

ORIGINAL ARTICLE

Technology, Labour Productivity and Industrialisation in Nigeria (1994 – 2023)

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Abstract: This study investigates the dynamic relationship between technology, labour productivity, and industrialisation in Nigeria from 1994 to 2023. Specifically, it explores how labour productivity (LBP) and technology (TECH) affect industrialisation in both the short and long run, and assesses how the interaction between labour productivity and technology affect industrialisation, while controlling for other macroeconomic variables such as investment, exchange rate, and literacy. Methods: Data analysis employed Autoregressive Distributed Lag (ARDL) estimation technique as proposed by Pesaran et al. (2001) including pre-test comprising normality, multicollinearity and unit root tests and post-test comprising Ramsey reset, wald and serial correlation tests. Results: The findings reveal that labour productivity and technology have a significant negative effect on industrialisation in both the short and long run. Interestingly, the interaction between labour productivity and technology shows a positive statistically insignificant effect in both timeframes. Investment demonstrates a strong negative impact on industrialisation across both periods, while the exchange rate exhibits a positive significant effect on industrialisation. Literacy has no significant effect on industrialisation in either the short or long run. Conclusion: The study underscores the complex adverse relationship between labour productivity, technology, and industrialisation in Nigeria. While technological advancements and labour productivity are critical components of economic development, their combined influence on industrialisation appears limited, suggesting the need for more robust policies. There is need to invest in skill development programmes that align with the need of industry and in research and development to foster technological advancements.

Keywords: Industrialisation; Labour Productivity; Technology; Nigeria.

JEL Classification: O14; R23; N70.

1. Introduction

Industrialisation, the process by which economies transit from traditionally agricultural dominated economy into an advanced industry dominated producing unit, often characterised by a significant increase in the use of machinery, innovative technologies, and large-scale manufacturing, is recognized as a crucial catalyst of economic development. The importance of industrialisation in modern economies cannot be overstated; as it engineers expansion in productive capacities, employment levels, and overall economic growth (Obienyi *et al.*, 2018). Several factors influence industrialisation, including technology, labour productivity, human capital development, infrastructure, capital accumulation, government policies, and global trade integration. Among these, technology and labour productivity stand out as primary catalysts for accelerating industrialisation.

The role of technology in enhancing industrialisation has become a central focus of global discussions, as the transition from agrarian-based economies to industrialised societies has historically been marked by significant technological breakthroughs through the change in method of production from manual labour to mechanized processes during the industrial revolution. This shift was responsible for increased large-scale productivity gains, which fuelled economic growth. Scholars have repeatedly argued that industrialisation is virtually impossible without technological advancements (Dauda & Akingbade, 2011). Furthermore, advancement in technology via Information and Communication Technologies (ICT) have transformed how organisations operate, making technology an indispensable tool for achieving performance and productivity goals. ICTs, such as automation, artificial intelligence (AI), and the Internet of Things (IoT), have allowed industries to streamline processes, reduce costs, and enhance competitiveness. Likewise, countries that have effectively adopted and utilized technology experience rapid industrial growth and higher economic output (Sulaiman *et al.*, 2024).

Labour productivity which is closely linked to human capital development, particularly through education and skill enhancement is also an important catalyst of industrialisation (Ngutsav & Ijirshar, 2018). It is the amount of output produced per unit of labour input and a critical measure of economic efficiency which can be assessed at various levels, including national, sectoral, and organizational levels. As noted by Ngutsav and Ijirshar (2018), labour productivity improvements in agricultural sector can enhance food security and reduce dependency on imports. Similarly, in services, improved labour productivity can foster economic diversification and innovation. These sectoral improvements in productivity are tied to broader industrialisation efforts, which require not only advancements in technology but also investments in human capital. Equally, technology plays a pivotal role by enhancing production and operational efficiencies. Technology impacts labour productivity by automating repetitive tasks, improving precision, and reducing the time required to complete various tasks. (Brynjolfsson & McAfee, 2014)

The Nigerian government has implemented various policies aimed at fostering industrial growth and technological adoption, such as import substitution of 1960s; Indigenisation policy of 1972; Structural Adjustment Programme of 1986; establishment of Bank of Industry in 2000; National Integrated Industrial Development (NIID) in 2007, the National Digital Economy Policy and Strategy (2020-2030) and the National Industrial Revolution Plan (NIRP) as well as many programmes to encourage small and medium scale enterprises (Obienyi *et al.*, 2018). Despite these efforts, the country has struggled with significant obstacles including inadequate infrastructure, low levels of technology adoption, and a workforce that often lacks the necessary skills for effective technology utilization (Oyegoke & Wasiu, 2021). Comparative statistics highlight the disparity between Nigeria and more industrialised nations. For instance, Nigeria's manufacturing output as a percentage of GDP has stagnated around 9% in recent years, a stark contrast to emerging economies like China, where manufacturing has been a major driver of

economic growth (World Bank, 2022). Additionally, Nigeria's labour productivity is notably low, with the International Labour Organisation (ILO) reporting that in 2020, Nigeria's productivity was only 20% of the global average (ILO, 2020). These figures underscore the need for more effective policies and interventions to enhance technological integration and boost productivity.

Existing literature provides a mixed perspective on the relationship between technology, labour productivity, and industrialisation. Studies from developed economies have consistently shown that technology drives productivity gains and economic growth. For example, research on advanced manufacturing sectors in developed countries reveals that technological innovations lead to significant productivity improvements and competitive advantages (Brynjolfsson & McAfee, 2014). In contrast, research on developing economies, including Nigeria, often highlights challenges such as infrastructural deficits, governance issues, and limited access to modern technologies that impede productivity gains (Obioma, 2019). While policies and frameworks have been proposed to address these challenges, their implementation has been inconsistent and often hindered by structural constraints (Awode & Oduola, 2024). This discrepancy between the theoretical potential of technology and its actual impact in Nigeria points to a need for further investigation into how technology can be more effectively integrated into the country's industrial and labour systems. The study aims to bridge this gap by providing a detailed analysis of how technology influences labour productivity and drives industrialisation in Nigeria. The specific objectives are:

- i. investigate the effect of technology on industrialisation;
- ii. examine the effect of labour productivity on industrialization; and
- iii. examine the interactive effect of technology and labour productivity on industrialisation.

While previous research has explored various aspects of this relationship, there remains a need for a comprehensive examination of how technological advancements intersect with Nigeria's unique economic and infrastructural conditions. By exploring the barriers to effective technology adoption, this study will contribute valuable insights into how Nigeria can leverage technology to enhance productivity and foster industrial growth. This approach not only addresses the existing literature gaps but also offers practical recommendations for policymakers to improve technological integration and boost Nigeria's industrial capabilities.

This study is structured as follows; section two contains the literature review, section three and four presents the methodology and results respectively while section five contains the conclusion and recommendations.

2. Literature Review

Industrialisation refers to the process of transforming an economy from primarily agrarian and manual labour-based to one dominated by industry and machine manufacturing. It involves the growth of industries such as manufacturing, mining, and construction, which contribute to economic development through increased production, technological advancement, and job creation. Industrialisation typically leads to urbanization, improved infrastructure, and higher standards of living Ugwoke, Onyenama, and Ugwoke (2021).

Productivity refers to the efficiency with which resources are utilized to produce goods and services, typically measured as the ratio of output to input. It encompasses various forms, including labour productivity (output per labour unit), capital productivity (output per unit of capital), and total factor productivity (TFP), which captures the overall efficiency of all inputs combined Ndiyo (2003). Labour productivity refers to the amount of output produced per unit of labour input. It is a critical measure of economic efficiency and can be assessed at various levels, including national, sectoral, and organisational. In the context of Nigeria, labour

productivity encompasses productivity across different sectors such as agriculture, manufacturing, oil and gas, and services. Each sector presents unique challenges and opportunities for productivity improvements Ngutsav and Ijirshar (2018).

Labour productivity is a measure of how effectively labour inputs are utilized to produce output. It is typically quantified as the amount of output produced per unit of labour input, such as output per hour worked or output per worker. High labour productivity indicates that workers are generating more value with the same or fewer resources, contributing to overall economic growth and efficiency Okwuchukwu et al. (2022). According to Obienyi et al. (2018), labour productivity is a measure of the efficiency with which labour inputs are used to produce output. It is typically calculated as the ratio of total output (goods and services) to the number of labour hours or workers. High labour productivity indicates that workers are producing more output per unit of input, which is essential for economic growth and industrial development. Factors influencing labour productivity include health, education, and technological advancements.

Technology refers to the application of scientific knowledge for practical purposes, particularly in the production of goods and services. The concept of technology is closely related to the concept of innovation, which involves the development and adoption of new ideas, processes, and products. Technological progress is widely recognized as a key driver of economic growth, as it enables economies to produce more output with the same or fewer inputs, thereby increasing productivity and fostering innovation Sulaiman et al. (2024). The historical development of technology has been marked by several key innovations, including the Industrial Revolution, which saw the widespread adoption of mechanization and the development of new manufacturing processes. In the 20th century, technological progress was driven by advancements in areas such as information and communication technology (ICT), biotechnology, and nanotechnology. These advancements have had a profound impact on the global economy, leading to increases in productivity, changes in the structure of industries, and the emergence of new economic sectors.

The endogenous growth theory, developed by Paul Romer in 1990, shifts the focus on source of growth from external factors to internal mechanisms driving economic growth. Unlike traditional growth theories that view technological progress and innovation as exogenous factors, the theory argues that growth results from factors within the economy, such as human capital, research and development, and infrastructure investments (Chiemeké & Imafidior, 2024). This model suggests that policy measures and investments in education, innovation, and infrastructure can significantly enhance long-term economic productivity and growth. According to Romer, strategic investments in human capital and R&D contribute to sustained economic development by continuously improving technological capabilities and productivity. For example, Kitur and Rotich (2014) illustrate how investments in education and technology can lead to persistent economic growth. In the context of industrialisation, this theory underscores the importance of fostering a skilled workforce and supporting technological innovation to drive economic advancement.

Solow growth theory, proposed by Robert Solow in 1956 focuses on capital accumulation, labour, and technological progress. The relevance of the Solow Growth Theory in the context of technology, labour productivity, and industrialisation lies in its assertion that technological improvements are crucial for maintaining long-term economic growth. In industrialisation, the model highlights that technological advancements are necessary for increasing productivity and achieving sustained economic development.

Human capital theory, primarily associated with economists like Gary Becker and Theodore Schultz, posits that investments in education, training, and health significantly enhance individuals' productivity and economic outcomes. This theory builds on the assumption that human skills and knowledge are crucial determinants of economic performance. Basic principles include the idea that individuals who acquire more education and skills can perform

more complex tasks, leading to higher productivity and, consequently, greater economic growth. Human capital theory is pertinent to the link between technology, labour productivity, and industrialisation because it underscores the necessity of skilled labour to fully leverage technological advancements.

Empirical-wise, the study by Chiemeké and Imafidior (2024) examines the impact of digital technology adoption on economic growth and labour productivity in Nigeria, spanning the period from 1990 to 2019. Using an Augmented Solow Model within a Structural Vector Autoregressive (SVAR) framework, the study found that while digital technology shocks initially had a negative effect on economic growth and labour productivity, these effects became positive in the medium to long term. Additionally, they found a unidirectional causality from digital technology to economic outcomes. These findings are somewhat contrasted by the study of Diao, McMillan, and Wangwe (2018), which investigated the relationship between agricultural labour productivity and industrialisation in Africa. The researchers found that improvements in agricultural productivity positively impacted manufacturing employment shares, but this relationship was only statistically significant in Africa from 1996 onward. Unlike Chiemeké and Imafidior (2024), who focus on digital technology's short-term negative impact transitioning into long-term growth, Diao *et al.* (2018) emphasize the gradual and relatively late positive structural shift in Africa's economic landscape, which becomes significant only in the later period.

Obioma (2019) complements the findings of Chiemeké and Imafidior (2024) by focusing on technology's impact on public sector workers' productivity in Nigeria. Utilizing a survey-based method, the study concluded that inadequate training on technology significantly hindered productivity within federal ministries and agencies, a finding that aligns with the short-term negative effects of digital technology adoption observed by Chiemeké and Imafidior. The emphasis on training deficiencies as a limiting factor for productivity mirrors the broader issue of technology's disruptive effects before its benefits are fully realized. However, Obioma's study introduces a more micro-level perspective by specifically addressing the issue of technological training within organisations, contrasting with the macroeconomic focus of Chiemeké and Imafidior.

Awode and Oduola (2024), in their investigation into technological innovation and human capital development across African nations, found that while technological innovation alone negatively impacted industrial productivity, the combination of technological innovation and human capital development led to a positive synergistic effect. This finding is aligned with the broader pattern observed by Chiemeké and Imafidior, where digital technology adoption initially disrupts productivity before contributing to long-term growth. Awode and Oduola's study adds an important dimension by showing how human capital development can mitigate the negative transitional impacts of technology, suggesting that investments in education and skill development are critical to maximizing the benefits of technological advancements. This observation resonates with Obioma's findings, which underscore the importance of training and development for harnessing technology's potential within organisations.

Dauda and Akingbade (2011) focused on the effects of technological change on employee performance in Nigerian manufacturing industries, finding that technological change did not significantly influence employee relations, and employee involvement in technological innovation was often overlooked. This finding presents a contrast to the emphasis placed by Awode and Oduola on human capital development as a key factor in mitigating the negative effects of technological innovation. The lack of focus on employee involvement and training in Dauda and Akingbade's study mirrors the training deficiencies highlighted by Obioma, further emphasizing the critical role of human capital in enabling technology to enhance productivity.

Okwuchukwu *et al.* (2022) and Ugwoke *et al.* (2021) extend the discussion by examining the determinants of labour productivity and indigenous technology in industrialisation.

Okwuchukwu et al. (2022) reveal that human capital development, capital intensity, and governance positively affect labour productivity in Nigeria. However, ICT usage and per capita income are found to have negative impacts, suggesting that certain contextual factors limit the effective implementation of technology. In contrast, the study by Ugwoke et al. (2021) reveals that indigenous technology is not significantly driving industrial output, pointing to Nigeria's heavy reliance on the oil sector. These studies reflect contrasting perspectives on the impact of technology, with the former emphasizing its mixed effects on productivity and the latter questioning its current role in industrialisation.

The study by Sulaiman et al. (2024) offers insights into the broader role of human capital and technology in economic growth, affirming that both human capital (measured by secondary and tertiary enrolments) and technology (measured by R&D expenditure) significantly contribute to growth. This is consistent with the findings of Okwuchukwu et al. (2022), where human capital and capital intensity positively affect labour productivity in the long run. However, Sulaiman et al.'s (2024) reliance on school enrolment rates as proxies for human capital draws critique, as it may not accurately reflect education quality, potentially overestimating the true impact of human capital on growth. This contrasts with the more comprehensive approach taken by Okwuchukwu et al. (2022), which includes governance and globalization indices in its analysis. In a broader international context, the study by McMillan and Zeufack (2022) extends the analysis of labour productivity by examining Africa's industrialisation prospects. Similar to the sectoral disaggregation found in Ngutsav and Ijirshar (2018), McMillan and Zeufack (2022) emphasize structural change as a key driver of labour productivity in Africa's manufacturing sector, particularly the shift from low-productivity agriculture to higher-productivity manufacturing. However, unlike the Nigerian context where technology and TFP play varied roles, McMillan and Zeufack (2022) find that labour productivity improvements across Africa are primarily driven by this structural shift rather than within-sector technological advances. This underscores regional variations in how productivity is linked to economic growth.

3. Methodology

This study examines the relationship between technology, labour productivity and industrialisation and the theoretical framework of this study is anchored on the Solow Neo-Classical Growth Model and the Lewis Model which highlights the dynamics of labour migration from low productivity sectors to high-productivity sectors, such as industrialisation. In line with the Lewis model, the model for this study was adapted from the study of Obienyi et.al. (2018) on Health, Labour productivity and industrialisation in Nigeria, where industrial output is the dependent variable, while health outcome, labour productivity, investment, literacy rate are the explanatory variables.

$$IOP = f(HOU, LBP, INV, EXR, LIT) \quad (1)$$

This study modified the aforementioned model by making industrial output the dependent variable while labour productivity, technology, investment, exchange rate and literacy rate were the explanatory variables. The functional model was specified as follows:

$$IND = f(LBP, TECH, INV, EXR, LIT) \quad (2)$$

Following the structure of the ARDL model by Pesaran et al. (2001) in Abonazel and Elnabawy (2020), the short-run representation can be written with first differences (Δ) and lagged terms, along with an error correction term (ECT) representing the long-run relationship.

Given the long run equation as:

$$IND_t = \alpha_0 + \alpha_1 LBP_t + \alpha_2 TECH_t + \alpha_3 INV_t + \alpha_4 EXR_t + \alpha_5 LIT_t + \mu_t \quad (3)$$

The short-run ARDL model with error correction can be written as:

$$\Delta IND_{t-1} = \alpha_0 + \sum_{i=1}^p \alpha_{1i} \Delta IND_{t-1} + \sum_{i=0}^p \alpha_{2i} \Delta LBP_{t-1} + \sum_{i=0}^p \alpha_{3i} \Delta TECH_{t-1} + \sum_{i=0}^p \alpha_{4i} \Delta INV_{t-1} + \sum_{i=0}^p \alpha_{6i} \Delta EXR_{t-1} + \sum_{i=1}^p \alpha_{8i} \Delta LIT_{t-1} + \beta_1 ECT_{t-1} + \mu_t \quad (4)$$

Where: Δ represents the first difference operator (i.e., $\Delta Y_t = Y_t - Y_{t-1}$), α_0 is the constant term, $\alpha_{1i}, \alpha_{2i}, \dots, \alpha_{7i}$ are the short-run coefficients for each lagged difference term, β_1 is the speed of adjustment coefficient, which shows how quickly the model corrects back to the long-run equilibrium after a shock, μ_t is the error term. IND is industry value added (% of GDP), LBP is labour productivity proxy by Total Labour Force Participation Rate (%) (Odusanya, Toriola, & Ajayi, 2023), Technology is number of people with access to the internet as a percentage of the population, INV is Gross fixed Capital Formation, EXR is exchange rate and LIT is literacy rate. (Odusanya, Toriola, & Ajayi, 2023)

The a priori expectation of the relationship among the variables is summarized in the Table 1.

Table 1. *Apriori* Expectation

Variables	Apriori expectation	Sign
LBP	$\frac{\partial IND}{\partial LBP} > 0$	Positive
TECH	$\frac{\partial IND}{\partial TECH} > 0$	Positive
INV	$\frac{\partial IND}{\partial INV} > 0$	Positive
EXR	$\frac{\partial IND}{\partial EXR} > 0$ or $\frac{\partial IND}{\partial EXR} < 0$	Mixed
LIT	$\frac{\partial IND}{\partial LIT} > 0$	Positive

Source: Authors' Compilation, 2024.

The study covers the period 1994-2023 which is a period of thirty (30) years. The choice of this period is informed by the availability of data for technology which is core independent variables. The data was collected on Nigeria from the data portal of African Development Bank Group.

Table 2. Measurement of Variables

Variable	Definition	Measurements	Sources
IND	Industrial Output	industry value added (% of GDP)	African Development Bank Group (2024)
LBP	Labour productivity	Total Labour Force Participation Rate (%)	African Development Bank Group (2024)
TECH	Technology	number of people with access to the internet as a percentage of the population	African Development Bank Group (2024)
INV	Investment	Gross fixed capital formation (% GDP)	African Development Bank Group (2024)
EXR	Exchange rate	Real Exchange Rate Index (2000=100)	African Development Bank Group (2024)
LIT	Literacy	Literacy rate, adult total (% of people ages 15 and above)	African Development Bank Group (2024)

Source: Authors' Compilation, 2024.

4. Results and Discussion

4.1. Pre-Estimation Results

4.1.1. Descriptive statistics

Table 3. Descriptive Statistics

	IND	LBP	TECH	INV	EXR	LIT
Mean	23.937	59.261	18.677	15.580	100.728	56.329
Median	24.785	60.246	10.400	15.554	61.247	54.773
Maximum	34.172	60.532	67.384	20.072	607.700	70.198
Minimum	17.043	55.270	0.008	10.653	8.390	51.077
Std. Dev.	3.932	1.533	21.054	2.370	136.052	6.146
Skewness	0.265	-1.180	0.987	0.008	2.589	0.949
Kurtosis	2.832	3.257	2.716	2.569	8.939	2.793
Jarque-Bera	0.386	7.044	4.646	0.231	77.628	3.651
Probability	0.824	0.029	0.097	0.890	0.000	0.161
Observations	30	30	28	30	30	24

Note: IND: Industrialisation, LBP: Labour productivity, TECH: Technology, INV: Investment, EXR: Exchange rate, LIT: Literacy.

Source: Authors' Computation, 2024.

The descriptive statistics for the variables related to technology, labour productivity, and industrialisation in Nigeria provide key insights into their economic implications. The mean values suggest a central tendency, with the mean of industrialisation (IND) at 23.937 and labour productivity (LBP) at 59.261, indicating moderate levels of these variables relative to their respective ranges. In comparison, technology (TECH) has a mean value of 18.677, which appears lower compared to its maximum value of 67.384, suggesting that technological advancements in the country may be underdeveloped. The investment (INV) and exchange rate (EXR) show means of 15.580 and 100.728, respectively, with EXR displaying a wide range from 8.390 to 607.700, implying significant fluctuations in the foreign exchange market, likely reflective of economic instability. Literacy (LIT), with a mean of 56.329, suggests moderate literacy rates, although its minimum value of 51.077 could highlight areas of concern.

The standard deviations across the variables reveal varying levels of dispersion. The standard deviation of technology (TECH) at 21.054 shows high variability around the mean, which suggests that technological development is highly inconsistent, potentially driven by uneven access to technological resources. The exchange rate (EXR) has an even higher standard deviation of 136.052, further confirming substantial volatility, which may contribute to economic unpredictability and inflationary pressures. In contrast, labour productivity (LBP) has the lowest standard deviation of 1.533, indicating a relatively stable performance, which could imply more consistent labour market outcomes. The moderate standard deviation of investment (INV) at 2.370 indicates some fluctuations, which could affect capital accumulation and industrial growth.

The skewness values provide insights into the asymmetry of the data distributions. Most variables show positive skewness, including industrialisation (IND) at 0.265 and technology (TECH) at 0.987, indicating a rightward skew, where higher values are less frequent but possible. This might suggest the existence of occasional spikes in these variables, possibly due to policy interventions or external shocks. On the other hand, labour productivity (LBP) has a negative skew of -1.180, implying that lower values are more frequent, which could indicate structural challenges in enhancing labour productivity. The exchange rate (EXR) shows a high positive skewness of 2.589, reinforcing the idea of occasional extreme fluctuations, which could be detrimental to economic planning.

Kurtosis measures the peakedness of the data distribution, with exchange rate (EXR) showing an extremely high kurtosis value of 8.939, suggesting the presence of extreme values or outliers. This could reflect episodes of sharp currency depreciation or appreciation, both of which can have significant implications for trade and investment. Other variables, such as labour productivity (LBP) and technology (TECH), have kurtosis values close to 3, indicating more or less normal distribution tendencies.

The Jarque-Bera statistics test for normality reveal mixed results. For the exchange rate (EXR), the Jarque-Bera statistic is 77.628 with a probability of 0.000, indicating that EXR is not normally distributed at the 5% significance level, which aligns with the high skewness and kurtosis observed. Similarly, labour productivity (LBP) also shows non-normality with a Jarque-Bera value of 7.044 and a probability of 0.029, pointing to deviations from normality, which might stem from underlying structural inefficiencies. In contrast, industrialisation (IND) and investment (INV) show Jarque-Bera probabilities of 0.824 and 0.890, respectively, suggesting normal distribution, implying more stable and predictable patterns in these areas. Technology (TECH), with a probability of 0.097, falls close to normality but with some deviations, likely due to the significant variability in technological advancements across different periods.

4.1.2. Correlation

Table 4. Pairwise Correlation Matrix

	IND	LBP	TECH	INV	EXR	LIT
IND	1.000	0.386	-0.601	-0.135	-0.616	-0.017
LBP	0.386	1.000	-0.577	0.530	-0.587	0.283
TECH	-0.602	-0.577	1.000	-0.533	0.782	0.121
INV	-0.135	0.530	-0.533	1.000	-0.499	0.102
EXR	-0.616	-0.587	0.782	-0.499	1.000	0.096
POP	0.481	0.441	-0.806	0.490	-0.688	-0.210
LIT	-0.017	0.283	0.121	0.102	0.096	1.000

Note: IND: Industrialisation, LBP: Labour productivity, TECH: Technology, INV: Investment, EXR: Exchange rate, LIT: Literacy.

Source: Authors' Computation, 2024.

The pairwise correlation coefficient shows that, the relationship between industrialisation and labour productivity is moderately positive (0.386), suggesting that increases in labour productivity are associated with higher levels of industrialisation. This reflects Nigeria's economic reality, where improvements in workforce efficiency may contribute to industrial growth. However, the correlation between industrialisation and technology is negative and moderately strong (-0.601), indicating an inverse relationship. This suggests that despite global trends, technological advancements in Nigeria have not fully integrate technology into industrial processes, potentially due to barriers in adoption or infrastructure.

Similarly, industrialisation shows a negative correlation with exchange rate (-0.616), implying that fluctuations in the exchange rate negatively impact industrial output. This is consistent with the country's reliance on imported capital goods, where exchange rate instability increase costs for industrial production. Interestingly, the relationship between industrialisation and literacy is very weak and negative (-0.017), indicating that improvements in literacy did not directly translate into increase in industrial growth, potentially highlighting a mismatch between educational outcomes and the needs of the industrial sector.

Labour productivity correlates negatively with technology (-0.577), suggesting that technological advancements do not effectively enhance labour productivity in Nigeria. This might be due to a lack of proper training or inefficient integration of technology in key sectors. Investment, on the other hand, has a moderate positive correlation with labour productivity

(0.530), indicating that increased capital investment is associated with higher productivity. However, labour productivity's negative correlation with exchange rate (-0.587) reinforces the notion that currency volatility can hinder productivity gains.

The correlation between technology and exchange rate is notably strong and positive (0.782) suggesting that technological development is highly dependent on the exchange rate. This is likely because technology imports are sensitive to currency fluctuations, further underscoring the impact of exchange rate volatility on Nigeria's technological growth. Investment correlates negatively with technology (-0.533), which might indicate that investment in certain sectors does not necessarily lead to technological advancements, reflecting possible inefficiencies in capital allocation.

Investment shows a weak positive correlation with literacy (0.102), suggesting that while literacy may play a role in attracting investment, the effect is minimal. This could point to a gap in human capital development, where literacy rates are not sufficiently aligned with the skills required for investment-driven growth. Similarly, literacy's weak correlations with other variables, such as industrialisation (-0.017) and exchange rate (0.096), suggest that while literacy is essential, its direct influence on economic variables like industrial growth or currency stability may be limited in the Nigerian context.

4.1.3. Unit root test

Table 5. ADF - Fisher Chi-square

Variables	LEVEL		FIRST DIFF.	
	Stats.	Prob.	Stats.	Prob.
IND	-3.821	0.007***	-7.190	0.000***
LBP	-2.181	0.216	-3.993	0.005***
TECH	-1.128	0.686	-3.635	0.013***
INV	-2.793	0.071	-6.390	0.000***
EXR	0.358	0.976	-6.517	0.000***
LIT	-2.273	0.188	-4.661	0.001***

Key: *10%, ** 5% & *** 1%.

Note: IND: Industrialisation, LBP: Labour productivity, TECH: Technology, INV: Investment, EXR: Exchange rate, LIT: Literacy

Source: Authors' Computation, 2024.

4.2. Estimation

Table 6. ARDL Result

Dependent variable: IND				
Variables	Co-efficient	Standard Error	T-statistics	P-value
Short Run Coefficient				
IND(-1)	-0.170	0.148	-1.151	0.270
D(TECH)	-2.428	0.633	-3.835	0.002
D(INV)	-1.106	0.183	-6.042	0.000
D(EXR)	0.705	0.209	3.363	0.006
D(LIT)	0.075	0.080	0.933	0.370
Cointeq01	-1.170	0.147	-7.910	0.000
Long Run Coefficient				
LBP	-1.109	0.323	-3.431	0.005
D(TECH)	-3.390	0.548	-6.187	0.000
D(INV)	-1.559	0.281	-5.533	0.000
D(EXR)	1.302	0.286	4.548	0.000
LIT	0.064	0.067	0.961	0.356

Note: IND: Industrialisation, LBP: Labour productivity, TECH: Technology, INV: Investment, EXR: Exchange rate, LIT: Literacy.

Source: Authors' Computation, 2024.

In the short run, labour productivity (LBP) has a negative and significant coefficient ($\beta = -1.298$; $t = -3.201$; $\text{Pr}(0.05) = 0.008$). This indicates that an increase in labour productivity reduces industrialisation in the short run. The size of the coefficient is relatively large, signifying that even marginal increase in labour productivity have substantial adverse effects on industrial growth. This negative relationship reflects structural issues in Nigeria's labour market, such as inadequate skill development or inefficiencies in workforce utilization, which limit the ability of industries to grow.

Similarly, technology (TECH) also has a negative and significant short-run coefficient ($\beta = -2.428$; $t = -3.835$; $\text{Pr}(0.05) = 0.002$), suggesting that technological advancements are not effectively driving industrialisation in the short term. The size of the coefficient is large, highlighting the substantial impact that underutilized or poorly integrated technology can have on industrial performance. This could be due to Nigeria's challenges in adopting and adapting foreign technologies, lack of infrastructure, or insufficient investment in research and development, which prevents technology from positively contributing to industrialisation in the short run.

Investment (INV) shows a negative and highly significant effect on industrialisation in the short run ($\beta = -1.106$; $t = -6.042$; $\text{Pr}(0.05) = 0.000$). The coefficient's magnitude indicates that investment is crucial for industrial growth, and increase in investment severely hampers industrial output. This result is counterintuitive, as investment is typically expected to drive industrialisation. However, this negative relationship reflects inefficient allocation of investment, where funds are directed toward sectors that are not contributing to industrial development or are mismanaged.

In contrast, the exchange rate (EXR) has a positive and significant coefficient in the short run ($\beta = 0.705$; $t = 3.363$; $\text{Pr}(0.05) = 0.006$), indicating that an appreciation of the local currency relative to foreign currencies boosts industrialisation. A stronger exchange rate makes Nigerian products more competitive internationally by reducing export prices, thereby stimulating industrial production. However, the coefficient size, while positive, suggests that this effect is moderate, implying that while exchange rate appreciation offer short-term industrial growth.

Literacy (LIT), however, has an insignificant short-run coefficient ($\beta = 0.075$; $t = 0.933$; $\text{Pr}(0.05) = 0.370$), suggesting that changes in literacy levels do not have a direct impact on industrialisation in the short term. This reflect a situation where the literacy improvements are not specifically aligned with the skills required for industrial jobs or when other structural issues overshadow human capital development.

The error correction term (Cointeq01) is highly significant and negative ($\beta = -1.170$; $t = -7.910$; $\text{Pr}(0.05) = 0.000$), confirming the existence of a long-run equilibrium relationship between industrialisation and the explanatory variables. The coefficient value of -1.170 indicates that approximately 117% of any disequilibrium is corrected within one period, implying a strong adjustment speed back to long-run equilibrium whenever industrialisation deviates from its long-run path.

In the long run, labour productivity (LBP) continues to have a negative and significant impact on industrialisation ($\beta = -1.109$; $t = -3.431$; $\text{Pr}(0.05) = 0.005$). This suggests that persistent inefficiencies in labour productivity can hinder long-term industrial development. Over the period from 1994 to 2023, structural issues such as low worker efficiency, lack of training, and inadequate labour market policies may have consistently undermined industrialisation efforts in Nigeria.

Technology (TECH) also has a significantly negative long-run coefficient ($\beta = -3.390$; $t = -6.187$; $\text{Pr}(0.05) = 0.000$), indicating that despite technological advancements, their application does not fully supports industrial growth in Nigeria in the long term. The large size of the coefficient suggests that improvements in technology, when not effectively integrated into the

industrial sector, tends to harm industrialisation, possibly due to issues like technological obsolescence or failure to adapt innovations to local conditions.

Investment (INV) similarly shows a negative and highly significant long-run impact on industrialisation ($\beta = -1.559$; $t = -5.533$; $\Pr(0.05) = 0.000$). The large coefficient further suggests that misallocation of investment resources or inadequate investment in critical industrial sectors has long-term detrimental effects on industrial growth. This result reflects Nigeria's economic reality, where investments does not always target the most productive industrial sectors or is hindered by poor infrastructure and corruption.

The exchange rate (EXR) continues to have a positive and significant long-run effect ($\beta = 1.302$; $t = 4.548$; $\Pr(0.05) = 0.000$). This result implies that over time, a stronger currency supports industrialisation by making domestic industries more competitive in the global market. Literacy (LIT) remains insignificant in the long run ($\beta = 0.064$; $t = 0.961$; $\Pr(0.05) = 0.356$), suggesting that literacy improvements alone have not translated into industrial growth. This could reflect the mismatch between the education system and the industrial sector's needs, where higher literacy rates do not necessarily mean an adequately skilled workforce for industrial purposes.

On the overall, while exchange rate appreciation appears to support industrial growth, persistent inefficiencies in labour productivity, technology, and investment are significant barriers. The large negative coefficients for these variables, both in the short run and the long run, point to deep-rooted structural issues in the Nigerian economy that hinder sustained industrial growth despite policy efforts.

Table 7. Diagnostic Test

Test Statistics	Test Types	Values	Prob.		
Normality Test	Jarque-Bera	0.784	0.675		
Wald Test	F-statistic	1.325	0.274		
F-Bounds Test	F-statistic	6.725		I(0)	I(1)
	K	3	5%	2.62	3.79
Breusch-Godfrey Serial Correlation LM Test	F-statistic	0.441	0.909		
Ramsey RESET Test	F-statistic	0.013	0.909		

Source: Authors' Computation, 2024.

From the table above, the ARDL post-estimation diagnostic tests provide essential validation for the reliability and robustness of the model. The normality test using the Jarque-Bera statistic yields a value of 0.784 with a probability of 0.675, indicating that the residuals are normally distributed, as the probability exceeds the 5% significance level. This suggests that the assumption of normality is not violated, which is critical for ensuring that the model's estimators are unbiased and efficient.

The Wald test, with an F-statistic of 1.325 and a probability of 0.274, assesses the joint significance of the coefficients in the model. Since the probability is greater than 0.05, we fail to reject the null hypothesis that the coefficients are jointly equal to zero. This result suggests that, individually, the coefficients may not significantly contribute to explaining the dependent variable in the short run. However, this does not necessarily undermine the overall model but indicates that further attention might be needed to interpret the significance of specific variables.

The F-bounds test, used to determine the existence of a long-run relationship, reports an F-statistic of 6.725, which is compared against critical values at different significance levels. At the 5% significance level, the lower bound I(0) is 2.62, and the upper bound I(1) is 3.79. Since the calculated F-statistic (6.725) exceeds the upper bound, the study concludes that a long-run

cointegrating relationship exists among the variables. This indicates that despite short-run fluctuations, the variables move together in the long run, which is essential for policy implications concerning industrialisation, labour productivity, and technology.

The Breusch-Godfrey Serial Correlation LM test produces an F-statistic of 0.441 with a probability of 0.909, suggesting no evidence of serial correlation in the residuals. The absence of serial correlation ensures that the estimates from the ARDL model are unbiased and efficient, validating the model's reliability for forecasting and policy analysis.

Finally, the Ramsey RESET test yields an F-statistic of 0.013 with a probability of 0.909, implying that the model is correctly specified. The high probability value indicates that there is no significant misspecification in the functional form of the model. This test further strengthens the credibility of the model, confirming that the relationships between the variables are correctly modelled without the need for additional higher-order terms.

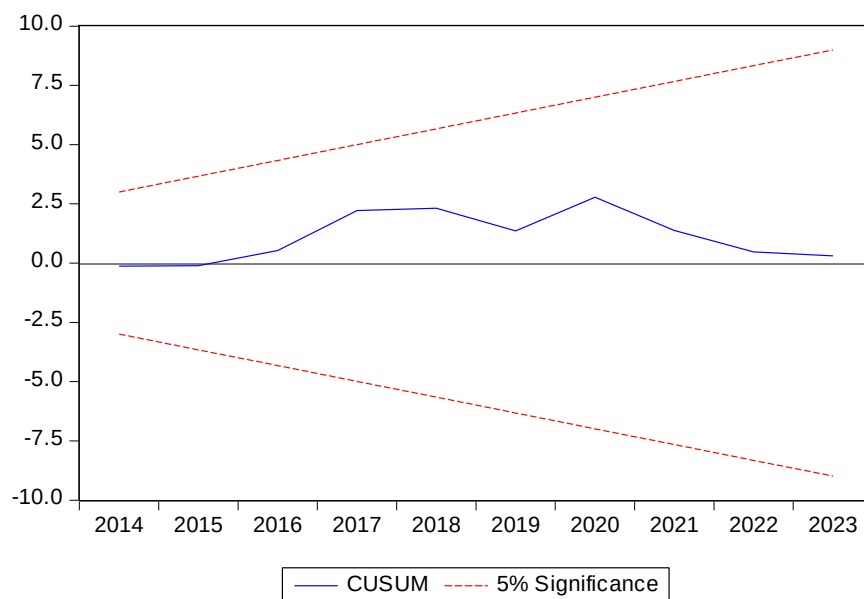


Fig. 1. CUSUM

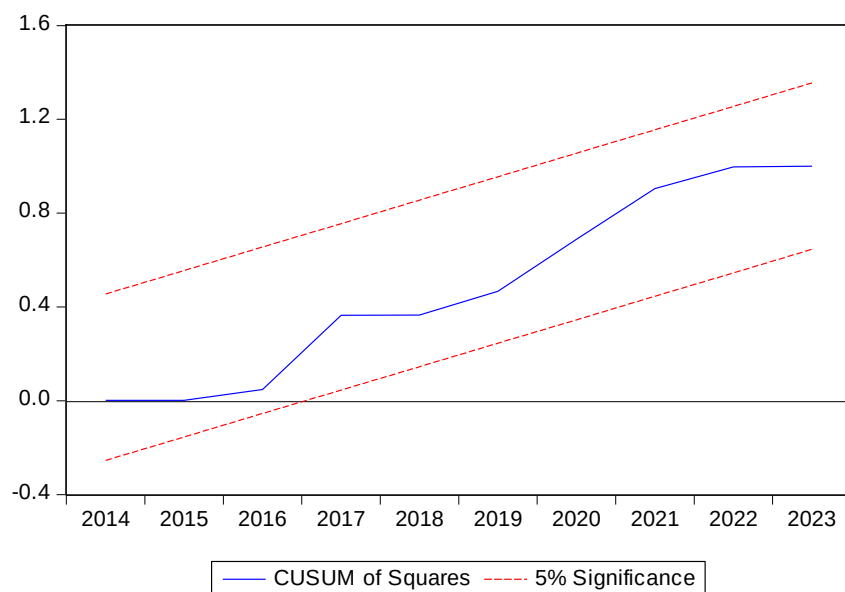


Fig. 2. CUSUM of Squares

The CUSUM (Cumulative Sum) and CUSUM of squares tests are commonly used to assess the stability of an estimated model's coefficients over time. When the blue line, representing the CUSUM and CUSUM of squares tests, falls within the red lines, which denote the critical bounds at a 5% significance level, the model can be considered structurally stable. This result implies that the estimated coefficients remain consistent and do not experience significant shifts or breaks over the sample period.

For the CUSUM test (Figure 1), the stability of the model suggests that the relationship between the dependent and independent variables has remained constant over time, with no significant structural changes. This is crucial for ensuring the reliability of long-term policy recommendations, as it indicates that the underlying economic relationships have been stable throughout the period under investigation.

Similarly, in the CUSUM of squares test (Figure 2), the blue line falling within the bounds suggests no evidence of variance instability, meaning the error variance has remained constant, further validating the model's robustness. This indicates that the model does not suffer from heteroskedasticity, and the estimators remain efficient. In the context of economic analysis, the stability of both tests underscores the model's suitability for making forecasts and drawing inferences about the dynamics between the variables under study, as the relationships have not been subject to significant disturbances over time.

Table 8. Interactive Effect of Technology and Labour Productivity on Industrialisation

Dependent variable: IND				
Variables	Co-efficient	Standard Error	T-statistics	P-value
Short Run Coefficient				
D(IND(-1))	0.497631	0.166136	2.995320	0.0067
D(LBP)	-2.237965	1.494044	-1.497924	0.1484
D(TECH)	-6.839281	4.876377	-1.402533	0.1747
D(LBP * TECH)	0.113862	0.082396	1.381898	0.1809
CointEq(-1)	-1.196565	0.221033	-5.413509	0.0000
Long Run Coefficient				
LBP	-1.870324	1.181860	-1.582526	0.1278
TECH	-5.715762	3.930605	-1.454169	0.1600
LBP*TECH	0.095158	0.066486	1.431244	0.1664

Note: IND: Industrialisation, LBP: Labour productivity, TECH: Technology, INV: Investment, EXR: Exchange rate, LIT: Literacy.

Source: Authors' Computation, 2024.

From the short-run dynamics, the coefficient of the lagged dependent variable, D(IND(-1)) ($\beta = 0.4976$; $t = 2.9953$ & $\Pr(0.05) = 0.0067$), is positive and statistically significant at the 5% level. This suggests that industrialisation in the previous period significantly impacts current industrialisation levels. The coefficient value of approximately 0.50 implies a moderate persistence of industrialisation over time, indicating that past industrial performance moderately carries over into the present. This persistence reflects Nigeria's gradual industrialisation process, where previous gains in manufacturing and industrial activities tend to have a lasting impact, though not overwhelmingly large.

Labour productivity, D(LBP) ($\beta = -2.2380$; $t = -1.4979$ & $\Pr(0.05) = 0.1484$), has a negative but statistically insignificant coefficient in the short run. Although the negative coefficient suggests that increases in labour productivity could potentially decrease industrialisation in the short run, this result lacks statistical support at the 5% level. The lack of significance may indicate that short-run fluctuations in labour productivity are not strong enough to drive immediate changes in industrialisation. In the Nigerian context, short-term changes in workforce efficiency might be insufficient to spur industrial growth, likely due to structural bottlenecks or inefficiencies in labour markets.

Similarly, technology, D(TECH) ($\beta = -6.8393$; $t = -1.4025$ & $\Pr(0.05) = 0.1747$), has a negative coefficient, suggesting that technological advancements hinder industrialisation in the short run. However, like labour productivity, this effect is statistically insignificant at the 5% level. This could be reflective of Nigeria's challenges in effectively integrating new technologies into industrial processes. Technological advancements alone, without the requisite infrastructure or skilled labour, may not translate into immediate industrial gains, as evidenced by the insignificant coefficient.

The interaction between labour productivity and technology, D(LBP*TECH) ($\beta = 0.1139$; $t = 1.3819$ & $\Pr(0.05) = 0.1809$), is also positive but statistically insignificant in the short run. The positive coefficient suggests that the combined effect of improvements in labour productivity and technology could potentially enhance industrialisation, but the lack of significance implies that this interaction is not a major driver in the short-term dynamics. This result points to the complexity of aligning both labour productivity and technological advancements to generate immediate industrial benefits, which could be hampered by structural challenges within the Nigerian economy.

The error correction term, CointEq(-1) ($\beta = -1.1966$; $t = -5.4135$ & $\Pr(0.05) = 0.0000$), is highly significant and negative, confirming the presence of a long-run equilibrium relationship among the variables. The magnitude of the coefficient indicates a strong adjustment speed, where approximately 119% of the disequilibrium from the previous period is corrected in the current period. This fast adjustment suggests that deviations from the long-run industrialisation path are quickly corrected, reflecting the strong long-run relationships between industrialisation, labour productivity, and technology in Nigeria.

In the long run, labour productivity, LBP ($\beta = -1.8703$; $t = -1.5825$ & $\Pr(0.05) = 0.1278$), remains negative but statistically insignificant. This suggests that in the long run, increases in labour productivity does not necessarily lead to higher levels of industrialisation, possibly due to the structural nature of Nigeria's economy, where labour-intensive sectors may not directly translate into increased industrial output without complementary improvements in capital and infrastructure.

Technology, TECH ($\beta = -5.7158$; $t = -1.4542$ & $\Pr(0.05) = 0.1600$), also maintains a negative but statistically insignificant relationship with industrialisation in the long run. The negative coefficient, although not significant, suggesting Nigeria's struggle with technological adoption. This imply that while technological advances occur, they may not be effectively harnessed to promote industrial growth, potentially due to issues such as poor infrastructure, inadequate technological training, or mismatches between technological innovations and the needs of the industrial sector.

The interaction between labour productivity and technology, LBP*TECH ($\beta = 0.0952$; $t = 1.4312$ & $\Pr(0.05) = 0.1664$), remains positive but statistically insignificant in the long run. The positive coefficient suggests that, improvements in both labour productivity and technology could complement each other to promote industrialisation, but the insignificance of the result points to the challenges in achieving this synergy. This indicate that while Nigeria has the potential to harness both factors for industrial growth, the current conditions may not be conducive to realising these benefits.

Table 9. Diagnostic Tests

Test Statistics	Test Types	Values	Prob.
Normality Test	Jarque-Bera	0.679	0.711
Wald Test	F-statistic	1.325	0.274
Breusch-Godfrey Serial Correlation LM Test	F-statistic	0.441	0.649
Ramsey RESET Test	F-statistic	0.366	0.551

Source: Authors' Computation, 2024.

The ARDL post-estimation diagnostics based on normality test using the Jarque-Bera statistic (0.679, $p = 0.711$) indicates that the residuals of the model are normally distributed, as the p-value is well above the 5% significance level. This suggests that the assumption of normality in the error terms holds, which is essential for ensuring that the model's estimators are unbiased and efficient.

The Wald test, with an F-statistic of 1.325 and a p-value of 0.274, tests the joint significance of the model's coefficients. Since the p-value exceeds 0.05, we fail to reject the null hypothesis that the coefficients are jointly insignificant, indicating that there is no overwhelming evidence to suggest that the estimated coefficients have a strong collective effect. This result could imply that while individual coefficients might hold some significance, their combined influence on the dependent variable may not be statistically powerful enough to drive robust conclusions.

The Breusch-Godfrey Serial Correlation LM Test, with an F-statistic of 0.441 and a p-value of 0.649, tests for the presence of serial correlation in the residuals of the model. A p-value above 0.05 indicates no significant serial correlation, meaning that the residuals are uncorrelated over time. This is crucial for the validity of the ARDL model as it ensures that the errors do not exhibit autocorrelation, thereby confirming that the estimates remain efficient.

Finally, the Ramsey RESET Test, with an F-statistic of 0.366 and a p-value of 0.551, examines whether the model is correctly specified or suffers from omitted variable bias. Given that the p-value is greater than 0.05, we cannot reject the null hypothesis, implying that the model is correctly specified and there is no strong evidence of misspecification. This suggests that the functional form of the model is adequate for capturing the relationships between the variables, and that no critical variables have been omitted.

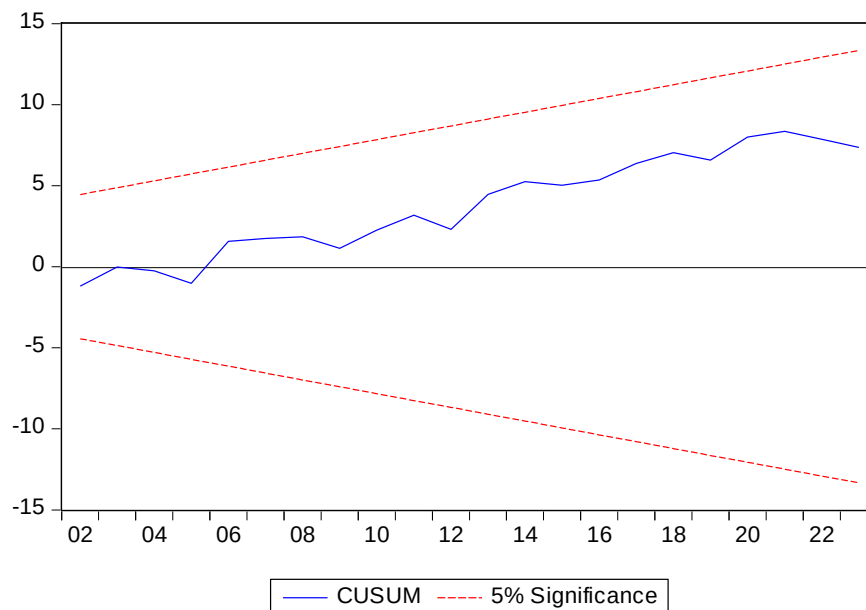


Fig. 3. CUSUM

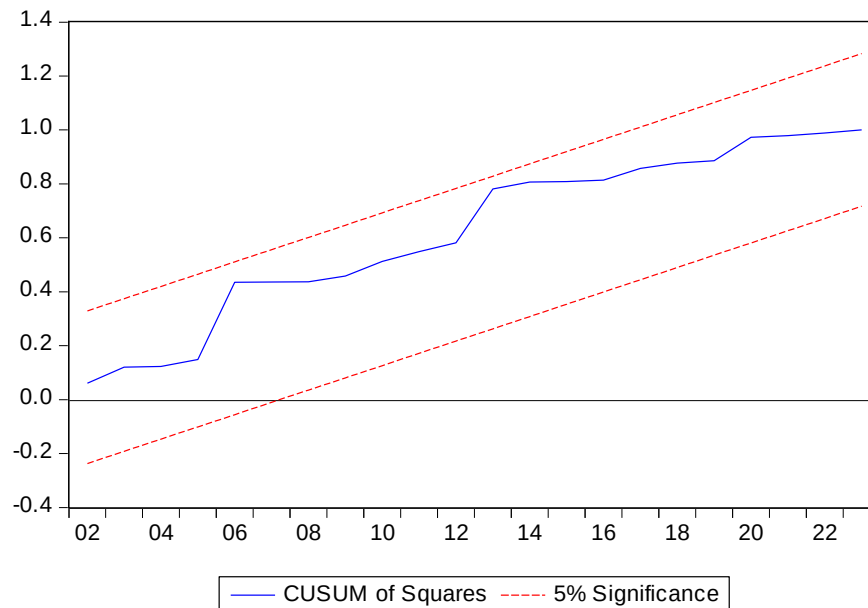


Fig. 4. CUSUM of Squares

The CUSUM (Cumulative Sum) and CUSUM of squares tests are commonly used to assess the stability of an estimated model's coefficients over time. When the blue line, representing the cumulative sum of recursive residuals (CUSUM) or their squares (CUSUM square), falls within the red lines, which denote the critical bounds at a 5% significance level, the model can be considered structurally stable. This result implies that the estimated coefficients remain consistent and do not experience significant shifts or breaks over the sample period.

For the CUSUM test (Figure 3), the stability of the model suggests that the relationship between the dependent and independent variables has remained constant over time, with no significant structural changes. This is crucial for ensuring the reliability of long-term policy recommendations, as it indicates that the underlying economic relationships have been stable throughout the period under investigation.

Similarly, in the CUSUM of squares test (Figure 4), the blue line falling within the bounds suggests no evidence of variance instability, meaning the error variance has remained constant, further validating the model's robustness. This indicates that the model does not suffer from heteroskedasticity, and the estimators remain efficient. In the context of economic analysis, the stability of both tests underscores the model's suitability for making forecasts and drawing inferences about the dynamics between the variables under study, as the relationships have not been subject to significant disturbances over time.

5. Conclusions and Recommendations

The study investigates the interplay between technology, labour productivity, and industrialisation in Nigeria over the period from 1994 to 2023, utilizing the ARDL model framework as outlined by Pesaran et al. (2001). The findings reveal that in both the short and long run, labour productivity (LBP) and technology (TECH) has a negative and significant impact on industrialisation while in the interactive result, they are both positive but statistically insignificant in both short and long run. Investment (INV) shows a strong negative effect on industrialisation in both the short and long run. On the other hand, the exchange rate (EXR) has a positive and significant short and run impact on industrialization. Literacy (LIT) does not have a significant short and long run effect on industrialization. The interaction term between labour productivity and technology (LBP*TECH) is positive but statistically insignificant in both short

and long run. The findings of this study are further corroborated by Chiemeké and Imafidor (2024) and that found negative effect of digital technology shocks on economic growth and labour productivity. Awode and Oduola (2024) also found that technological innovation alone negatively impacted industrial productivity. However, these findings are somewhat contrasted by the study of Diao, McMillan, and Wangwe (2018) Dauda and Akingbade (2011), which investigated the relationship between agricultural labour productivity and industrialisation in Africa.

Based on the findings, the following recommendations can be made: Enhance labour productivity: there is need to address structural issues in the labour market by investing in skill development programs and improving workforce efficiency to align with industrial needs; Optimise technology integration within industries by addressing infrastructure gaps and increasing investment in research and development in order to ensure that technological advancements positively impact industrialisation; Ensure that investments are strategically directed towards sectors with high industrial growth potential and are managed effectively to avoid misallocation and inefficiencies; Implement broader economic reforms to leverage the positive effects of exchange rate depreciation, while mitigating potential adverse impacts such as inflation and high input costs; and lastly, reform the education system to better align with the skills required in the industrial sector, ensuring that literacy improvements translate into tangible industrial benefits.

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