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ICT, Employment and Labor Productivity in Nigeria: An Ardl Bound Testing Approach

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Abstract
This study investigates the link between ICT, employment on labor productivity Nigeria in the time span of 31 years from 1990 to 2020. The Autoregressive distributed lag model (ARDL) is applied for ICT, employment-productivity nexus in the short and long run. Short run results indicate that in Nigeria ICT has positively increases labor productivity, while employment have a significant negative impact on worker productivity. The results also depict, in the long run ICT such as computer hardware and communication equipment positively and significantly impact productivity rate. ICT contributes around 0.32% in the long run on labor productivity. While employment shows higher negative and significant impact on labor productivity with about 15%. The higher employment rate is associated with lower productivity of workers in Nigeria. ent.
Keywords: ICT, Employment, Labor Productivity, Nigeria.

Introduction

Productivity is one of the most important factors influencing a country's competitiveness (Jorgenson and Kuroda, 1991), economic growth (Mills, 1952; Niebel, 2018), wealth (Nickell, 1996), and living standards (Backman and Gainsbrugh, 1949). One component of the total factor productivity is labor productivity.

The integrated financial rising level has been invigorated by propelling information and communication technology (ICT), rendering innovation selection an extraordinary significance for economic development and efficiency enhancement (Dimelis & Papaioannou, 2010). There is an agreement that the passage of ICT in advanced nations is related to critical performance changes. Moreover, the evidence proposes a significant difference among countries with European economies having less increment in ICT associated with ICT than the U.S., which has sustained productivity growth since the mid-1990s in sectors linked to ICT production and ICT usage (Basant et al., 2006). Unfortunately, its impact is minimal in underdeveloped or developing countries. Still, daily, there is progress in the application of ICT in these growing and underdeveloped countries as compared to before (Lovrić, 2012). For this reason, understanding the relationship between ICT and labor productivity in a selected developing country like Nigeria will further broaden the scope of its importance.

Nigeria is located in west Africa and has the highest population, with about 240 million people, in west Africa and the entire African continent. Even with its high labor force, productivity is less (World Population, 2022). labor dependency ratio is expected to reach 2.6 percent by this year, for this reasons, the impact of unemployment has been significant over time. The number of locals without jobs was predicted to increase to over 6.3 million in 2021 along with the growing number of people who are considered to be "active." Overall, Nigeria's unemployment rate has significantly increased, and in 2020 it was 9%. A nation's wealth and economic assets are influenced by productivity since more high-wage workers are prolific. Therefore, researchers and policymakers need to assess the impelling cause of efficiency and output increment. ICT is a modern innovation that uses artificial intelligence to improve future innovations (Cardona et al., 2013). Computers and the internet have aided in producing goods, services, creation, and aggregate production in the ICT sector. Furthermore, it impacts the generation, saving, and sharing of information and decreases market distortion (Biagi, 2013). The review indicates that ICT contributes positively to innovation and productivity and thus can raise productivity in growing economies.

In Nigeria, the use of information and communication technology (ICT) is more prevalent in the private sector than in the public sector. The private sector is primarily designed to maximise profit through human resource efficiency and proficiency while minimising costs. As a result, the public sector is less concerned with the electronic production process, as can be seen in Nigerian public institutions (Olalekan, 2012).

Further more, liberalization of the telecommunications sector and the establishment of large commercial telecommunication providers like ECONET (now AIRTEL), MTN, GLOBACOM, ETISALAT (now 9MOBILE), and others followed Nigeria's transition to democracy in 1999. The reform has greatly enhanced the ICT sector's contribution to Nigeria's economy and the wellbeing of its people. In terms of employment, the information and communications technology (ICT) sector has been a key driver in improving the lives of Nigeria's young people (Sofowora, 2009; Oladunjoye and Audu, 2014).

The objective of the study is to evaluates ICT's long- and short-run impact on workers' productivity using time series data from 1993-2020 in Nigeria. Nigeria as the highest population country in Africa with large number of workers, but most rural communities in Nigeria presently is the absence of telecommunication and electricity services. Even in the urban areas, the challenges of power failure and poor telecommunication network are still pervasive. Most businesses and individuals currently generate their own power supply (Ogbuabor et al., 2020). In addition, to our knowledge there is no study done on ICT in Nigeria and has been more specific on worker productivity.

The motivation behind this paper is first, to identify the short-term and long term structural factors that explain the impact of ICT on worker productivity in Nigeria. Second, Nigeria is associated with high population growth, yet productivity is very low compare with other African countries. Another motivation, past studies highlighted the ICT-growth nexus, however, the missing link between ICT and productivity of workers attracted and motivated this study to investigate this relationship.

Therefore, this study attempts contribute to previous studies by filling the gap in the impact of ICT and employment growth on workers' productivity in Nigeria. Hence, whether increasing ICT in Nigeria will influence growth in the long run and short run. The remainder of this article is organized as follows: Section 2 review previous literature, while section 3 outlines the materials and methods used in the study. Section 4 illustrates the findings and gives

discussions on the augmented results. Last, section 5 concludes and provides policy recommendations.

Literature Review

ICT is a modern innovation that uses artificial intelligence to improve future innovations. A nation's wealth and economic assets are productivity influenced. Productivity and growth are affected explicitly and implicitly by ICT. However, not every study conducted previously found the same result. Hence, the section entails write-ups and scholarly works from academics and non-academics on how ICT affects workers' productivity.

Nurmilaakso (2009) investigates the effect of ICT solutions on firm-level labor productivity growth. In 2005, between January and February, he gathered 5218 observations from 10 industries across five nations. In addition, the poll found that implementing an ICT solution can significantly increase worker output. Again, this result is valid only in the short term.

Studies on macrolevel such as, Chansarn (2010) conducted studies using data from wealthy and emergent nations. He partitioned the countries into four groups after running data for 25years, revealing a significant effect on ICT and workers' productivity. Still, he also found that emergent nations are less productive than developed nations. Similarly, Lovric (2012) studied 14 wealthy nations and 11 emergent countries for ten years. He also realized a remarkable impact on workers' productivity with ICT. Nonetheless, he figured that the positive effects of ICT in developed nations are far more than that of developing countries.

Additionally, Palvalin et al (2013) explores the prospects of ICT in the capacity building of workers. The author reviews previous studies and a case study in a medium-sized European teleoperator company. He deduces that ICT could end a hopeless task or bring about efficiency. Moreover, ICT can enhance workers' well-being through context transformation, which limits unimportant activities. He emphasized that examining the quality of ICT services and the organizational settings makes it easier to estimate ICT's effect on worker productivity knowledge.

A recent study by Lefophane and Kalaba (2022) examined the extent to which investment in ICT contributes to the growth in labor productivity, employment and output of South Africa's agro-processing subsector. This study ranked ten agroprocessing sectors using the ICT intensity index into two categories, the more ICT-intensive industries and the less ICT-intensive industries. PMG estimations were conducted to estimate the short- and long-run effects of ICT intensity on growth of labor productivity and the results show that, ICT intensity has a greater positive and significant impact on the growth of ICT-intensive industries. For the more ICT-intensive industries, there was evidence of a causal relationship.

Cardona et al (2013) explore the relationship between ICT and productivity in the U.S and Europe using different methodological approaches. The study adopts both parametric and nonparametric to empirically examine the impact of ICT on productivity at the macro and microeconomic levels and using data from the country, industrial and firm levels. They suggest a significant positive relationship between ICT and productivity. However, the impact of ICT differs according to the methodological models. The growth accounting results show that ICT influences cumulative and sectorial growth between the U.S and Europe. The findings from the firm analysis reveal an insignificant difference between the countries.

Also, Biagi (2013) investigates the effects of ICT and advanced innovation on financial and efficiency development. A large part of the analysis concurs on the significance of ICT for the U.S. development resurgence ranging from 1995 to 2006. ICT influences development and efficiency both directly and indirectly. He suggests that ICT plays a significant role in U.S

productivity in the producing segment and capital deepening. Also, he asserts that ICT is mainly responsible for the dissimilarity in production efficiency in the U.S and the E.U. From 1995 to 2005. However, after 2005 a break was observed in U.S work efficiency development, which decreased the E.U-US efficiency gap and subsequently the part of ICT.

Diaz-Chao et al (2015) examine the influence of ICT on a company's productivity and labor market output by surveying the manufacturing sector in Argentina. From their assertion, information technology enhances a firm's income and productivity. Nonetheless, this impact differs among the organization. However, the study reveals that adopting information and communication technology can significantly affect workers' employment. That is, the participation of unskilled labor in the labor force will decline due to replacing workers with ICT tools in Argentina's manufacturing sector.

Interestingly, Appiahene et al (2018) conducted their study in Asia, America, and Europe. They mentioned that Africa has limited information. He suggested that researchers study ICT and worker productivity in Africa because, according to him, from 2005 to 2017, about 8.51 percent of studies were conducted in Africa. While recent study by Viollaz (2019) on firm-level data (Micro and small manufacturing firms) in Peru. He gathered data from 2011 to 2013. The results of this research indicate a robust positive correlation between advances in information and communications technology and increases in worker productivity in small and medium-sized enterprises. This study only addressed the impact for a relatively brief time.

Intriguingly, Abramova and Grishchenko (2020), drawing on research in Russia using data from 2005-2017, find only a weak correlation between ICT and growth in labor productivity. Contrary to other research findings, theirs indicated that the decline in labor productivity due to expanding information and communication technologies was both small and inconsequential. Although labor productivity growth was slightly higher in some years, it was inconsistent. This research indicated that long-period data was necessary to observe the long-run period relationship.

The previous mentioned literatures differs in their studies of productivity. For instance, few studies used total factor prodctivity and others used GDP per capita as an indicator of worker productivity. While other paid more attention to micro level of entreprises productivity. Hence, studying the impact of ICT on labor productivity in Nigeria will broaden the literature and give significant contribution to scholars and policy makers. In addition, few studies focused on short run and long run analysis of ICT investment especially in developing countries such a case of Nigeria where investment environment and quality of institution is less developed.

Methodology

The study's data and methodology section outline the steps and actions the researcher took to look at how ICT affects workers' productivity at the national or macroeconomic level. The author uses an empirical model to reveal the relationship between the scout variable and the other two potential variables that might impact workers' productivity. These factors include the increase of physical capital, which the Gross Fixed Capital Formation represents, and the growth of employment, which shows the number of people employed. The typical Cobb-Douglas production function, as used in Mankiw et al. (1992) studiess of information technology, capital and physical human capital, is used in this study to examine the relationship between the variables of interest. The function is;

$$Y_t = AK_t^a L_t^{1-a} \qquad (1)$$

Where the dependent variable (Y_t) is the output, A is the level of technology that represents ICT, K_t is the capital inputs incorporated in the production process, L_t is the labor input, t is the time trend, and 0 < α < 1. Thus, we can have an extended Cobb-Douglass production function written as;

$$Y_t = ICT, K_t^a L_t^{1-a} \qquad (2)$$

By dividing both sides of the equation by the labor input, the following empirical resulting regression is;

$$Y_t/_{L_t} = ICT, \left(K_t/_{L_t}\right)^a L_t^{1-a} \qquad (3)$$

The equation (3) above is the capital- ratio and % age of labor at a particular period (t) in a given series.

The regression shown below is the study's final empirical model.

$$Y_t = \theta_0 + \theta_1 Z_t + \theta_2 W_t + \theta_3 X_t + \varepsilon_t \qquad (4)$$

Where Y is the dependent variable and *W, Z* and *X* are explanatory variables, θ_0 to θ_3 are the parameters of the explanatory variables and, ε_t. The random error term in the model includes all possible important factors not captured by equation (4) above.

Method and Model Specification

The study uses the Autoregressive Distributed Lag Model (ARDL) to examine the relationship between the latent variables econometrically. The ARDL model is a symmetric time-series model in which both the dependent and independent variables are related to contemporaneity and previous (lagged) values. Pesaran and Shin (1999) developed the first ARDL approach, which Pesaran et al (2001) expanded. ARDL has a currency integration approach with numerous benefits compared to conventional cointegration methods. Assume that the ARDL is not integrating the variables in the same order as the study. In this sense, ARDL is applicable whether a fundamental impediment is coupled with an order I (1) or I(0) integration or both.

Furthermore, cointegration techniques can be applied to small sample sizes. Third, ARDL, the method generally provides long-term balanced estimates samples and valid t-statistic even when some variables are Endogenous (Harris and Sollis, 2003). ARDL model used in this study based on equation (4) is expressed as follows.

$$\triangle GLP_t = \alpha_0 + \sum_{i=1}^{n} \beta_0 \triangle GLP_{t-1} + \sum_{i=1}^{n} \theta_0 \triangle ICT_{t-1} + \sum_{i=1}^{n} \nu_0 \triangle GPC_{t-1} + \sum_{i=1}^{n} \delta_0 \triangle EMP_{t-1} + \theta_1 ICT_t + \nu_1 GPC_t + \delta_1 EMP_t \qquad (5)$$

Where $\triangle$ it depicts the rate of the variables, et the random error terms t and n are time and lags, respectively.

It is necessary to determine the best lag length to utilize in the cointegration analysis to estimate the F-statistic value before performing the model computation. Three information criteria—the Akaike criterion (AIC), the Schwarz Bayesian criterion (SBC), and the Hannan-Quinn criterion (HQC)—are used to determine the latter. Based on the AIC, the analysis finds that three lags are the most effective. These findings mean that the dependent variable and its explanatory variables have a long-term relationship because the F-statistic value of 8.19 is larger than the upper bound critical value of 1%. Nkoro and Uko (2016) state that a long-run

relationship exists between the variables if and only if the F-statistic value is more significant than the upper-bound critical value.
The error correction ECM is used to ascertain the short-run relationship between variables. This method is categorized within the numerous time series models and utilized most effectively when working with data that has latent structures that exhibit long-run random patterns (cointegration). The term "error correction" describes how the divergence from long-run equilibrium that occurred in the previous period influences the short-run changes in the current period. Consequently, ECM is the rate at which the dependent variable readjusts to the new conditions following the introduction of a difference. The ECM must be negative and statistically significant to establish a short-term link between the variables.
Finally, normality, heteroskedasticity, and stability tests check the model's accuracy. The structural stability test employs CUSUM and CUSUMSQ, the cumulative sum and square of recursive residuals, respectively.

Data Sources
The analysis uses annual time series data for the Federal Republic of Nigeria from 1990 to 2020 (i.e., 31 observations). Because information on the relevant independent variables is readily available, the author has settled on this one. The World Bank's World Development Indicators and the Conference Board's Total Economy Database are the basis for the research. The study uses factors including the employment growth rate, ICT, physical capital growth (GPC), and labor productivity growth rate (EMP). Except for the number of people employed, which is transformed into the natural log (employment growth rate) to capture stabilized trends in the series and to assess their elasticity on each other. Therefore, all variables utilized in the study model are a percentage of the total population.

Empirical Results and Discussion
This section will discuss the descriptive statistics, the stationarity unit root test, the ARDL model's long relationship through the bounds F-test, and the short and long-run coefficients, including the error term correction term and the goodness of fit through diagnostics and structural stability test.

Table 1
Discriptive Statistics

Variable	Mean	Median	Max	Min	Standard Deviation
GLP	1.600000	1.800000	9.000000	-5.300000	3.661147
ICT	13.20323	12.90000	58.10000	-3.500000	11.53974
GPC	28.12813	26.16650	53.12219	14.16873	11.53255
EMP	10.68746	10.63048	11.21720	10.28473	0.304441

Table 1 above exhibits the descriptive statistics. Revealing that the growth rate of labor or workers' productivity throughout the research time is at about 1.6 %, the minimum growth rate of worker productivity of about -5.3 % in the year 2017, and the year 2002 chopped highest labor productivity growth rate at about 9.0 % "all things being equal." The growth rate of ICT, which is the scouted variable, has a mean growth rate of approximately 13.2 %. It experienced the least growth rate in 2017, with a robust comeback growth rate of about 58.1 % in 1991. In 1990 and 2018-2020, the annual maximum growth rates of physical capital and

employment were approximately 53.1 % and 11.2 %, respectively. 2012-2013 recorded the minimum growth rate for physical money (14.2 %) and the average growth for physical capital at 28.1 %. Finally, the minimum and average growth rates for employment happened in 1990-1994 and 2005, respectively.

Table 2
Results of Unit Root Test

Variables	Augmented Dickey-Fuller (ADF)				Phillips-Perron (PP)			
	Intercept		Intercept and Trend		Intercept		Intercept and Trend	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
GLP	-3.52612**	-8.6129*	-3.4296	-8.4966*	-3.68675*	-10.505*	-3.62332**	-19.705*
GICT	-3.85298*	-8.39318*	-4.168**	-8.23232*	-3.87035*	-11.930*	-4.16812**	-11.522*
GPC	-1.838871	-3.4835**	0.652991	-4.2651**	-2.48857	-3.3980**	0.859463	-4.265**
GEMP	1.581922	-3.122**	-1.9094	-3.8314**	1.375011	-3.2978**	-1.911010	-3.869**

Note: GLP is the labor productivity growth rate, GICT is the ICT growth rate, GPC is the physical capital growth rate, and EMP is the employment growth rate. * are significant levels at 1% and 5%.

Table 2 demonstrates that the unit root test did not reject the null hypothesis for all variables. Because a few variables still had unit roots at level, they all became stationary after taking their first difference. Thus, making stationary at the integration of order one or I(1).

Table 3
Bounds Cointegration-ARDL Long Run Coefficients

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	8.191***	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	29		Finite Sample: n=35	
		10%	2.618	3.532
		5%	3.316	4.194
		1%	4.428	5.816

As mentioned earlier, the conclusion of the bounds test depends on the F-statistic value. Following the estimations in the bounds tests above in Table 3, the F-statistic (8.191097) is

higher than the upper bound critical value of 4.66. Thus, a cointegration and long-run relationship exist between workers' productivity growth rate, ICT growth rate, physical capital growth, and employment growth rate.

Table 4
Long-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Probability
GICT	0.315531	0.057315	5.505251	0.0000
GPC	-0.480273	0.096771	4.962972	0.0001
GEMP	-15.83548	3.410899	4.642613	0.0003

From Table 4 above, the findings show the long-run relationship between the variables, the coefficients of the explanatory variables reveal the existence of a significant negative nexus between the growth rate of physical capital and worker productivity and labor productivity and employment growth rate but a positive relationship between ICT and labor productivity. If there is a 1% increase in the growth rate of physical capital and employment growth rate, worker productivity decreases by 0.48 % and 15.8 % holding all other things constant, respectively. In the long run, as observed in the estimation above, there is a positive and significant relationship between the ICT growth rate, the scouted variable in this study, and worker productivity in the Federal Republic of Nigeria. Intuitively, if ICT growth rate increases by 1 % worker productivity will increase by 0.32 % holding ll other things constant. The R^2 shows significant percentage changes in the worker growth rate (0.76) due to the explanatory variables used in this study.

Table 5
Estimations of Error Correction Model (ECM)

Variable	Coefficient	Std. Error	t-Statistic	Probability
D(GLP(-1))	0.357673	0.118084	3.028965	0.0080
D(ICT)	0.001943	0.026030	0.074657	0.9414
D(ICT(-1))	-0.244740	0.046999	-5.207314	0.0001
D(ICT(-2))	-0.143562	0.032791	-4.378137	0.0005
D(GPC)	0.195088	0.115641	1.687010	0.1110
D(GPC(-1))	0.623216	0.163704	3.806969	0.0015
D(GEMP)	-63.12165	11.30032	-5.585829	0.0000
CointEq(-1)*	-1.129747	0.157896	-7.155023	0.0000

Table 5 above shows the results of the error correction model (ECM) for short-run adjustments. In the short run, there is a negative and statistically significant relationship between some explanatory variables and the dependent variable; ICT growth rate and employment growth rate and labor productivity; a positive relationship between physical capital growth and worker productivity growth all things being equal. The error correction term is negative and statistically significant. Negative (ECM-1) implies that any deviation from the long-run equilibrium between variables will be adjusted by 1.13 percent each to return to the long-run equilibrium.

Table 6

Diagnostic Test

Test		Coefficient	P-value
Serial correlation LM test	F-statistic	2.927350 Prob. F(2,14)	0.0867
Heteroskedasticity test	F-statistic	2.234495 Prob. Chi-Square(11)	0.9975

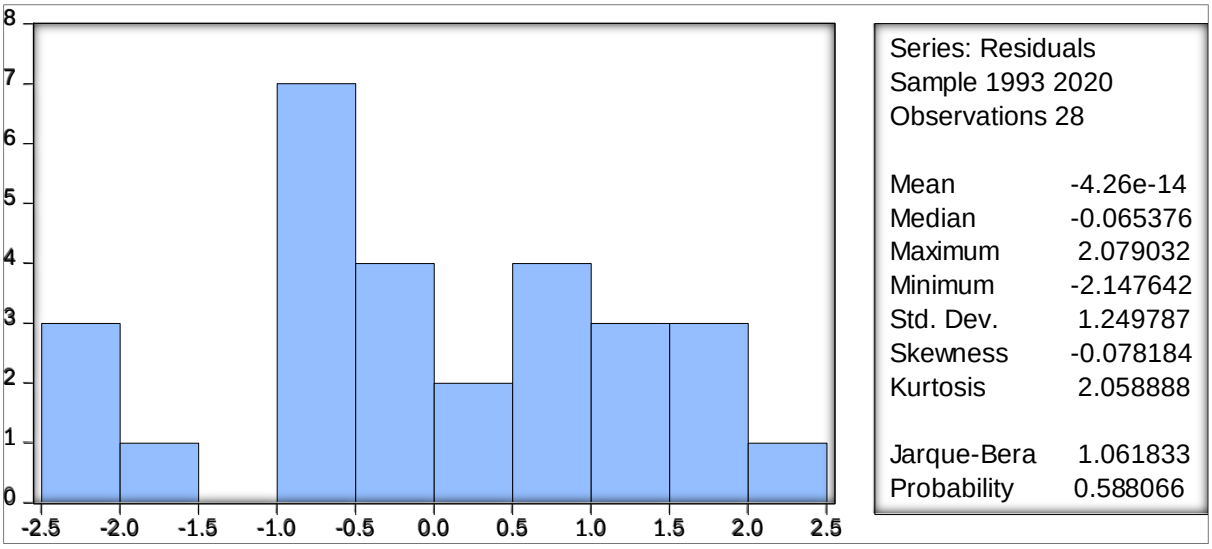

Figure 1: Normality test

The diagnostic test showed no heteroskedasticity, serial correlation, or multicollinearity. The error term is also normally distributed, according to the Jarque-Bera normality test. Finally, the CUSUM and CUSUMSQ test indicates that the parameters are stable because they lie within the 5 percent line. See the results in Figures 1, 2, and Table 6 above.

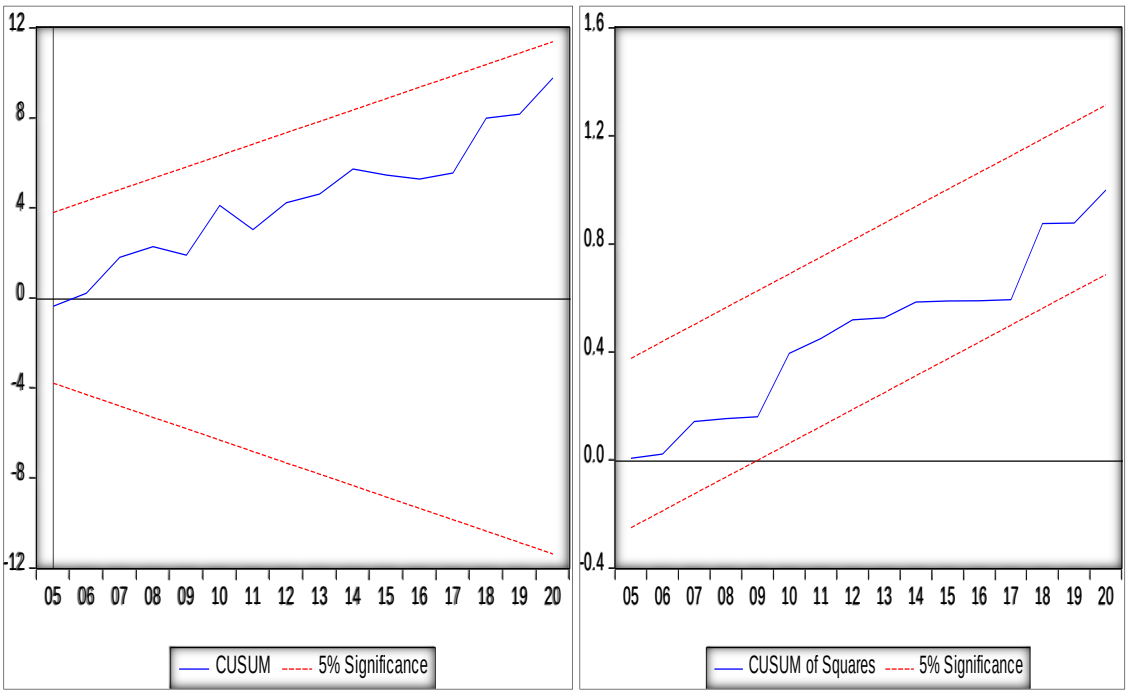

Figure 2: Stability test (CUSUM & CUSUMSQ)

Over the years, several works and research have investigated the impact of ICT on worker or labor productivity globally. Nonetheless, literature on this topic has been few in African scholarly works. Appiahene et al (2018) suggest the relationship between ICT and worker productivity is about 8.51 percent of the literature available worldwide, triggering the research on the continent. The Federal Republic of Nigeria is chosen as a potential research area because it is the most populous country in West Africa and Africa. The study shows Nigeria has a great future with ICT as it uncovers interesting short- and long-term findings. The Autoregressive Distributed Lag Model assesses the short-term and long-term relationship between ICT and workers' productivity levels. The ARDL long-run bounds test findings indicate a positive and significant relationship between the ICT growth rate and labor productivity. Intuitively, in the long run, more investment in ICT assets will boost the rate at which workers produce or worker efficiency. This finding is in line with the study of Biagi (2013), which states that ICT is a recent innovation that will impact the generation. That is, saving and sharing information to fast-track work in the organization. Therefore, ICT will contribute positively to worker novelty and productivity and help increase productivity in growing economies in the long run.

The finding from the ECM reckons that there is a negative and statistically significant relationship between the dependent and explanatory variables in the short run. That is all things equal: the ICT growth rate, employment growth rate, and labor productivity. Also, the estimations show that in the ARDL model, in the long run, there exists a significant negative relationship between labor productivity and both employment growth and physical capital growth. In the long run, increasing investment in human and physical capital will reduce labor productivity in the country. Rationally, there will be a diminishing return to scale when more workers maintain fewer available jobs following the country's expansion of its IT sector. Because more labor will not add more value to the production output (holding all things constant).

Conclusion

The objective of this study is to examine the nexus between ICT and employment on labor productivity growth in Nigeria using annual time series data. Specifically, our central objective is to determine whether ICT and employment influence growth in both short and long run. Despite a large number of reviews and scholarly research on this topic, there have been few works on Nigeria specifically, one of the fastest-rising and most populated economies in Africa. The Autoregressive Distributive Lag Model provides a more robust analysis because it incorporates the same model's dynamic changes in both the long and short runs. Furthermore, the diagnostic and goodness of fit test proves that the model was stable, normally distributed, with no multicollinearity, and the error term was homogenous. Thus, there was no problem encountered in the model. Labor productivity, employment growth, and physical capital growth are only a few in this comprehensive analysis. The revelation from the short-run estimation of the ARDL contradicts most of the previous studies in which the findings show a positive relationship, while the study's revelations in the long run concord with these previous studies, which appeared to have a positive relationship with workers' productivity growth.

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Appendix

Table A1

Data Details and Source

Variable	Variable Type	Definition	Year	Data source
Worker productivity	Dependent	It is proxied by the labor productivity growth rate, the growth of labor productivity per person employed in % change (de Vries & Erumban, 2017).	1990 to 2020	Conference Board Total Economy Database
ICT	Explanatory	The investment growth of Capital Services provided by ICT Assets such as computer hardware and communication equipment as part of machinery and software as part of intangible assets in % changes (de Vries & Erumban, 2017).	1990 to 2020	Conference Board Total Economy Database
Physical capital	Explanatory	It is known as the gross domestic fixed investment is the investments in plants and other fixed assets during a given period plus certain additions to the value of non-produced assets realized by the productive activity of a firm or country, measured in the average %age change of GDP (Abri & Mahmoudzadeh, 2015).	1990 to 2020	World Bank Database
Employment	explanatory	This measures the employment growth rate, resenting the %age growth in the number of people employed annually (de Vries & Erumban, 2017).	1990 to 2020	Conference Board Total Economy Database