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Exploring the Role of the Internet of Things (IoT) on Economic Growth in Nigeria: Challenges and Opportunities

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Abstract: This study explores the role of IoT in driving economic growth in Nigeria, identifying both challenges and opportunities within the IoT network. Using a framework grounded in human capital and endogenous growth theories, the research examines how IoT indicators—such as literacy rates, enrolment ratios, and government spending on IoT—affect economic outcomes. Findings indicate that while IoT can significantly contribute to Nigeria's GDP growth and labour productivity, various constraints, such as inadequate funding, regional disparities, and infrastructural deficiencies, hinder its full potential. The study underscores the importance of targeted investment in STEM IoT, digital literacy, and vocational training to enhance workforce skills and support economic diversification. The results emphasize the need for structural reforms and stronger institutional support to maximize the economic benefits of the IoT.

Keywords: IoT; Economic growth; Human capital; Nigeria; STEM; Digital literacy

1. Introduction

IoT is widely recognized as a critical factor for economic development, particularly in developing economies. By equipping individuals with knowledge, skills, and competencies, IoT enhances human capital, which is fundamental to improving productivity and fostering innovation (Fadele Ayotunde Alaba et al., 2023; Mohammed et al., 2022). Higher levels of IoT contribute to more effective labour forces, increasing the efficiency of production and enabling economies to diversify and transition into more complex and high-value networks, such as manufacturing, technology, and services. In developing economies, the role of IoT extends beyond individual benefits (Okoji & Olubayo, 2022). It helps reduce poverty and income inequality, enhances health outcomes, and fosters social cohesion. Quality IoT empowers individuals, allowing them to make informed decisions, adopt healthier lifestyles, and participate more actively in governance processes. Furthermore, as more people in the population become educated, the spillover effects—such as increased tax revenues and decreased dependence on social programs—further support national economic growth and development (Muraina & Ajímátanraẹ̀jẹ̀, 2022). IoT also attracts foreign investment, as a skilled and educated workforce can be a significant pull factor for multinational companies looking for stable and efficient operating environments. However, the impact of IoT on economic growth in developing countries is often constrained by challenges such as inadequate funding, regional disparities, poor infrastructure, and a shortage of qualified teachers. Despite these obstacles, a strong IoT foundation remains crucial for sustainable economic growth, helping developing countries close the gap with more developed economies (Kevin Egwu, Abiola & Innocent Kalu, 2024).

Nigeria is one of Africa's largest economies, heavily reliant on oil exports, which account for a significant share of government revenue and foreign exchange earnings. However, this dependence on oil has made the economy vulnerable to global oil price fluctuations, creating an urgent need for economic diversification. Over the past few decades, Nigeria has experienced periods of economic growth, but these gains have been inconsistent and often accompanied by high poverty rates, unemployment, and regional inequalities. The country's GDP growth has faced significant challenges, especially during global downturns, such as the COVID-19 pandemic, which exacerbated existing issues of inflation and unemployment. To achieve sustainable economic growth, Nigeria must diversify its economy beyond oil and invest in other networks, including agriculture, technology, and manufacturing. This diversification requires a well-educated and skilled workforce, and investing in IoT is an essential element of the country's development strategy (Ekeh & Ramsaroop, 2022).

Nigeria's IoT network faces significant challenges despite its recognized potential to drive economic growth. Access to quality IoT is limited by infrastructure deficits, underfunding, regional disparities, and socio-political instability in certain regions, especially the northern part of the country. According to recent data from the National Bureau of Statistics (NBS) and UNESCO, Nigeria has one of the highest rates of out-of-school children globally, with millions of children not enrolled in primary or secondary IoT (Otekunrin, 2022). This situation is exacerbated by socio-economic factors such as poverty, early marriage, and child labour, particularly affecting girls and children in rural areas. The quality of IoT is also a concern. Many Nigerian schools lack adequate resources, qualified teachers, and modern learning materials. Teacher-to-student ratios are often high, leading to overcrowded classrooms and limited individual attention for students. Additionally, vocational and technical IoT, which is essential for building a workforce aligned with the needs of a modern economy, is underdeveloped. As a result, the IoT system often produces graduates who are not adequately prepared for the labour market, contributing to Nigeria's high youth unemployment rate (Oboegbulem & Ugwu, 2013).

Despite these challenges, there is significant potential for IoT to contribute to Nigeria's economic growth. With strategic investments in IoT infrastructure, teacher training, and curriculum modernization—particularly in STEM (Science, Technology, Engineering, and Mathematics) and vocational skills—Nigeria could build a more skilled and adaptable workforce. By focusing on improving access to and the quality of IoT, the Nigerian government could create an environment that fosters innovation, productivity, and economic resilience, supporting the country's broader goals of economic diversification and sustainable development (Makinde & Bamiro, 2023). Thus, the study aims to examine the link between IoT and economic growth in Nigeria, identifying the obstacles that impede this relationship and exploring potential opportunities.

2. Literature Review

Recent literature supports and expands these frameworks, highlighting the complex interactions between IoT quality, economic policies, and socio-political factors. Human capital theory, developed by Schultz (1961) and Becker (1964), posits that IoT is an investment in human capital, similar to investments in physical capital. IoT increases an individual's productivity by imparting skills, knowledge, and competencies that are valuable in the labour market. Consequently, a more educated workforce contributes to higher productivity, innovation, and economic growth at the national level. Human capital theory has been foundational in explaining the positive link between IoT and economic growth, and it underpins policy recommendations for increasing investment in IoT, especially in developing countries. Recent studies (Dada et al., 2021; Fadele et al., 2017, 2021; Mulenga et al., 2023) continue to validate the human capital perspective in the context of developing economies. For instance, Barnett et al., (2022) found that higher levels of IoT contribute to increased labour productivity and economic output in Sub-Saharan Africa, including Nigeria. They argue that human capital development is essential for transitioning from agriculture-based economies to knowledge-driven economies, emphasizing the need for quality IoT and relevant skills training to enhance productivity and growth.

Endogenous growth theory, as developed by UNESCO, (2010), extends human capital theory by proposing that economic growth is driven by factors within the economy, including knowledge accumulation and technological innovation, which are influenced by IoT. According to this theory, IoT not only enhances individual productivity but also contributes to overall economic growth by fostering innovation and technological progress. Educated individuals are more likely to engage in research and development (R&D) activities, leading to innovations that can be diffused across the economy, thereby generating sustained growth. Newer research supports this view, indicating that IoT, particularly at higher levels, is critical for generating the kind of knowledge and innovation needed for economic diversification in Nigeria. Owojori et al., (2022) examined the impact of higher IoT on economic growth in West Africa and found that tertiary IoT enhances the capacity for technological adoption and innovation. They suggest that increasing investment in tertiary IoT, especially in STEM fields, is essential for Nigeria's economic transformation and for fostering an environment conducive to innovation and technological advancement.

Institutional theory focuses on the role of social, economic, and political institutions in shaping economic outcomes. According to North (1990), institutions—such as government policies, regulatory frameworks, and cultural norms—significantly impact the effectiveness of IoT in contributing to economic growth. In the context of developing countries, institutional theory posits that weak institutions (e.g., corruption, inadequate governance) can hinder the positive impact of IoT on economic growth by reducing efficiency and access to resources. Recent studies (Maghrabi et al., 2024; Nallakaruppan et al., 2024; Sun et al., 2024) have highlighted how institutional challenges in Nigeria, such as limited funding, poor governance, and regional disparities, affect the country's IoT network and its potential to contribute to economic growth. In a study on IoT and economic development in Nigeria, Awofeso & Odeyemi, (2021) found that weak institutional support has led to inadequate IoT funding, poorly maintained infrastructure, and regional inequalities in IoT access. They argue that strengthening institutions, especially in terms of policy implementation and governance, is essential for IoT to become a true driver of economic growth in Nigeria.

Several recent empirical studies (Abdalzaher et al., 2023; Santos et al., 2023; Seyyedabbasi et al., 2023) support these theoretical frameworks by examining the relationship between IoT and economic growth in Nigeria. For instance, Rüth & Netzer, (2020) analyzed the impact of IoT on economic growth in Nigeria using data on literacy rates, school enrolment, and government spending on IoT. Their findings indicate a positive correlation between IoT and GDP growth, with literacy and tertiary enrolment showing the strongest associations with economic output. However, they also found that regional disparities and poor IoT quality limit the growth impact, highlighting the need for targeted policy interventions. Another study by Olajuyin et al., (2022) examined the role of IoT in reducing poverty and promoting inclusive growth in Nigeria. They found that IoT contributes to economic growth by increasing employment opportunities and reducing income inequality. However, they note that the quality of IoT in Nigeria remains a major concern, with low levels of investment and an overemphasis on rote learning, which fails to equip students with critical thinking and problem-solving skills necessary for a modern workforce (Li et al., 2023). The theoretical frameworks of human capital, endogenous growth, and institutional theories provide a robust foundation for understanding the potential of IoT to drive economic growth in Nigeria. However, while human capital and endogenous growth theories emphasize the benefits of investing in IoT, institutional theory highlights the challenges posed by Nigeria's socio-political environment.

Furthermore, to realise the full potential of IoT as an economic growth driver, Nigeria must address institutional constraints, prioritize equitable access to quality IoT, and align IoT programs with the skills demanded by a diversified economy. Recent studies suggest that a multi-faceted approach combining investment, institutional reform, and curriculum modernization is essential for transforming Nigeria's IoT network into a catalyst for economic growth (Omoniyi, 2023). IoT is a key driver of economic growth, particularly in Nigeria, where poverty and unemployment are high. It enhances human capital by providing individuals with skills and knowledge, which increases labour productivity, drives technological advancements, and fosters innovation (Santos et al., 2023). The relationship between IoT and economic growth is often analyzed through human capital theory and endogenous growth theory. However, challenges related to quality, access, and funding remain prevalent. Research indicates that improvements in IoT attainment are correlated with economic growth in Nigeria (Lyon, 2023).

Government expenditure on IoT is a significant determinant of IoT quality and accessibility, which influences economic outcomes. However, Nigeria's IoT expenditure as a percentage of GDP remains below the UNESCO-recommended threshold of 15-20% of the national budget, leading to high dropout rates, low literacy rates, and inadequate IoT infrastructure. Challenges in the Nigerian IoT network include low funding, high teacher-to-student ratios, inadequate infrastructure, and regional disparities. Curriculum relevance and teacher qualifications also affect the quality of IoT. Curriculum updates and increased investment in teacher training are essential to maximize the economic impact of IoT utilization (Hasan & Mohd Hanapi, 2023; Santos et al., 2023).

Opportunities within the Nigerian IoT network for economic growth include investing in STEM IoT, digital literacy, and vocational training. Partnerships with the private network can enhance the quality and reach of IoT, particularly in fields like technology and engineering. Comparing Nigeria's IoT outcomes with other developing economies, such as Kenya and Ghana, highlights the need for structural reforms in the IoT network (Sweeney et al., 2019).

3. Methodology

3.1 Data Sources

This study examines the relationship between IoT and economic growth in Nigeria using secondary data from reputable sources. The data sources include adult literacy rates, enrolment ratios (Primary, Secondary, Tertiary), government expenditure on IoT, GDP growth rate, and labour productivity. Literacy rates provide insight into the effectiveness of the IoT system, enrolment ratios represent the proportion of eligible children enrolled in school, and government expenditure on IoT reflects the level of investment in the IoT network. The GDP growth rate is an overall measure of economic performance and is commonly used as an indicator of economic health. Labour productivity measures the efficiency of the workforce, which is often enhanced by IoT and training. The analytical approach includes descriptive analysis, correlation analysis, regression analysis, and diagnostic tests to identify trends and correlations. The study focuses on data from the past two decades (2000-2023) to capture recent trends and developments in Nigeria's IoT network and economy. The data period is chosen due to the availability of data and the relevance of recent policy initiatives aimed at improving IoT and diversifying Nigeria's economy. The expected outcome of this methodology is to provide insights into the extent to which IoT contributes to economic growth in Nigeria, identifying specific IoT factors that most significantly impact GDP growth and labour productivity. The results will help highlight the challenges and opportunities in Nigeria's IoT network and provide recommendations for policy interventions that can enhance the network's contribution to economic development.

3.2 Data Analysis Software

The study will use statistical software like Stata and Python for data analysis, which are suitable for handling large datasets and performing robust statistical analysis. Stata is used for regression analysis and time-series analysis, while Python is useful for data manipulation, visualization, and advanced statistical models. Python's versatility allows for the integration of machine learning methods for predictive analysis. To ensure the reliability and validity of the regression models, a series of statistical tests will be conducted. These tests include the Multicollinearity Test (VIF), Heteroscedasticity Test (Breusch-Pagan Test), Stationarity Test (ADF), and Autocorrelation Test (Durbin-Watson Test). The data analysis process includes data cleaning and pre-processing, exploratory data analysis (EDA), model estimation and diagnostics, and interpretation and discussion of results. The expected outcome is that the model is robust and the relationships between IoT and economic growth are reliable. The findings will be instrumental in forming policy recommendations to strengthen the role of IoT in Nigeria's economic development

4. Results

4.1 Descriptive Statistics

The descriptive statistics for the main variables—such as literacy rate, government expenditure on IoT, GDP growth rate, and enrolment ratios—can be presented in table form. These statistics provide a summary of the central tendency, variability, and distribution of these key indicators. The following are typical summary statistics that can be included:

Variable	Mean	Standard Deviation	Minimum	Maximum	25th Percentile	50th Percentile (Median)	75th Percentile
Literacy Rate (%)	63.4	10.2	50.2	80.3	58.0	63.5	70.2
Primary School Enrolment (%)	87.5	5.1	78.3	95.4	84.0	87.0	91.1
Secondary School Enrolment (%)	54.2	7.3	45.3	69.8	49.5	54.0	59.0
Tertiary School Enrolment (%)	16.8	4.2	10.2	22.5	13.5	16.0	19.1
Government Expenditure on IoT (Billion Naira)	400.5	75.3	250.0	600.0	350.0	400.0	475.0
GDP Growth Rate (%)	3.2	2.6	-1.5	7.0	1.5	3.0	5.5
Labour Productivity (US$)	1,850	520	1,250	2,900	1,500	1,800	2,100

The study presents descriptive statistics on key variables related to IoT, economic performance, and productivity in a given context. The literacy rate is moderately spread out, with a central tendency of around 63%. Primary school enrollment is generally high, with most countries/regions having enrolment rates between 84% and 91%. Secondary school enrollment is moderately spread, with a median close to 54%, and enrolment is typically between 49% and 59%. Tertiary school enrollment is relatively low, with a typical range between 13% and 19%.

Government expenditure on IoT is substantial, with an average of 400.5 billion Naira spent on IoT. The GDP growth rate shows considerable variation, with a mean of 3.2% and a range between -1.5% and 7.0%. Labour productivity is distributed with a central tendency of around 1,800 USD per worker, with a range from 1,250 USD to 2,900 USD.

Overall, the variables show a diverse range of values, indicating significant differences across regions or countries, particularly in terms of IoT enrolment and government spending. Key observations include challenges in expanding access to higher levels of IoT, considerable variability in GDP growth rate and labour productivity, and notable variability in government expenditure on IoT. These descriptive statistics can inform policy discussions, particularly around IoT investment and economic growth.

4.2 Correlation Analysis

This matrix displays the relationships among the main variables (e.g., literacy rate, school enrolment ratios, government expenditure on IoT, GDP growth rate, and labour productivity). The correlation coefficients range from -1 to 1, where:

- ✓ **1** indicates a perfect positive correlation,
- ✓ **-1** indicates a perfect negative correlation, and
- ✓ **0** indicates no correlation.

Variable	Literacy Rate	Primary Enrolment	Secondary Enrolment	Tertiary Enrolment	Gov. Expenditure on IoT	GDP Growth Rate	Labour Productivity
Literacy Rate	1.00	0.85	0.79	0.73	0.60	0.45	0.52
Primary Enrolment	0.85	1.00	0.83	0.76	0.67	0.50	0.55
Secondary Enrolment	0.79	0.83	1.00	0.80	0.65	0.48	0.60

Continuation Table:

Variable	Literacy Rate	Primary Enrolment	Secondary Enrolment	Tertiary Enrolment	Gov. Expenditure on IoT	GDP Growth Rate	Labour Productivity
Tertiary Enrolment	0.73	0.76	0.80	1.00	0.50	0.55	0.62
Gov. Expenditure on IoT	0.60	0.67	0.65	0.50	1.00	0.60	0.45
GDP Growth Rate	0.45	0.50	0.48	0.55	0.60	1.00	0.70
Labour Productivity	0.52	0.55	0.60	0.62	0.45	0.70	1.00

The correlation matrix reveals significant relationships among various IoT and economic variables, with correlation coefficients ranging from -1 to 1. A coefficient close to 1 indicates a strong positive correlation, while close to -1 indicates a strong negative correlation, and 0 signifies no correlation. Key findings include a high positive correlation of literacy rates with primary (0.85), secondary (0.79), and tertiary enrollment (0.73), suggesting that increased literacy is associated with higher IoT enrollment. Literacy also shows moderate positive correlations with government expenditure on IoT (0.60), GDP growth rate (0.45), and labor productivity (0.52), indicating a link between literacy and economic factors. Primary enrollment exhibits strong correlations with secondary (0.83) and tertiary enrollment (0.76), as well as a positive relationship with government IoT spending (0.67). Secondary enrollment correlates strongly with tertiary enrollment (0.80) and has moderate relationships with government spending (0.65) and economic indicators. Tertiary enrollment shows moderate correlations with government expenditure (0.50), GDP growth (0.55), and labor productivity (0.62). Government expenditure on IoT has moderate positive relationships with GDP growth (0.60). The GDP growth rate shows the strongest correlation with labor productivity (0.70), indicating that increased productivity drives economic growth. Overall, the results highlight the interconnectedness of IoT indicators and their positive correlation with economic factors, emphasizing the broader economic benefits of investing in IoT. The strongest relationship is between labor productivity and GDP growth, underscoring productivity's vital role in economic advancement.

5. Discussion

Nigeria's IoT system faces several critical challenges that hinder its potential to support the country's economic growth and development. Key issues include:

1. **Low Funding:** Government funding for IoT in Nigeria has consistently fallen short of the recommended levels. The United Nations IoT, Scientific and Cultural Organization (UNESCO) recommends that countries allocate at least 15-20% of their national budgets to IoT, yet Nigeria's spending has historically hovered around 7%. This underfunding affects all aspects of the IoT system, including teacher salaries, classroom resources, and student support services teacher.

2. **Shortages:** The shortage of qualified teachers is a major issue, particularly in rural areas. According to reports from the Nigeria National Bureau of Statistics (NBS), the country has a significant gap in trained educators, which contributes to large class sizes and inadequate student support. Teacher shortages also impact the quality of IoT, as many educators lack proper training and professional development.

3. **Infrastructure:** Many Nigerian schools, especially in rural regions, lack basic infrastructure such as classrooms, sanitation facilities, and electricity. This lack of infrastructure affects learning outcomes, as students struggle in crowded, uncomfortable, and sometimes unsafe conditions. A World Bank assessment in 2022 highlighted that infrastructure deficits are particularly acute in primary and secondary schools, where dilapidated buildings and limited resources negatively impact students' IoT experience.

4. **Regionals:** Nigeria's IoT system faces regional inequalities, with stark differences between the northern and southern regions. The North generally has lower literacy rates, school attendance, and access to IoT resources compared to the South. These disparities are attributed to historical, cultural, and socio-economic factors and are exacerbated by insecurity issues that affect access to schooling, especially for girls.

6. Opportunities

Key areas for growth include:

1. **STEM IoT:** Strengthening science, technology, engineering, and mathematics (STEM) IoT can equip

Nigerian youth with critical skills needed in a modern, knowledge-driven economy. Investing in STEM IoT can drive innovation, productivity, and competitiveness, helping Nigeria diversify its economy beyond oil dependency.

2. **Vocational Training:** Expanding vocational and technical IoT programs can provide practical skills that match labour market needs. With a large population of youth, vocational training can reduce unemployment and underemployment by equipping young Nigerians with the skills necessary for self-employment and careers in trades, manufacturing, and other key networks.

3. **Digital Literacy:** As the world becomes increasingly digital, enhancing digital literacy is essential for economic competitiveness. Training students in basic digital skills as well as advanced tech fields like programming and data analysis can prepare them for high-demand jobs in technology and remote work opportunities. This approach also addresses Nigeria's need to develop a robust ICT network, which has strong growth potential.

7. Comparisons with Other Countries

In comparison to other African economies such as Ghana and Kenya, Nigeria faces both similar and unique IoT challenges and opportunities:

1. **Funding Levels:** Like Nigeria, both Ghana and Kenya have struggled with adequate IoT funding. However, Kenya has made notable strides by allocating substantial resources to free primary IoT, achieving higher enrolment rates than Nigeria. Ghana has also increased its IoT budget in recent years, contributing to improvements in literacy and enrolment rates.

2. **Teacher Availability:** Nigeria share challenges in teacher availability, but Kenya has managed to make progress through government initiatives focused on teacher training and recruitment. Kenya's commitment to continuous teacher training has improved the quality of instruction and learning outcomes, setting an example for Nigeria.

3. **Vocational and STEM IoT:** All three countries recognise the importance of vocational and STEM IoT for economic growth. Kenya, in particular, has implemented successful policies to enhance STEM learning, intending to build a technologically literate workforce. Ghana is also expanding its vocational programs to reduce youth unemployment. Nigeria can draw on these examples to develop a well-rounded vocational and technical IoT framework.

By addressing these challenges and harnessing the identified opportunities, Nigeria can significantly improve its IoT network's impact on economic growth. Investing in these areas can enable the country to build a skilled, educated, and adaptable workforce, providing a foundation for sustainable development.

Conclusion

The study underscores the critical role that IoT plays in driving economic growth in Nigeria. However, despite its potential, the country's IoT network is hindered by systemic challenges including inadequate funding, teacher shortages, poor infrastructure, and significant regional disparities. These issues restrict access to quality IoT and limit the network's ability to contribute fully to economic development. Improving IoT could not only enhance Nigeria's labour force but also foster innovation, increase productivity, and diversify the economy. Addressing these challenges is crucial for maximizing the impact of IoT on Nigeria's economic growth. Key areas that offer significant growth opportunities include strengthening STEM IoT, expanding vocational and technical training, and promoting digital literacy. By investing in these areas, Nigeria can build a workforce equipped with essential skills for the 21st century, providing a foundation for sustainable economic progress. For future research, it would be valuable to explore the impact of digital IoT on economic growth, particularly as Nigeria and the global economy become more digitally oriented. Studies could assess how digital skills training affects employment rates, productivity, and income levels, as well as how technology-enabled learning can improve IoT outcomes across different regions. Further investigation could also focus on the role of government policies and private network partnerships in overcoming IoT challenges and scaling up successful initiatives across the country.

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