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## Re-examining Agricultural Output and Economic Growth Nexus in Nigeria: New Insights from Dynamic ARDL and Kernel-Based Regularized Least Squares

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### Abstract

The role of agriculture in reforming the social and economic framework of an economy cannot be overemphasized. It is against this backdrop that this study reinvestigates the role of the agricultural sector on real output in Nigeria for the period 1981-2019, while controlling for manufacturing output, broad money supply, real effective exchange rate and inflation. We employ a dynamic simulated autoregressive distributed lag model and the kernel-based regularized least squares (KRLS) approach. Empirical results show that all regressors except conventional money supply are insignificant in the short run, while agricultural output has an increasing effect and unconventional monetary policy has a decreasing effect on economic growth in the long run. Using the KRLS, we find that beyond a threshold, when decreasing marginal returns begin to take effect, higher levels of agricultural output increase economic growth. This indicates that there is a limitation to the extent to which agricultural output growth is able to stimulate economic growth. Thus, we are of the opinion that policymakers, in formulating agricultural policies, should exercise caution in advocating for increase in agricultural output beyond what is normal for growth, while the negative impact of conventional monetary policy on economic growth calls for caution by the monetary authority.

**Key words:** Agricultural output; economic growth; money supply; dynamic ARDL; KRLS; Nigeria.

**JEL Classification:** C22, C40, E51, O47 and Q10

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## 1. Introduction

The role of agriculture in reforming both the social and economic framework of an economy cannot be overemphasized. It is not an overstatement to assert that the economic growth and development of any nation depends, to a large extent, on the development of agriculture (Iganiga & Unemhilin, 2011). As a roadmap to attaining development, the Sustainable Development Goals (SDGs) were adopted in 2016 to achieve some fundamental objectives such as zero hunger and no poverty. Central to achieving these objectives is the development of the agricultural sector. In Africa, the prevalence of undernourishment has been seen to rise from 17.6% of the population in 2014 to

19.1% in 2019, more than twice the world average and highest of all regions of the world (Food and Agriculture Organization, 2020). Agriculture has been mapped as a tool to help bridge this gap as it serves as the main source of gainful employment, basic food supply, foreign exchange earnings, local raw materials for industries and government revenue (World Bank, 2014).

Generally, the agricultural sector contributes to the development of an economy in four major ways—product contribution, factor contribution, market contribution and foreign exchange contribution. In realization of this, various policies and programmes aimed at strengthening

the sector have been formulated by the authorities in order to enhance the agricultural sector and therefore improve real output. Some of these policies include the Directorate of Food, Road and Rural Infrastructure (DFRRI) in 1986, National Economic Empowerment and Development Strategy (NEEDS) in 1999 and Agricultural Transformation Agenda (ATA) in 2011-2015. However, according to [Ogbonna \(2011\)](#), despite Nigeria's rich agricultural resource endowment, there have been fluctuations in agricultural output and a consistent decline in the contribution of the agricultural sector to the nation's economy. Productivity is low and basically stagnant. Farming systems, which are mostly small in scale, are still predominantly subsistence-based ([Ogbonna, 2011](#)). The growth of the agricultural sector has declined drastically, with the contribution of agriculture to the national economy dropping from 80% in the 1960s to 24% in 2003, a further decline to 21.3% between 2011 and 2016, and as low as 20.13% between 2017 and 2020 (Statista, 2020).

According to [Adisa \(2012\)](#), the incessant farmers/herders clash, which is largely due to land-related issues, especially on grazing fields, has also dragged down the contribution of agricultural output to real output. As a result of this demeaning situation, many farmers have not been able to continue their farming activities and some have completely abandoned their farms for safety. This has clearly been the case in states such as Benue and Plateau. This situation has resulted in the migration of some farmers from rural areas where there are large farm spaces to urban centres. This has significantly resulted in a shock on agricultural productivity, which has negatively impacted on real output. Other factors include; low level of irrigation farming, climate change and land degradation, low technology, high production cost and poor distribution of inputs, limited financing, poor land tenure system, high post-harvest losses and poor access to markets. These challenges have stifled agricultural output, thereby affecting the sector's contribution to real output as well as increased food imports due to population rise, and hence, declining levels of food sufficiency. For instance, between 2016 and 2019, Nigeria's cumulative agricultural imports stood at ₦3.35 trillion, four times higher than the agricultural export of ₦803 billion within the same period. Hence, this necessitated a critical review of the agricultural sector output and its impact on real output.

In the course of reviewing the existing literature, it was observed that various studies conceptualized the agricultural output shock on real output in different dimensions. For instance, [Olajide et al. \(2012\)](#) used ordinary least squares (OLS) regression method to analyse the relationship between agricultural resource and economic growth in Nigeria between 1970 and 2010. The OLS method, according to literature, can produce spurious and significantly low estimations of the true slope of a linear relationship. [Bakare \(2013\)](#) examined the relationship between sustainable agriculture and rural development in Nigeria. The vector autoregression (VAR) analytical technique was employed for the empirical study. This method can impose a unidirectional relationship, which therefore limits the scope of the analysis.

This study is however unique as it focuses on examining the impact of agricultural output shock on real output from

a new perspective using the dynamic ARDL and kernel-based regularized least squares. The kernel-based regularized technique is a simplified machine learning-based algorithm with strength in its interpretation and accounting for heterogeneity, additivity and nonlinear effects. The dynamic autoregressive distributed lag (ARDL) simulations algorithm is useful for testing cointegration, long-run and short-run equilibrium relationships, and has a visualization interface to examine the possible counterfactual change in the desired variable based on the notion of *ceteris paribus*. Thus, the dynamic ARDL simulations and the kernel-based regularized least squares are superior for policy formulation. Also, it is important for policymakers to understand how changes in agricultural output impact on real sector output in order to guide policy decisions.

Empirical results show that all regressors except conventional money supply are insignificant. This indicates that agricultural output, manufacturing output and exchange rate do not necessarily influence changes in economic growth in the short run over the sampled period. However, conventional monetary policy (money supply) impacts economic growth negatively in the short run. In the long run, we find that agricultural output has an increasing effect and conventional monetary policy has a decreasing effect on economic growth. However, using the KRLS, we find that higher levels of agricultural output increase economic growth beyond a threshold when decreasing marginal returns take place. This indicates that increase in agricultural output is not always growth-stimulating. Thus, we are of the opinion that policymakers, in formulating agricultural policies, should exercise caution in advocating for increase in agricultural output beyond what is normal for growth. The negative impact of conventional monetary policy on economic growth also calls for caution by the monetary authority.

The rest of the study is organized as follows; following the introduction, section two reviews relevant literature. Section three details the data and methodology. Section four presents the empirical results. Section five discusses the findings. Section six concludes the study with attendant policy suggestions.

## 2. Literature Review

The paradox of poverty in the midst of plenty has long plagued the understanding of the role of agriculture in economic growth. Though linkages do exist between the agricultural sector and key sectors of the economy such as the manufacturing sector, a major question asked in literature is whether agricultural productivity can serve as a catalyst for economic growth in both the developing and developed countries, as agriculture has the potential to boost export, create employment, generate income and ultimately stimulate economic growth. However, despite initiatives implemented to boost the Nigerian agricultural sector, challenges still prevail that deter the growth and development of the sector. Does this affect economic growth? Or is there an existence of any kind of relationship between agricultural output and economic growth in Nigeria? While the impact of agricultural output on economic growth has been extensively discussed in literature, our aim is to bring to fore some salient highlights of past studies that are crucial for the motivation

of our study. There have been contracting views, as some studies establish a negative relationship between agricultural output and economic growth, while others refute this position.

In the study by [Ogunbadejo and Oladipo \(2017\)](#), two main conclusions are drawn, using the exponential generalized autoregressive conditional heteroscedasticity (EGARCH) to analyse the impact of agricultural output volatility on economic growth in Nigeria. First, it is concluded that agricultural output volatility has a negative impact on growth. Second, agricultural output has a positive impact on growth and labor force in the Nigerian economy. Also, in the study conducted by [Susilastuti \(2018\)](#), the impact of agricultural production on gross regional production, economic growth and poverty reduction in Indonesia is analysed, using the path analysis method (PAM). The author states that agricultural output has no significant effect on growth and has not been able to reduce poverty. In the same vein, [Safder et al. \(2012\)](#), in an investigation of the impact of agricultural volatility on economic growth in Pakistan, using the autoregressive conditional heteroscedasticity (ARCH) model, finds that agricultural volatility negatively contributes to economic or output growth.

Other reviewed studies offer varying insightful dimensions to the dynamics of the agricultural sector and how it impacts economic growth, using different models. These studies find a positive relationship between agricultural output and economic growth in Nigeria (see [Izuchukwu, 2011](#); [Ahungwa et al., 2012](#); [Aminu & Anono, 2012](#); [Olajide et al., 2012](#); [Odetola & Etumnu, 2013](#); [Abula & Modedcai, 2016](#); [Ismail & Kabuga, 2016](#); [Ogunlana & Lawal, 2016](#); [Afolabi et al., 2017](#); [Olabanjo et al., 2017](#); [Ibe & Obodoechi, 2018](#); [Joseph & Andrew; Okunlola et al., 2019](#)).

From the perspectives of long-run and short-run relationships, the study by [Runganga and Mhaka \(2021\)](#) addresses the impact of agricultural production on economic growth in Zimbabwe. Using the autoregressive distributed lag model (ARDL), the authors conclude that agricultural production has a positive impact on economic growth in the short run, while no relationship is found in the long run. However, [Tfof and Osman \(2020\)](#) establish a long-run relationship between agricultural output and economic growth in Ghana, in their research on the agricultural output and economic growth nexus, using the vector error correction model (VECM). Also, a unidirectional causal relationship from agricultural output to economic growth is detected. Still on causal relationships, [Orji et al. \(2020\)](#) study the linkage between agricultural output growth in developing economies, using Nigeria as a case study. Adopting the pairwise Granger causality test, the authors conclude that there is no causal linkage between agricultural financing and agricultural output growth in Nigeria. Going by a disaggregated approach, [Jatoi \(2021\)](#) examines agriculture in Pakistan and its impact on economic growth, using correlation and regression to analyse the data. The study concludes that agriculture and its subsectors have significant impacts on economic growth in Tanzania.

Based on the different dimensions of the literature reviewed, our study fills the gap in literature by using the dynamic autoregressive distributed lag (ARDL) approach

to analyse agricultural output shock and how it impacts real output growth in the Nigerian economy. This method, to the best of our knowledge, has not been used to examine the relationship that exists between economic growth and the dynamics in the Nigerian agricultural sector.

### 3. Methods

#### 3.1 Data and measurement

This study investigates the impact of agricultural output shock on real output in Nigeria for the period 1981-2019<sup>4</sup>. The control variables include real manufacturing output, broad money supply, real exchange rate and inflation. Data on real output (measured in billions of naira), real agricultural output (measured in billions of naira), real manufacturing output (measured in billions of naira), broad money supply (measured in billions of naira), real exchange rate (measured by average end period naira per dollar official exchange rate) and inflation rate (measured by the annual percentage change in consumer price index) is obtained from the World Development Indicators (WDI) of the [World Bank \(2020\)](#).

#### 3.2 Methodology

This study employs a dynamic simulated autoregressive distributed lag model developed by [Jordan and Philips \(2018\)](#) and the kernel-based regularized least squares approach in achieving the stated objectives. However, the implementation of the dynamic ARDL begins with the estimation of an ARDL model to test for co-integration.

##### 3.2.1 ARDL/bounds test approach to cointegration

The ARDL bounds testing approach to co-integration was developed by [Pesaran et al. \(2001\)](#) in order to circumvent the disadvantages of existing standard approaches such as [Engle and Granger \(1987\)](#) and [Johansen \(1988\)](#). The ARDL bounds test is applicable whether the order of integration of the series is I(0), I(1) or mixed, and does not place a restriction on the sample size.

The following ARDL model will be estimated to test the existence of a cointegration relationship among the variables in the model. Since inflation rate is in percentage, a logarithmic transformation of the rest of the variables yields the econometric linear form of the ARDL version of the error correction model as shown in equation (1).

$$\begin{aligned} \Delta \ln \text{RGDP}_t = & \gamma_0 + \sum_{i=1}^p \delta_i \Delta \ln \text{RGDP}_{t-i} + \\ & \sum_{j=0}^q \sigma_j \Delta \ln \text{AGO}_{t-j} + \sum_{l=0}^q \vartheta_l \Delta \ln \text{MAN}_{t-l} + \\ & \sum_{m=0}^q \omega_m \Delta \ln \text{MS}_{t-m} + \sum_{n=0}^q \rho_n \Delta \ln \text{EXR}_{t-n} + \\ & \sum_{o=0}^q \alpha_o \Delta \ln \text{INF}_{t-o} + \gamma_1 \ln \text{RGDP}_{t-1} + \gamma_2 \ln \text{AGO}_{t-1} + \\ & \gamma_3 \ln \text{MAN}_{t-1} + \gamma_4 \ln \text{MS}_{t-1} + \gamma_5 \ln \text{EXR}_{t-1} + \gamma_6 \\ & \ln \text{INFL}_{t-1} + \varepsilon_t \quad (1) \end{aligned}$$

Where RGDP is real gross domestic product, AGO is real agricultural output, MAN is real manufacturing output,

<sup>4</sup> The period covered is based on data availability.

MS is broad money supply measure i.e., M2, EXR is the official naira per US dollar average period exchange rate, and INF is the inflation rate.

$\delta, \sigma, \partial, \omega, \rho$  and  $\alpha$  are short-run parameters

$\gamma_1 - \gamma_6$  are the long-run parameters

$\gamma_0$  is the drift component

$\Delta$  is the difference operator

$\varepsilon_t$  is the white noise residual

The procedure for use of ARDL bounds testing approach starts with the estimation of equation (1) through the application of ordinary least squares (OLS) estimator before testing for the existence of cointegration among the variables. The null hypothesis of the F-test for joint significance is stated as:

$$H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0$$

The alternative hypothesis follows the form:

$$H_1: \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq 0$$

The test is conducted by comparing the asymptotic upper and lower bound critical values provided by [Pesaran et al. \(2001\)](#) with the computed F-statistic. The decision rule offers three possibilities. First, if the upper bound critical values are less than the computed F-statistic, the null hypothesis is rejected, indicating the existence of cointegration among the variables in the model. Second, if the lower bound critical values are greater than the computed F-statistic, the null hypothesis is not rejected, implying the absence of cointegration among the variables in the model. Third, if the F-statistic lies within the lower and upper bound critical values, the decision is inconclusive.

Following the validation of a cointegration relationship among the relevant variables, the long-run form of the model is estimated as specified in equation (2) below.

$$\ln \text{RGDP}_t = \gamma_0 + \sum_{i=1}^p \delta_i \ln \text{RGDP}_{t-i} + \sum_{j=0}^q \sigma_j \ln \text{AGO}_{t-j} + \sum_{l=0}^q \partial_l \ln \text{MAN}_{t-l} + \sum_{m=0}^q \omega_m \ln \text{MS}_{t-m} + \sum_{n=0}^q \rho_n \ln \text{EXR}_{t-n} + \sum_{o=0}^q \rho_o \ln \text{INF}_{t-o} + \varepsilon_t \quad (2)$$

Thereafter, the short-run estimates and error correction form of the model are estimated as specified in equation (3). The error correction coefficient defines the speed of adjustment from short-run disequilibrium to long-run equilibrium.

$$\Delta \ln \text{RGDP}_t = \gamma_0 + \sum_{i=1}^p \delta_i \Delta \ln \text{RGDP}_{t-i} + \sum_{j=0}^q \sigma_j \Delta \ln \text{AGO}_{t-j} + \sum_{l=0}^q \partial_l \Delta \ln \text{MAN}_{t-l} + \sum_{m=0}^q \omega_m \Delta \ln \text{MS}_{t-m} + \sum_{n=0}^q \rho_n \Delta \ln \text{EXR}_{t-n} + \sum_{o=0}^q \rho_o \Delta \ln \text{INF}_{t-o} + \lambda \text{ECT}_{t-1} + \varepsilon_t \quad (3)$$

The study further implements the post-estimation diagnostic and stability tests in order to ensure that some basic assumptions of the OLS estimator are not violated.

### 3.2.2 Dynamic autoregressive distributed lag model

[Jordan and Philips \(2018\)](#) adduced two major reasons for the superiority of the dynamic simulated ARDL model over the conventional ARDL model. First, it overcomes the complexities associated with the interpretation of the ARDL model in terms of lag structure, current values, first differences and lagged first differences of the independent variables, and by extension, the dependent variable. Second, the dynamic simulated ARDL model uses stochastic simulation techniques to provide output with visualization effect in order to determine the likely counterfactual change in an explanatory variable, holding other variables constant. The dynamic simulated ARDL model is specified as shown in equation (4), in line with [Jordan and Philips \(2018\)](#), [Khan et al. \(2020\)](#), [Nwani and Omoke \(2020\)](#) and [Sarkodie and Owusu \(2020\)](#).

$$\Delta \ln \text{RGDP}_t = \alpha_0 + \beta_0 \ln \text{RGDP}_{t-1} + \pi_1 \Delta \ln \text{AGO}_t + \beta_1 \ln \text{AGO}_{t-1} + \pi_2 \Delta \ln \text{MAN}_t + \beta_2 \ln \text{MAN}_{t-1} + \pi_3 \Delta \ln \text{MS}_t + \beta_3 \ln \text{MS}_{t-1} + \pi_4 \Delta \ln \text{EXR}_t + \beta_4 \ln \text{EXR}_{t-1} + \pi_5 \Delta \ln \text{INF}_t + \beta_5 \ln \text{INF}_{t-1} + \varepsilon_t \quad (4)$$

### 3.2.3 Kernel-based regularized least squares (KRLS)

The kernel-based regularized least squares approach was proposed by [Hainmueller and Hazlett \(2014\)](#), with useful application in the determination of causal-effect relationship, using machine learning algorithm to implement the pointwise derivatives. The methodology provides a modeling framework that conveniently strikes a balance between the rigid generalized linear models and machine learning methods defined by more flexibility and interpretation difficulty. In other words, the kernel-based regularized least squares approach is suitable for preserving inferences from the penalty of misspecification bias without eroding their interpretative and statistical value ([Hainmueller & Hazlett, 2014](#)).

## 4. Results

In this section, we present the empirical results and discuss them accordingly. The use of the novel dynamic ARDL is built on some technical procedures. The ARDL bounds testing framework (as reported in [Table 3](#)) employed in the novel dynamic ARDL simulations necessitates a strict first-difference stationarity in the dependent variable. That is, the dependent variable has to be non-stationary, while other regressors can either be integrated at levels  $I(0)$ , or integrated at first difference  $I(1)$  or partially integrated, i.e.,  $I(0)/I(1)$ , without structural breaks, heteroscedasticity and serial correlation, respectively. In order to control for possible heteroscedasticity, we generate the series in natural logarithms. [Table 2](#) presents the time series unit root test results for the augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) tests conducted to control for possible spurious regression, both at level and at first difference. Based on the results, we are not able to reject the null hypothesis of unit root (except for money supply, exchange rate and inflation) at level. We are however able to reject the null hypothesis for all the variables at first difference. Thus, we conclude that the series are integrated of a mixed order.

Table 1. Unit root test

Variables	Phillips-Perron		ADF	
	Level	First Difference	Level	First Difference
lnRGDP	0.023	-5.327***	0.123	-5.337***
lnAGO	-0.238	-5.502***	-0.225	-5.499***
lnMAN	0.218	-3.191**	0.748	-3.113**
lnMS	-2.461	-3.166**	-3.014**	-3.084**
lnEXR	-3.031	-5.920***	-2.845*	-5.892***
INF	-3.183**	-5.297***	-3.109**	-5.159***

Note: \*\*\*, \*\* and \* represent 1%, 5% and 10% levels of significance, respectively.

Having satisfied the condition of strict first-difference stationarity for the dependent variable i.e., economic growth (real GDP), we proceed to determine the optimal

lag length for the proposed model, using the selected optimal lag length (maximum lag length of 2 as shown in Table 2) via the Pesaran, Shin and Smith (PSS) bounds testing approach with the novel Krispfganz and Schneider (KS) approximate probability values and critical values.

Table 2. Lag selection

Lag	LL	LR	Df	p-value	FPE	AIC	HQIC	SBIC
0	-29.465				3.7e-07	2.216	2.307	2.491
1	180.041	419.01	36	0.000	7.5e-12	-8.627	-7.989	-6.703
2	247.168	134.25*	36	0.000	1.4e-12*	-10.573*	-9.388*	-7.000*

## 5. Discussion

We proceed to examine the long-run cointegration relationship of the series via the modified PSS bounds test with KS critical values and approximate probability values, and based on the ARDL (1, 0, 0, 0, 0). The results of the PSS bounds test are reported in Table 3. The results show that the estimated F-statistic is 6.768, a

value above the upper critical values (3.351, 5.649) at 1 percent significance level. The KS approximate probability values less than 1 percent also validate the PSS bounds test results; hence, we reject the null hypothesis of no cointegration relationship. In a nutshell, both PSS bounds test and the KS approximate probability values with critical values affirm the existence of a cointegration relationship among the series.

Table 3. PSS Bounds test

	10%		5%		1%		P-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
<b>F</b>	2.065	3.351	2.546	4.020	3.732	5.649	0.000	0.004
<b>T</b>	-1.611	-3.464	-1.983	-3.903	-2.732	-4.801	0.002	0.096
<b>F-Stat = 6.768***</b>								

Note: \*\*\* represents 1% level of significance.

The estimated coefficients obtained from the ARDL model are reported in Table 4 and Table 5. Based on the outcome, we observe (in Table 5) that all regressors except agricultural output and conventional money supply are insignificant at all levels in the long run. This indicates that agricultural output, manufacturing output and exchange rate do not necessarily influence changes in economic growth in the short run over the sampled period. This finding resonates with those of Olabanji et al. (2017) and Sertoglu, Ugral and Bekun (2017) for Nigeria, as well as those of Chebbi (2010) and Matahir and Tuyon (2013) for Tunisia and Malaysia, respectively. However, we find that conventional monetary policy (money supply) impacts economic growth negatively in the short run at 1

percent significance level. In the long run, we find that agricultural output has an increasing impact and conventional monetary policy has a decreasing impact on economic growth at 1 percent significance level. This is in line with the studies of Ahungwa et al. (2012), Bakare (2013) and Okunlola et al. (2019), while Ogunmuyiwa and Ekone (2010) and Omodero (2019) find an insignificant impact of money supply in Nigeria and Ghana, respectively.

As part of the precondition of the dynamic ARDL simulations, we conduct various diagnostic tests that capture heteroscedasticity, serial correlation, structural breaks and normality violation. The resulting estimates of heteroscedasticity, serial correlation, structural breaks and normality violation are reported in Table 6.

Table 4. ARDL long-run coefficients

lnRGDP	Coefficient	Std. Error	T-statistic	Prob.
lnAGO(-1)	1.347	0.175	7.6-9	0.000***
lnMAN(-1)	-0.042	0.192	-0.22	0.829
lnMS(-1)	-0.206	0.068	-3.01	0.006***
lnEXR(-1)	0.121	0.103	1.17	0.251
INF(-1)	-0.017	0.048	-0.37	0.713

Note: \*\*\* represents significance at 1%.

Table 5. ARDL short-run coefficients

ΔlnRGDP	Coefficient	Std. Error	T-statistic	Prob.
ΔlnAGO	0.098	0.124	0.79	0.435
ΔlnMAN	-0.012	0.055	-0.22	0.825
ΔlnMS	-0.061	0.020	-2.93	0.007***
ΔlnEXR	-0.039	0.033	-1.16	0.258
ΔINF	-0.005	0.014	-0.38	0.709

Note: \*\*\* represents significance at 1%.

Table 6: Post-estimation diagnostic test

Test	Test type	Test statistic	Prob.
Serial correlation	Breusch-Godfrey LM test	0.797	0.540
Heteroscedasticity	White's test	33.00	0.418
Normality	Skewness/Kurtosis	3.970	0.137
Parameter stability	Cumulative sum test	0.540	1% = 1.627 5 % = 1.358 10% = 1.224

Based on the outcome, we could not reject the null hypothesis of no serial correlation at 1 percent significance level, affirming that the residuals of the estimated ARDL model are autocorrelation-free. Also, we test for heteroscedasticity. We also could not reject the null hypothesis of homoscedasticity at 1 percent significance level. This signifies that the residuals of the ARDL model are homoscedastic. We also examine the independence of the series by checking for normality violation. Results show that the null hypothesis that the series are normally distributed could not be rejected at 1 percent significance level.

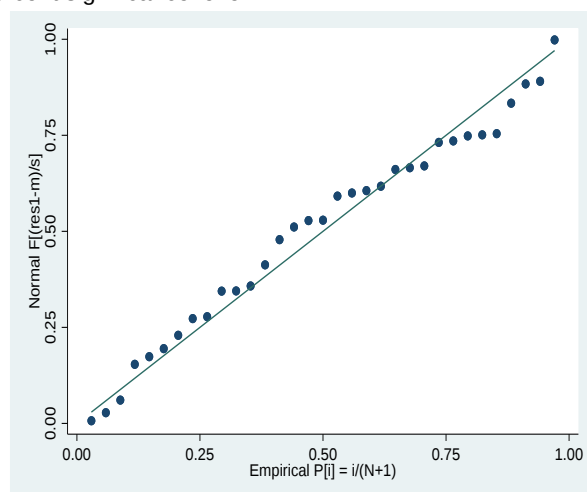


Figure 1: Standardized normal probability plot.

The normality distribution of the series was further validated via both the conventional normal distribution probability plot (see Figure 1) and the

quantiles of residuals versus quantiles of normal distribution (see Figure 2).

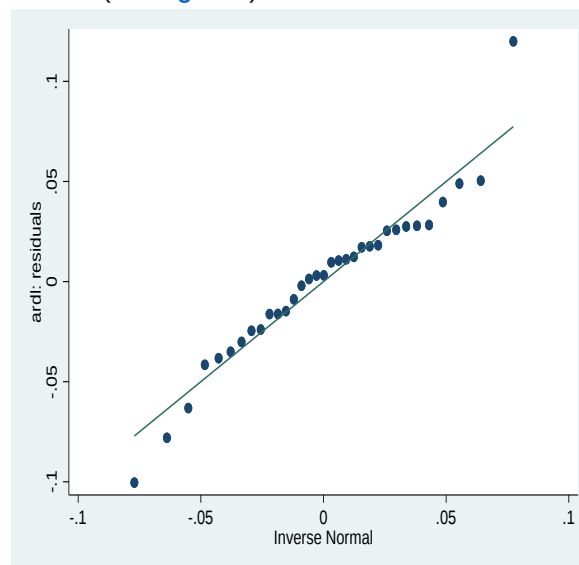


Figure 2: Quantiles of residuals against quantiles of normal distribution.

Figure 2 affirm that the series residuals (based on the estimated ARDL model) are normally distributed. Lastly, we examine possible structural breaks via cumulative sum test for parameter stability. The result shows that the estimated cumulative sum test statistic falls within the 95 percent confidence interval band; thus, we affirm the stability of the series over the sample period (see Figure 3).

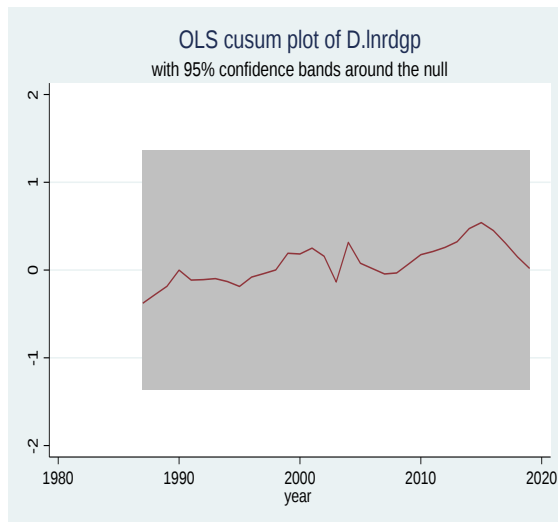


Figure 3: Cumulative sum test using OLS CUSUM plot for parameter stability.

Having established the diagnostic features of the series, we proceed to estimate the novel dynamic ARDL model that accounts for possible shocks in regressors (Table 7). The dynamic ARDL simulation is conducted

based on a 10-year future forecast of the contribution of the agricultural sector to economic growth. This period is employed as a counterfactual shock to estimate the potential contribution of the recent agricultural intervention programme, Nigeria Digital Agricultural Strategy (NDAS) pegged 2020-2030. NDAS is a ten-year strategic plan that is expected to enhance the efficiency of the Nigerian agricultural sector, and hence, output via the use of digital technology for both the rural and the urban centres. For the dynamic ARDL model, the shockvar here is the agricultural output, while the shockval is the unit of shock applied (10 years) to the target series (economic growth). Similar to the conventional ARDL model estimates (Tables 4 & Table 5), long-term agricultural output has an increasing effect on economic growth. This might perhaps be due to several intervention programmes of the Federal Government (Agricultural Credit Guarantee Scheme Fund via the Central Bank of Nigeria) and agency-based intervention programmes in the agricultural sector, such as the Directorate of Food, Road and Rural Infrastructure (DFRRI) in 1986.

Table 7. Estimates of dynamic simulated ARDL model

$\Delta \ln \text{RGDP}$	Estimate	SE	P-value	Min 95	Max 95
$\ln \text{RGDP}(-1)$	-0.491	0.152	0.003***	-0.805	-0.177
$\ln \text{AGO}(-1)$	0.425	0.096	0.000***	0.227	0.623
$\ln \text{MAN}(-1)$	0.010	0.061	0.865	-0.116	0.137
$\ln \text{MS}(-1)$	-0.008	0.029	0.763	-0.068	0.050
$\ln \text{EXR}(-1)$	0.011	0.024	0.651	-0.039	0.062
$\ln \text{INF}(-1)$	0.012	0.012	0.319	-0.013	0.039
Prob>F	0.0007***	R <sup>2</sup>	0.5691	Root MSE	0.044

Note: SE represents standard error; \*\*\* denotes statistical significance at 1%.

Table 8. Pointwise derivatives using KRLS.

$\ln \text{RGDP}$	Avg.	SE	t	P>t	p-25	p-50	p-75
$\ln \text{AGO}$	0.136	0.020	6.710	0.000***	0.060	0.107	0.194
$\ln \text{MAN}$	0.277	0.028	9.850	0.000***	0.103	0.237	0.465
$\ln \text{MS}$	0.027	0.006	4.279	0.000***	0.006	0.031	0.050
$\ln \text{EXR}$	0.052	0.011	4.560	0.000***	0.122	0.055	0.085
$\ln \text{INF}$	-0.019	0.017	-1.137	0.265	-0.074	-0.005	0.043
Diagnostics							
Lambda	0.06902	Sigma	5.000	R <sup>2</sup>	0.995	Obs.	34
Tolerance	0.034	Eff.Df	13.59	Looloss	0.2741		

Note: Avg. is the average marginal effect; SE is the standard error; p-25, p-50, and p-75 denote 25th, 50th and 75th percentiles, respectively. \*\*\* represents statistical significance at 1%.

Finally, we apply the kernel-based regularized least squares (KRLS). The KRLS is a machine learning algorithm that executes the pointwise derivatives to test the causal relationship among the series<sup>2</sup>. To examine the

effect of the 2030 (ten-year) strategic plan designed to enhance efficiency of the Nigerian agricultural sector and thus improve agricultural output, we test the structural adjustments in economic growth via empirical estimation using pointwise marginal impact as reported in Table 8. Based on the results, the model is significant at 1 percent, with a predictive power of 0.995. This implies that the

<sup>5</sup> For more information about the mathematical explanations of the method, please see Hainmueller and Hazlett (2014).

explanatory variables explain 99.5 percent changes in economic growth. The assessment of heterogeneous marginal impacts via derivatives of regressors are reported as 25<sup>th</sup>, 50<sup>th</sup> and 75<sup>th</sup> percentiles (Table 8), where we observe no evidence of heterogeneous marginal impacts for the series, hence affirming the robustness of the KRLS technique. Results show that the mean pointwise marginal impact of agricultural output,

manufacturing output, money supply and exchange rate are 0.136 percent, 0.277 percent, 0.027 percent and 0.057 percent, respectively. This emphasizes the significance of agricultural output, manufacturing output, money supply and exchange rate in improving economic growth in Nigeria.

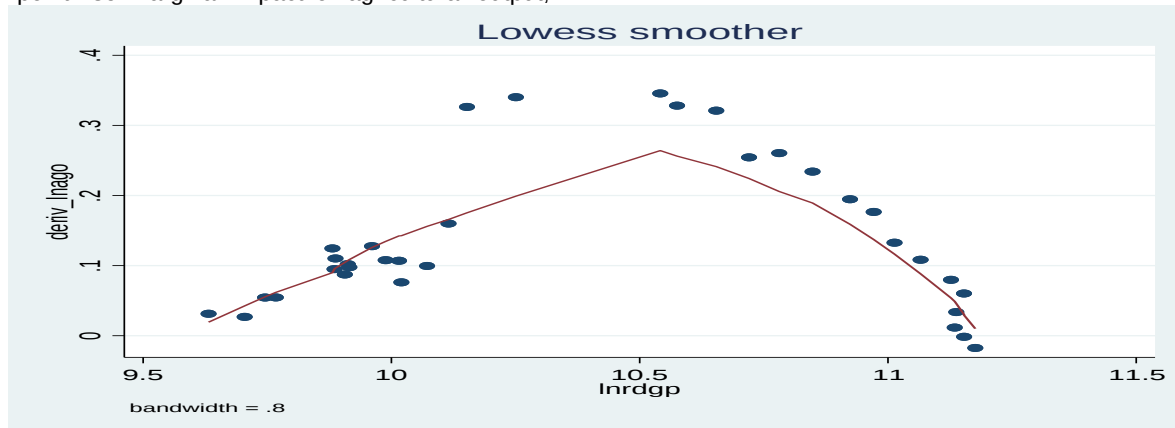


Figure 4: Lowess smoother.

One significant question here is how the phasing out of agricultural intervention programmes to improve agricultural output will impact on economic growth and development in the future (long term). Thus, we evaluate the long-run changes in agricultural output and how it impacts on economic growth, and vice versa. To achieve this objective, we plot the pointwise derivatives of agricultural output against economic growth to account for changing marginal impacts. From [Figure 4](#), we observe that higher levels of agricultural output increase economic growth beyond a threshold when decreasing marginal returns take place. Therefore, agricultural output exhibits decreasing marginal returns with decreasing economic growth. This validates the potential agricultural output-led economic growth and indicates that agricultural output is not always growth-stimulating.

## 6. Conclusion

This study reinvestigates the impact of agricultural output on economic growth in Nigeria for the period 1981-2019, while controlling for manufacturing output, broad money supply, real effective exchange rate and inflation. To achieve the stated objective, the study employs a dynamic simulated autoregressive distributed lag model developed by [Jordan and Philips \(2018\)](#) and the kernel-based regularized least squares proposed by [Hainmueller and Hazlett \(2014\)](#) with useful application in the determination of causal-effect relationship, using machine learning algorithm to implement the pointwise derivatives.

Empirical results show that all regressors except conventional money supply are insignificant. This indicates that agricultural output, manufacturing output and exchange rate do not necessarily influence changes in economic growth in the short run over the sampled period. However, conventional monetary policy (money supply) impacts economic growth negatively in the short

run. In the long run, we find an increasing effect of agricultural output and a decreasing effect of conventional monetary policy on economic growth. However, using the KRLS, we find that higher levels of agricultural output increase economic growth beyond a threshold when decreasing marginal returns take place. This indicates that increase in agricultural output is not always growth-stimulating.

We are thus of the opinion that policymakers, in formulating agricultural policies, should exercise caution in advocating for increase in agricultural output beyond what is normal for growth. We observe that increase in agricultural output can get to a point where agricultural output supply would exceed demand, leading to decrease in agricultural output prices. As agricultural product prices decrease, existing and potential farmers are discouraged from engaging in farming activities. If this situation persists, first, there would be shortages in agricultural products, and second, there would be an increase in government expenditure in terms of incentives and intervention programmes to motivate farmers and reengage them in farming activities.

Finally, the negative impact of conventional monetary policy on economic growth, both in the short and long run, calls for caution by the monetary authority. Its adverse effect on growth should be considered when formulating and making economic policy decisions. Basically, this study re-examines the relationship that exists between agricultural output and economic growth. We urge future researchers to examine the threshold at which agricultural output becomes a problem for economic growth. Understanding this threshold would help policymakers to control output and the unnecessary expenditure that follows.

**Competing interests:** There is no conflict of interests reported by the authors.

## Abbreviations:

Agricultural Transformation Agenda

(ATA)

Augmented Dickey-Fuller	(ADF)	and interpretable machine learning approach. <i>Political Analysis</i> , 22(2), 143-168.
Better Life Programme	(BLP)	
Dynamic Autoregressive Distributed Lag	(ARDL)	Ibe Etea and Divine Obodoechi, (2018), Agricultural Output and Economic Growth: The Nigeria Case, <i>Journal of Economic and Sustainable Growth</i> 3
Directorate of Food, Road and Rural Infrastructure	(DFRRI)	
Exponential Generalized Autoregressive Conditional Heteroscedasticity	(EGARCH)	
Kernel-based Regularized Least Square	(KRLS)	Iganiga, B O., & Unemhilin, D. (2011). The Impact of Federal Government Agricultural Expenditure on Agricultural Output in Nigeria. <i>Journal of Economics</i> , 2(2), 81-88.
National Agricultural Land Development Authority	(NALDA)	
National Fadama Development Project	(NFDP)	
National Economic Empowerment and Development Strategy	(NEEDS)	Ismail, A. A., and Kabuga, N. A. (2016). Impact of agricultural output on <i>Journal of Agricultural and Development Economics (NIJADE)</i> Vol. 6 <i>Journal of Agricultural and Veterinary Science</i> , 7(1), 50-55 No1June, 2016. 2276-8378
National, Special Programme on Food Security	(NSPFS)	
Nigeria Digital Agricultural Strategy	(NDAS)	
Ordinary Least Squares	(OLS)	
<b>Pesaran, Shin and Smith</b>	(PSS)	
Phillip-Perron	(PP)	Izuchukwu, O. O. (2011). Analysis of the contribution of agricultural sector on the Nigerian economic development. <i>World review of business research</i> , 1(1), 191-200.
Path Analysis Method	(PAM)	
Root and Tuber Expansion Programme	(RTEP)	Jatoi, F. Z. (2020). Agriculture in Pakistan and its impact on Economic growth. Available at SSRN 3771914
World Development Indicators	(WDI)	

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