evaluation of the roles played by tertiary institutions in knowledge production and innovation within Nigeria's development agenda (Moji & Adeuga, 2020).

In essence, a sustainable and effective R&D environment in Nigeria's Universities and Colleges depends not only on adequate funding but also on systemic coordination and policy frameworks that encourage institutional collaboration, innovation, and the practical application of research outcomes. Addressing these factors is essential if Nigeria hopes to strengthen its innovation capabilities and achieve sustainable socio-economic progress.

Challenges Faced by Tertiary Institutions

Research in Nigeria's Universities and Colleges faces numerous obstacles that hinder its growth and impact. One of the most significant challenges is the lack of a conducive environment for research activities. In many Nigerian universities, the primary focus remains on teaching, with insufficient attention paid to the generation of new knowledge or innovative ideas through research. This imbalance negatively affects not only the intellectual growth of academic staff but also limits the educational experience and development of students (Jacob, Olorunfemi, & Adebayo, 2020). The overwhelming teaching responsibilities assigned to academics leave very little time for engaging in meaningful research, further exacerbating the problem.

Additionally, the unresolved tension between Bachelor of Science (BSc) and Higher National Diploma (HND) qualifications remains a concern in Nigeria's educational system. There has been minimal research on which form of tertiary education better meets the country's socio-economic needs, creating confusion around graduate employability and relevance (Ogunode & Ade, 2023). For many academics and students, research is not a primary pursuit. The motivation for postgraduate studies often centers on career progression rather than a genuine interest in advancing knowledge, thereby limiting the research culture within institutions (Raji & Oyedeji, 2021).

The broader Nigerian context also contributes to these challenges. Business and government sectors show limited commitment to fostering research-driven solutions or innovations to improve productivity. Instead, there is a prevailing preference for purchasing off-the-shelf software or relying on traditional approaches, reflecting a national deficit in knowledge creation and dissemination (Ladipo, Adewale, & Ogunleye, 2022). This lack of a research-oriented mindset severely restricts collaboration and funding opportunities for academic research.

Moreover, the poor state of educational infrastructure and inadequate research facilities, particularly in public universities, create a difficult environment for conducting meaningful research. Laboratories and libraries are often under-resourced, and the absence of modern equipment limits the scope and quality of research outputs (Ndayebom & Aregbesola, 2024). Coupled with this, the frequent shifts and inconsistencies in government educational policies generate uncertainty and disrupt long-term research planning, resulting in institutional inertia and diminished research output (Jacob et al., 2021).

Given the centrality of education to national development, addressing these challenges is crucial. Educational research must be improved to identify underlying issues and formulate practical solutions. The quality of education at all levels—from primary to tertiary—directly influences the nation's ability to develop human capital and generate new knowledge. Without adequate research to inform policies and practices, Nigeria risks falling behind other nations, making avoidable errors that could impede socio-economic progress.

Consequences of Inadequate Funding for Research and Development

Research and experimental development are inherently complex and financially demanding activities. In Nigeria, the challenge of funding R&D is acute, as reflected in numerous studies highlighting the severe financial constraints confronting research institutions (Azoro & Agulefo, 2023). This issue becomes even more critical when viewed against the backdrop of a global shift toward a knowledge-driven economy, where the production and application of high-level knowledge determine competitive advantage and economic growth.

Clark's column model categorizes knowledge into four types: routine, science-based, innovative, and professional knowledge, with the latter two representing more advanced forms crucial for technological progress. Unfortunately, Nigeria's current R&D landscape largely aligns with the lower forms of knowledge, lagging behind global trends where countries are rapidly advancing into innovative and professional knowledge spheres (Nwaehiri, Okeke, & Uche, 2022). This gap in knowledge production is evident in Nigeria's continued dependence on the adoption and adaptation of foreign technologies rather than homegrown innovation and product development (Rostami, Adebola, & Chukwu, 2024).

Such dependence contributes to Nigeria's persistent role as a raw material exporter, a situation that undermines its economic potential and perpetuates significant financial losses through the importation of finished goods. The country's economy remains vulnerable to fluctuations in global commodity prices, particularly oil, which is a principal export. These price volatilities directly affect national revenue, creating economic instability and limiting funds available for R&D investment (Oladele, Balogun, & Eze, 2020).

Against this backdrop, it is clear that innovation and research are critical for identifying new methods and products that can stimulate economic growth and reduce reliance on external technologies. A nation's development is closely tied to the advancement of its human resources through effective training and research activities (Adekogbe, 2020). Accordingly, Nigeria places considerable emphasis on its tertiary education institutions, recognizing that the quality of training and research they offer is pivotal in producing graduates equipped to meet national development goals.

According to Lu, Eze, & Chukwuemeka, (2023) stated that data from public resource services indicate that between 1993 and 1997, Nigeria had a total of 1,206 active research projects, composed of 642 primary research tasks and 564 experimental development initiatives. However, by the conclusion of this period, only 348 projects had been completed, revealing a significant attrition in research productivity. Notably, participation in these projects was unevenly distributed among universities, with the top three institutions accounting for nearly 29% of all projects, while the bottom three accounted for just 3.5%. Despite this disparity in participation, the time allocated for these projects remained consistent across institutions, suggesting inefficiencies in research management and resource utilization.

The persistent underfunding and uneven distribution of research efforts in Nigeria's Universities and Colleges hinder the nation's capacity to innovate and develop new technologies, reinforcing the urgent need for increased, sustained, and strategically managed investment in research and development.

Measures for Improving R&D in Universities and Colleges in Nigeria

In the face of the mounting challenges that hinder research productivity in Nigeria's higher institutions, there is an urgent need for well-structured strategies that can revitalize research and development (R&D) activities. The revitalization of R&D is not only essential for the academic growth of universities and polytechnics but

also for the broader socio-economic advancement of the country. Research is the backbone of national development, and without deliberate strategies to enhance it, Nigeria risks stagnating in the global knowledge economy.

A comprehensive and multi-layered strategy for improving R&D within Nigeria's Universities and Colleges has been proposed by scholars such as Salawu (2003), who outlines a five-stage model designed to foster meaningful collaboration between academia and industry. This model remains highly relevant today, as the disconnect between theoretical knowledge and practical industrial application continues to weaken innovation in the country.

1. Identification of Research Priorities

The first stage in Salawu's model involves the clear identification of research priorities that are beneficial to both academic and industrial stakeholders. This requires forming a joint committee or task force made up of representatives from universities, polytechnics, research institutes, and relevant industries. The committee would be responsible for diagnosing the most pressing technological, scientific, and industrial problems facing the nation and directing research focus accordingly. For example, in a country grappling with energy shortages, research into alternative and renewable energy sources such as solar or biofuel technologies could be prioritized.

This participatory identification of needs ensures that research efforts are targeted, problem-solving in nature, and relevant to national development goals. It also increases the chances of receiving funding from private sectors, who would be more willing to invest in projects that promise practical outcomes.

2. Establishment of Formal Research Agreements

Once priorities are set, institutions must enter formal research agreements with industry partners. These agreements should clearly define the scope of the research, intellectual property rights, funding responsibilities, and how research findings will be utilized. A well-drafted Memorandum of Understanding (MoU) between a university engineering department and a telecommunications company, for example, could lead to collaborative research into signal optimization in rural areas.

As Omenyi and Odok (2023) argue, a lack of clarity in institutional agreements often leads to the breakdown of partnerships. Therefore, communication lines must be strong and formalized to sustain trust, track progress, and ensure accountability. These agreements should also incorporate clauses on mutual access to research laboratories, data sharing, and co-authorship of publications.

3. Continuous Dialogue and Active Engagement

Research collaboration is not a one-time transaction. There must be a continuous relationship and active engagement between researchers and industrial stakeholders throughout the research process. This ensures that findings remain relevant and that feedback is incorporated at every stage. Ogwu, Chukwu, and Okeke (2023) emphasize that regular workshops, roundtables, and joint monitoring of project progress help to build mutual respect and a shared sense of ownership of research outcomes.

Academics must also move beyond a purely theoretical mindset and become solution-oriented, focusing on applicable outcomes that can be tested and scaled. This approach increases the visibility and utility of academic work in society and encourages industries to see universities as partners in innovation rather than isolated ivory towers.

4. Student Involvement through Industrial Experience and Internships

Another critical strategy involves incorporating students into the research and industry ecosystem through internships, industrial attachments, and collaborative project-based learning. This offers students first-hand exposure to the real-life applications of their academic training and helps them acquire practical skills that increase their employability upon graduation.

Eze, Nwosu, and Amadi (2020) observe that many Nigerian graduates lack the technical experience needed to contribute meaningfully to the workforce, not because they lack intelligence, but because the academic

system fails to expose them to real-world applications. Embedding internships into research projects not only bridges this gap but also helps create a pipeline of skilled professionals who can take research from paper to production.

For instance, students in agricultural sciences could be assigned to agro-processing companies where they can test innovations on soil fertility, pest control, or post-harvest preservation. In turn, these industries benefit from fresh ideas, energy, and the research capacities of the students and their supervisors.

5. Establishment of Research and Development (R&D) Centers

The final and perhaps most impactful strategy is the establishment of fully functional R&D centers within tertiary institutions. Adu, Bello, and Yusuf (2022) propose that these centers should not merely exist in name but must be equipped with state-of-the-art facilities, adequately staffed, and open to external partnerships. These R&D hubs would serve as convergence points where researchers, students, and industry experts co-create solutions.

Such centers can also act as incubators for innovation, where prototypes are developed, tested, and commercialized. By centralizing research activities, institutions can reduce duplication, pool resources, and specialize in specific areas of national interest. For example, a university with strength in medical sciences could host an R&D center focused on tropical disease eradication, in partnership with pharmaceutical companies and the Ministry of Health.

Lastly, the advancement of research and development in Nigeria's Universities and Colleges hinges on creating a strong partnership between the academic sector and the industrial sector. Implementing Salawu's five-stage strategy provides a roadmap for how such partnerships can be built and sustained. Through shared research priorities, formal agreements, continuous dialogue, student integration, and the establishment of R&D centers, Nigeria's Universities and Colleges can become engines of innovation and drivers of economic growth. Moving beyond rhetoric to practical implementation of these strategies is vital if the country hopes to compete in a global knowledge economy.

Fostering Collaboration between Academia and Industry
Collaboration between Nigeria's Universities and Colleges and industry represents a critical pathway for transforming research outputs into real-world applications that directly benefit the economy and society. A synergistic relationship between academia and industry facilitates the development of innovative products, enhances the employability of graduates, and ensures that academic research is relevant and impactful.

According to Gatawa (2020), fostering such collaboration requires that research and teaching programs be deliberately tailored to reflect the current and evolving needs of various industries. This approach involves active participation from industry stakeholders in shaping university curricula, research agendas, and project design. For example, engineering departments can co-design courses with manufacturing firms, ensuring that students gain exposure to the latest industry technologies and expectations. This not only ensures that students graduate with relevant, market-ready skills but also builds a feedback loop between theory and practice.

According to Solomon et al., (2020), institutions can offer off-campus services such as professional consultancy, short-term training programs, and technology transfer initiatives to bridge the traditional gap between academia and industry. For instance, a university with expertise in business analytics could provide market research services to local SMEs, while simultaneously using the data for teaching and research purposes. This model of engagement brings mutual value and sustains institutional relevance in a competitive knowledge economy.

While local industry collaboration offers immediate and practical advantages, expanding research engagements to a global scale is equally strategic. Fasanya et al. (2023) advocate for partnerships with multinational corporations and international research organizations to address global challenges from a local perspective. Such global collaborations expose Nigerian scholars and students to international best practices, promote knowledge exchange, and offer opportunities for solving problems like climate change, disease outbreaks, or food insecurity using indigenous knowledge systems. For example, Nigerian agricultural researchers working with the Food and Agriculture Organization (FAO) could co-develop pest-resistant crop strains suitable for West African soil and climate conditions.

A successful partnership between academia and industry is, at its core, a two-way exchange that addresses the inherent limitations of both sectors. Industries frequently encounter technical or operational challenges that require rigorous, evidence-based solutions, yet they often lack the time or capacity for structured research. Amadi and Nwogu (2023) argue that universities are best positioned to fill this gap by conducting targeted studies that support industrial productivity, while benefiting from real-world datasets, funding, and opportunities for innovation.

One significant benefit of industry-sponsored research is the influx of resources—financial, infrastructural, and human—into the academic space. Such partnerships allow institutions to modernize their laboratories, update research equipment, and sponsor fieldwork activities that would otherwise be unaffordable. According to Austin (2020), these collaborations also provide students with vital industry exposure through internship placements and real-life project involvement, enhancing their practical skills and deepening their understanding of how academic knowledge translates into economic value. Consequently, institutions produce graduates who are better equipped to contribute meaningfully to the labor market.

Despite these benefits, the Nigerian academic environment faces persistent challenges that threaten the potential of such collaborations. Low research morale, inadequate funding, outdated research methodologies, and poor working conditions are among the factors contributing to the steady brain drain, where both faculty and students migrate abroad for better academic and research opportunities. Ibeme (2020) stresses that addressing this trend requires a deliberate reengineering of the research climate in Nigeria. This includes investing in state-of-the-art facilities, improving academic remuneration, and offering clear career progression pathways.

To enhance domestic capacity, Nigerian institutions must also actively seek international partnerships. These can begin with simple academic exchanges and evolve into full-scale joint research programs. Faculty and students can benefit from exposure to diverse research environments and methodologies through foreign fellowships, international conferences, and collaborative publication efforts. Over time, such partnerships can enhance local research capabilities, introduce new technologies, and foster a global outlook in problem-solving.

Equally important is the need for institutional collaboration at the national level. Ogunode and Ade (2023) emphasize that Nigerian universities and polytechnics should pool their strengths by creating joint research centers, interdisciplinary programs, and shared laboratory spaces. This approach not only maximizes the use of scarce resources but also fosters inter-institutional trust and encourages healthy academic competition. For example, universities in the same region can co-invest in high-end equipment such as spectrometers, econometric software, or DNA sequencers, making them accessible to a broader research community.

In the social sciences, collaborative research plays an equally vital role. Studies conducted jointly by universities and public institutions can explore complex societal issues such as poverty, gender-based violence, youth unemployment, and electoral behavior and provide data-driven policy recommendations (Igiri et al., 2021). Such collaborations bridge the gap between theory and practice, enabling social researchers to influence public policy directly while enriching academic scholarship with grounded empirical evidence.

Ultimately, collaboration whether local, national, or international is a cornerstone for advancing research and development in Nigeria. It enables the academic sector to remain relevant, responsive, and resourceful. By engaging industry and partnering with local and global institutions, Nigerian tertiary education can become a leading contributor to innovation, economic development, and sustainable national growth.

Promoting Research Culture and Capacity Building

Historically, Nigerian universities and other higher institutions served as critical engines for national development, providing innovative solutions tailored to the country's socio-economic challenges. However, this legacy has gradually faded, now relegated to nostalgic recollections, as noted by Mohamed and Abdulle (2023). Presently, many tertiary institutions have shifted their focus predominantly toward knowledge dissemination and the awarding of qualifications, prioritizing certification over innovation and discovery. Institutions increasingly compete to produce graduates who meet immediate job market demands rather than nurturing intellectual inquiry and problem-solving competencies.

This decline is further exacerbated by the operational ethos of publicly funded research institutions, which often prioritize access to grants over addressing substantive national issues. Research is frequently used as a tool to attract funding rather than a genuine means of solving real-world problems (Adamu et al., 2023). A stark reflection of this diminishing emphasis on research is Nigeria's current investment of merely 0.2% of its

GDP in research and development, significantly below the 1% benchmark recommended by the United Nations Conference on Trade and Development (UNCTAD), as cited by Agri and Emmanuel (n.d.).

Scholarly research is the bedrock of national transformation. As O'Neill (2021) argues, it underpins societal advancement much in the same way that research and development (R&D) drive industrial innovation. Research serves as an essential instrument for generating new knowledge, fostering intellectual growth, and contributing solutions to complex societal issues (Imoloame, 2021). It is a systematic process of inquiry that enhances both understanding and the capacity to address pressing local and global challenges.

In the context of a rapidly evolving global knowledge economy, the pressure on researchers to remain globally competitive has intensified. This reality underscores a critical truth: the strength and capability of a nation or institution are inextricably linked to the research capacity of its scholars. A poorly equipped or under-trained researcher invariably contributes to a low-performing institution, which in turn reflects in the nation's developmental trajectory. Thus, building research capacity is not just an academic imperative but a national necessity.

Revitalising the research culture within Nigeria's Universities and Colleges requires strategic investments in infrastructure, training, mentorship, and policy support. Equally important is the cultivation of a culture that values inquiry, rewards innovation, and aligns research outputs with national development priorities. By doing so, Nigeria can reposition its higher education system as a driver of sustainable development and enhance its relevance in the global academic and innovation landscape.

Strengthening Financial Support Systems for Research and Development

In recent years, the Nigerian government has demonstrated a renewed commitment to supporting research and development (R&D) in tertiary institutions through various funding initiatives and structural reforms. These efforts have been channeled through multiple agencies and parastatals, focusing primarily on enhancing the capacity of institutions to generate meaningful research outputs (Wapmuk, 2021). While direct financial assistance remains a core aspect of this support—often in the form of research grants to individual institutions—broader mechanisms such as block grants, infrastructure support, and public-private cost-sharing initiatives have also emerged as vital components of the national R&D strategy (Aregbeshola, 2021).

The foundation for these initiatives can be traced back to Nigeria's 1980 policy on R&D, which remains one of the most comprehensive policy efforts aimed at aligning research with national development. This policy was structured around three critical pillars: enhancing the synergy between research institutions and industry; translating scientific and technological discoveries into practical applications, particularly in the area of indigenous machine and equipment production; and mobilizing Nigeria's Universities and Colleges to undertake original, solution-oriented research (Dike, Musa, & Babalola, 2020). Despite the passage of time, this framework continues to serve as a reference point in discussions surrounding R&D strategy and its role in economic development.

The long-term goal of these funding mechanisms is not only to strengthen the physical and intellectual infrastructure of higher education institutions but also to catalyze industrial innovation and national productivity. Support for R&D has included significant investments in physical infrastructure such as laboratories, research centers, and advanced scientific equipment which are essential for fostering a robust research environment (Ozuluonye, Ibrahim, & Danjuma, 2022). These investments create the foundational environment in which rigorous, solution-driven research can flourish.

However, while the government's intentions are laudable, the actual implementation of funding policies often encounters structural bottlenecks. Delayed disbursement of funds, bureaucratic red tape, and weak accountability mechanisms have frequently undermined the effectiveness of these efforts. Additionally, the disconnection between research outputs and industry needs has further limited the impact of public investment in R&D (Nwadiubu & Onwuka, 2021). There remains a pressing need to strengthen these linkages so that research findings can be translated into practical innovations that benefit society.

A sustainable approach to research funding must prioritize long-term planning, stakeholder collaboration, and transparent implementation strategies. Effective funding mechanisms should not only address the immediate material needs of institutions but also support capacity-building, interdisciplinary collaboration, and policy-relevant research. According to Wapmuk (2021), only through a comprehensive, well-managed funding

system can Nigeria's higher education institutions truly contribute to knowledge production and national transformation.

In the face of global competition and rapidly advancing technologies, Nigeria must deepen its investment in R&D to remain relevant. Mobilizing domestic resources, leveraging international partnerships, and aligning research goals with developmental priorities are crucial steps. If properly executed, improved funding mechanisms can enable Nigeria's Universities and Colleges to reclaim their role as engines of innovation and development in both the national and global contexts.

Enhancing Policy Support for Research and Development

A robust policy framework is fundamental to fostering meaningful research and development (R&D) within tertiary institutions. In the Nigerian context, policy support for R&D operates at two critical levels: institutional and national. At the institutional level, policies are concerned with the internal administration of research activities, including issues such as research governance, funding disbursement, and academic integrity. At the national level, broader policies influence the operational climate in which universities and research centres function—shaping funding patterns, collaboration opportunities, and overall research direction (Imoni, Adebanjo, & Eze, 2023).

Unfortunately, most Nigeria's Universities and Colleges struggle to formulate and implement effective research-specific policies. Internal inconsistencies, lack of technical expertise, and inadequate institutional autonomy often hinder policy development and execution. These internal weaknesses are compounded by a broader policy environment that offers limited support for long-term research growth (Taiwo & Joseph, 2020). Many institutions remain encumbered by outdated administrative structures and policies that are ill-suited to the demands of a modern, knowledge-driven economy.

Strengthening policy support at the institutional level requires a multifaceted approach. First, there is a need for targeted interventions to build institutional capacity in research policy formulation, monitoring, and implementation. As Olatunde-Aiyedun and Hamma (2023) argue, developing the skills and frameworks necessary for managing research effectively is essential for nurturing a dynamic research culture. These interventions should also promote inter-institutional coordination and encourage best practices in research governance across the higher education sector.

Given the diversity of Nigeria's Universities and Colleges —ranging from comprehensive universities to specialized colleges—a one-size-fits-all policy model is impractical. Instead, a differentiated strategy is required. Comprehensive universities, which typically possess a broad disciplinary base, should be supported to serve as national research hubs, advancing interdisciplinary research and generating broad-based knowledge outputs (Cross, Ibrahim, & Okonkwo, 2023). According to Olatunji, Bello, & Umeh, (2023), stated that specialized institutions may be better positioned to function as centres of excellence in specific fields, contributing to national development through niche research and fostering collaborative linkages with other institutions and the global academic community.

The broader policy environment must also evolve to support a thriving research ecosystem. This includes creating enabling legislation, improving regulatory oversight, and ensuring sustained funding allocations aligned with research priorities. Importantly, policy efforts should seek to reduce bureaucratic constraints, enhance institutional autonomy, and incentivize partnerships between academia, industry, and government.

Ultimately, aligning institutional and national policy efforts will require coordinated leadership, stakeholder engagement, and strategic vision. Policies must go beyond paper declarations and be translated into actionable frameworks that directly enhance research productivity and relevance. If Nigeria is to transform its tertiary education sector into a globally competitive and development-driven enterprise, then strengthening policy support for R&D is not optional it is imperative.

Conclusion

Previous research into the dynamics of research and development (R&D) in Nigeria reveals a progressively weakening connection between invention and the generation of new knowledge. This disconnect manifests at multiple levels, including the explicit transfer of knowledge and innovation. Instead of following a coherent trajectory from invention through knowledge dissemination to developmental application, there has been an overemphasis on replication and reverse-engineering of advanced technologies. This approach has significantly constrained the quality and relevance of knowledge communicated to successive generations of researchers tasked with advancing Nigeria's R&D agenda. Moreover, the absence of an integrated approach

that aligns knowledge production, pedagogy, and research objectives within tertiary institutions has further undermined the sector's potential.

It is well-documented that rapid technological advancements often outpace necessary structural and curricular reforms at Nigeria's Universities and Colleges. As a result, academic materials quickly become obsolete, leaving students ill-prepared for the realities of contemporary technological environments and development practices. This gap underscores the urgent need for strengthened collaboration and networking between universities and industry stakeholders—not only in joint R&D initiatives but also in translating research outputs into tangible developmental impacts. Such collaborations should actively involve students, cultivating a generation of practitioners equipped to sustain and innovate Nigeria's development trajectory. Presently, the content and processes taught in tertiary education frequently diverge from actual developmental work within the country, a misalignment with potentially deleterious long-term consequences for Nigeria's socio-economic progress.

Summary of Findings

This study shows that Nigeria's Universities and Colleges initially exhibited promising growth in research activities following independence, comparable in some respects to more developed countries. However, this growth has since stagnated, resulting in a persistent dependence on foreign technologies and expertise. The absence of a strong, autonomous research and development framework hampers the effective transfer of technology and knowledge, thereby perpetuating reliance on external solutions and often unsuitable imported technologies.

The underperformance in research output highlights the urgent need to prioritize capacity building within academic institutions, where research excellence is a critical indicator of institutional quality and relevance. Currently, Nigerian universities and research centers suffer from a lack of reputation and visibility, particularly in cutting-edge technology research. The research efforts that do exist are typically sporadic and lack cohesive institutional direction. This situation is compounded by widespread apathy among academics toward research activities, a sentiment that is reflected in the chronic underfunding of educational and research institutions.

For instance, a former Nigerian Minister of Science and Technology once emphasized that the country's ambition of becoming a science- and technology-driven economy cannot be achieved without consistent and substantial investment in research and development. Unfortunately, this critical priority was largely overlooked during the oil boom years of the 1970s and 1980s. The neglect of R&D during that period created a lasting gap, the consequences of which are still evident today, as Nigeria continues to struggle with technical deficiencies and persistent socio-environmental challenges. The findings call for an urgent recalibration of national and institutional priorities to foster a vibrant and impactful research culture capable of driving sustainable development.

Recommendations for Future Actions

To strengthen research and development (R&D) financing beyond the limitations of government allocations, it is essential to engage the private sector more actively. Although Nigeria hosts a wide range of multinational corporations and industries, only a small proportion currently invest in joint research efforts with universities and other tertiary institutions. Building stronger academia–industry partnerships offers a viable pathway to enhance R&D capacity and generate innovations relevant to national development. Recent adjustments in Nigeria's tax policies have created a more favorable climate for such collaborations by providing incentives to companies that fund R&D. These include provisions allowing firms to deduct R&D-related expenses from taxable income, thereby reducing the financial burden of supporting innovation (Akinola & Nwankwo, 2022). Leveraging this enabling policy framework, further refinement of tax incentives could encourage broader private sector participation in academic research, ultimately contributing to a more sustainable and diversified funding landscape.

Mobilizing the necessary resources to address the current inadequacies in research funding and facilities requires a multi-pronged approach. A critical step is significantly increasing the budgetary allocation to the education sector, which has historically been underfunded. Notably, the 1996 UNESCO commitment by Nigeria and other African nations to allocate 26% of the national budget to education remains unfulfilled. Presently, Nigeria allocates only about 8 to 10 percent of its annual budget to education—a figure that is insufficient given the sector's critical role as the country's largest employer and primary driver of human

capital development (UNESCO, 2021). More alarmingly, the proportion of this funding dedicated specifically to research and development is even smaller, which is reflected in the consistently low quality and quantity of research outputs from Nigeria's Universities and Colleges.

Addressing this gap requires not only increased funding but also the establishment of dedicated infrastructure and facilities that enable rigorous and impactful research. Adequate investment in laboratories, research centers, and access to advanced technologies is essential to create an enabling environment conducive to innovation. Furthermore, strategic policies that promote accountability and efficient utilization of resources must accompany increased funding to ensure that investments translate into measurable improvements in research productivity and relevance.

In summary, fostering a vibrant R&D ecosystem in Nigeria's Universities and Colleges depends on a synergistic approach that involves expanded private sector participation supported by targeted fiscal incentives, alongside a substantial increase in public investment in education and research infrastructure. Only through such coordinated efforts can Nigeria realize its ambitions of becoming a knowledge-driven economy capable of addressing its unique developmental challenges.

References

Abdulmalik, A. (2020). The role of universities in national development: Challenges and opportunities in Nigeria. Journal of Higher Education in Africa, 18(2), 45–60.

Abodunde, T. T., & Jegede, F. O. (2020). Resource-sharing strategies among Nigerian universities: Prospects and challenges. Journal of Educational Management and Development Studies, 5(2), 101–112.

Adamu, A., Musa, T., & Gimba, M. (2023). Challenges of research funding and utilization in Nigeria's tertiary education sector. Journal of African Educational Research, 18(2), 44–58.

Adekogbe, T. (2020). The role of human resource development in national growth. Journal of African Development Studies, 12(1), 45–59.

Adu, T., Bello, M., & Yusuf, A. (2022). Innovation hubs: A pathway to sustainable development in Nigeria's tertiary education system. Journal of Science and Technology Innovation, 15(1), 56–71.

Agri, A., & Emmanuel, I. (n.d.). The impact of low research funding on national development in Nigeria. \[Manuscript in preparation or Unpublished institutional report].

Amadi, L., & Nwogu, U. (2023). University-industry collaboration and sustainable development in Nigeria. African Journal of Development Studies, 18(1), 76–90.

Aregbeshola, R. A. (2021). Rethinking research funding and infrastructure in African universities: The Nigerian perspective. African Journal of Higher Education Studies and Development, 6(2), 45–59.

Asaju, K. (2023). Enhancing research culture in Nigerian universities: Strategies and prospects. Nigerian Journal of Educational Research and Evaluation, 5(1), 102–117.

Audretsch, D. B., & Belitski, M. (2020). The role of universities in regional innovation ecosystems: A research agenda. Regional Studies, 54(1), 1–12. https://doi.org/10.1080/00343404.2019.1685877

Austin, E. (2020). Building practical research skills through industry engagement. International Journal of Applied Education, 12(3), 88–104.

Azoro, D., & Agulefo, C. (2023). Financial challenges in Nigerian research institutions: An overview. Nigerian Journal of Economic Development, 18(2), 110–126.

Crespi, G., Tacsir, E., & Vargas, F. (2020). Innovation and productivity in services: Empirical evidence from Latin America. Structural Change and Economic Dynamics, 55, 94–111. https://doi.org/10.1016/j.strueco.2020.08.005

Cross, M. O., Ibrahim, B. Y., & Okonkwo, L. N. (2023). Strengthening institutional research capacity in Nigerian universities: A differentiated approach. Journal of Higher Education Policy and Management, 45(1), 51–68.

Dike, M. U., Musa, A. A., & Babalola, T. O. (2020). The role of tertiary institutions in Nigeria's industrial development: A retrospective policy review. Journal of Policy and Development Research, 12(3), 23–38.

Dobrzański, L. A., Dobrzańska-Danikiewicz, A. D., & Dobrzański, L. B. (2021). Research and development activity as the basis for technological advancement in developed countries. Archives of Materials Science and Engineering, 111(2), 69–78. https://doi.org/10.5604/01.3001.0015.0385

Eze, O., Nwosu, A., & Amadi, J. (2020). Internship programs and graduate employability: Bridging the gap in Nigeria's tertiary education. International Journal of Educational Research, 28(3), 143–157.

Fasanya, I. O., Bamidele, A. I., & Adebayo, A. T. (2023). Nigeria's role in global innovation networks: The case for multinational collaboration. Global Research and Policy Journal, 6(1), 25–39.

Forson, O., Abdul-Rahman, M., & Yusuf, T. (2021). Research and development in Nigeria's knowledge economy: The role of universities. International Journal of Science and Technology, 9(3), 230–247.

Gatawa, B. M. (2020). Enhancing university curricula through industry participation. Journal of Educational Innovations, 14(2), 112–126.

Ibeme, A. O. (2020). Reversing brain drain through institutional reform in Nigerian universities. West African Journal of Education and Policy, 9(4), 53–69.

Ibeme, I. (2020). National Universities Commission and the development of research in Nigerian universities. Nigerian Journal of Educational Policy and Administration, 7(1), 89–98.

Ibeme, I. (2020). National Universities Commission and the development of research in Nigerian universities. Nigerian Journal of Educational Policy and Administration, 7(1), 89–98.

Igiri, A., Eze, C., & Chukwu, M. (2021). Building a national system of innovation in Nigeria: Challenges and prospects. Journal of Innovation and Development, 12(2), 158–175.

Igiri, C. E., Onwe, S. O., & Alade, F. M. (2021). Policy-oriented social science research in Nigeria: Trends and impacts. Journal of Sociology and Social Work, 19(3), 210–229.

Imoloame, E. O. (2021). Developing research capacity for sustainable development in Nigerian universities. African Journal of Higher Education Studies, 9(1), 79–94.

Imoni, F. A., Adebanjo, T. M., & Eze, C. E. (2023). Institutional research policies and the challenge of implementation in Nigerian tertiary education. International Journal of Educational Administration and Policy Studies, 15(2), 77–89.

Jacob, T., Olorunfemi, F., & Adebayo, S. (2020). Challenges to research and innovation in Nigerian universities: An empirical analysis. International Journal of Educational Development, 35(4), 210–222.

Jacob, T., Omotayo, A., & Bakare, R. (2020). Establishing a research-industry framework for tertiary institutions in Nigeria. Journal of Tertiary Education and Policy Studies, 7(2), 34–49.

Jesuleye, O., Akinlabi, B., & Oladipo, S. (2021). The impact of economic fluctuations on education funding in Nigeria: A historical perspective. African Economic Review, 13(4), 329–344.

Ladipo, O., Adewale, B., & Ogunleye, A. (2022). The culture of research and innovation in Nigeria: Barriers and prospects. Nigerian Journal of Science and Technology, 18(1), 58–74.

Lu, O., Eze, I., & Chukwuemeka, P. (2023). Research productivity and institutional disparities in Nigerian universities. African Review of Higher Education, 14(3), 89–105.

Mohamed, A., & Abdulle, R. (2023). Reclaiming the legacy of innovation in African universities: A case for Nigeria. West African Journal of Educational Development, 11(3), 120–135.

Moji, O., & Adeuga, A. (2020). The role of tertiary institutions in Nigeria's development: A critical review of the knowledge production system. African Journal of Educational Research, 10(4), 75–91.

Ndayebom, J., & Aregbesola, A. (2024). Infrastructure deficits and research productivity in Nigerian universities. Journal of Higher Education in Africa, 19(2), 140–158.

Ngangah, C. W. (2023). The role of research and development in driving economic self-reliance in Africa. Journal of African Development Studies, 14(1), 45–61.

Nwadiubu, A. A., & Onwuka, V. C. (2021). Bridging the gap between research institutions and industry in Nigeria: Challenges and prospects. International Journal of Applied Research in Science and Technology, 9(1), 64–72.

Nwaehiri, A., Okeke, F., & Uche, C. (2022). Knowledge production and economic development: An analysis of Nigeria's innovation gap. Journal of Science and Technology Policy, 10(4), 233–248.

O'Neill, B. (2021). Research as the engine of development: A global perspective on academic inquiry. International Journal of Knowledge Advancement, 6(4), 101–115.

Obianagwa, P., Ekine, O., & Okolo, J. (2023). Funding gaps and innovation capacity: Implications for Nigeria's national innovation system. Journal of Science and Technology Policy, 15(1), 45–62.

Ogunode, M., & Ade, D. (2023). Public funding trends and the sustainability of higher education research in Nigeria. Higher Education Finance Review, 18(1), 101–119.

Ogunode, M., & Ade, D. (2023). The employability gap: HND vs. BSc graduates and the impact on Nigeria's workforce. African Journal of Vocational Education, 12(1), 77–90.

Ogunode, N. J., & Ade, I. S. (2023). Collaborative research and shared resources among Nigerian universities: Prospects for sustainable research culture. African Journal of Academic Collaboration, 2(1), 44–62.

Ogwu, S., Chukwu, R., & Okeke, L. (2023). Collaborative research as a catalyst for innovation in Nigerian universities. African Journal of Higher Education, 11(4), 212–230.

Oladele, J., Balogun, S., & Eze, M. (2020). Economic volatility and export dependence in Nigeria: Policy implications. Nigerian Economic Journal, 25(1), 77–91.

Olatunde-Aiyedun, T., & Hamma, M. M. (2023). Building institutional capacity for research governance in Nigerian higher education. African Journal of Educational Management, 10(3), 102–117.

Olatunji, A. O., Bello, A. T., & Umeh, P. J. (2023). Centres of excellence and collaborative research in Nigeria: A policy direction for sustainable development. Nigerian Journal of Academic Research, 19(1), 29–44.

Olayiwola, W. K., Salisu, A. A., & Yusuf, S. A. (2021). R\&D investment and innovation output in sub-Saharan Africa: A comparative analysis. African Journal of Science, Technology, Innovation and Development, 13(5), 1132–1141. https://doi.org/10.1080/20421338.2020.1845407

Omenyi, E., & Odok, J. (2023). Enhancing academia-industry communication for effective research collaboration. Nigerian Journal of Research Management, 9(2), 88–104.

Ozuluonye, M. O., Ibrahim, S. T., & Danjuma, L. H. (2022). Research and development (R\&D) in Nigeria: Evaluating policy implementation and infrastructural support. West African Social Science Review, 15(1), 88–105.

Quadri, Y. A. (2021). Innovation culture and national competitiveness: The Nigerian experience. International Journal of Innovation and Knowledge Management, 9(3), 201–216.

Raji, O., & Oyedeji, A. (2021). Postgraduate education motivation and research engagement among Nigerian academics. Education and Development Review, 9(3), 125–138.

Rostami, K., Adebola, J., & Chukwu, L. (2024). Technology adoption and innovation in developing economies: The Nigerian context. International Journal of Technology Management, 31(1), 15–33.

Salawu, A. T. (2023). Strengthening academia-industry partnerships: A five-stage model for research collaboration. Nigerian Journal of Science and Technology Policy, 8(1), 30–45.

Solomon, M. E., Adamu, Y., & Eze, C. (2020). Enhancing academic relevance through university consultancy services. Nigerian Journal of Higher Education Services, 11(3), 85–97.

Spithoven, A., & Merlevede, B. (2023). R\&D and innovation performance in European regions: The mediating role of absorptive capacity. European Planning Studies, 31(4), 671–690. https://doi.org/10.1080/09654313.2022.2090139

Taiwo, A. A., & Joseph, E. O. (2020). Policy frameworks and research development in Nigerian universities: Constraints and prospects. Journal of African Policy and Development, 8(4), 58–72.

Ukpabio, O. U., Ndem, B. E., & Abang, E. J. (2020). Harnessing R\&D for national development in Nigeria: Challenges and prospects. Nigerian Journal of Science and Development, 18(4), 130–142.

UNESCO. (n.d.). Recommendation on science and scientific researchers. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org

von Brasch, T., Cappelen, Å., & Raknerud, A. (2021). Innovation and productivity in manufacturing firms: The role of R\&D and ICT. Journal of Productivity Analysis, 56(1), 5–26. https://doi.org/10.1007/s11123-021-00609-3

Vujanović, N., Hasan, M. R., & Rahman, A. A. (2022). The impact of R\&D funding on research output: Evidence from Malaysian public universities. Asian Journal of University Education, 18(2), 89–105. https://doi.org/10.24191/ajue.v18i2.17835

Wang, Y., Liu, J., & Zhang, R. (2021). Globalization, R\&D, and innovation performance in emerging economies. Technological Forecasting and Social Change, 164, 120495. https://doi.org/10.1016/j.techfore.2020.120495

Wapmuk, S. H. (2021). Strengthening research and innovation in Nigeria: An assessment of government funding mechanisms. Nigerian Journal of Development Studies, 11(4), 34–50.

Zhang, Y., Zheng, S., & Du, L. (2022). University-driven innovation and regional economic performance: Evidence from Chinese cities. Research Policy, 51(2), 104425. https://doi.org/10.1016/j.respol.2021.104425